Dilutions / Molarity

Other ideas for the title: (please add yours!)
Solutions and Dilutions
Beer's Law
Molarity and Dilutions
KL: Beer's Law Lab
(Maybe 2 sim names with different starting tabs?
Solutions and Dilutions (sim 1)
Beer's Law Lab

PhET Sim Design Document

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Public URL:
https://docs.google.com/document/pub?id=1H9-ZJznqsh_YFwiRTsPGriqbcKo8AfNMRvq_y9m3dHo

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Mockup
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Discussion History
- 07/20/11 - PhET Chem Meeting
- 07/22/11 - JC & KL discussion
- 07/25/11 - JC & EM discussion
- 07/27/11 - PhET Chem Meeting
- 08/03/11 - PhET Chem Meeting
- 9/21/11 - JC and CM disussion of mockup (first 3 tabs)

9/29/11 - PhET Chem Meeting
10/06/11 - PhET Chem Meeting
10/20/11 - PhET Chem Meeting
10/27/11 PhET Chem Meeting
11/03/11 - PhET Chem Meeting
01/19/12 - PhET Chem Meeting

Online Resources

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

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.

Learning Goals

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

- connect volume and amount of solute to concentration
- calculate the concentration of solutions in units of molarity (mol/L)
- use molarity to calculate the dilution of solutions
- calculate and "prepare" a set of standard solutions of known concentration by dilution of a stock solution

(The above learning goals are addressed in Tabs 1-3 of the mock up)
(The following learning goals will be addressed in Tabs 4-5 of the mock up)

- connect solution concentration with the intensity of light that is absorbed/transmitted
- describe the relationships in Beer's Law (Absorbance, molar absorptivity, path length, concentration)
- measure and record the transmittance of the standard solutions
- determine the relationship between concentration and % transmittance by creating a calibration curve
- measure the transmittance of a solution of unknown concentration and use the relationship described by the calibration curve to find its molarity

Important Equations:

1. Calculating Molarity

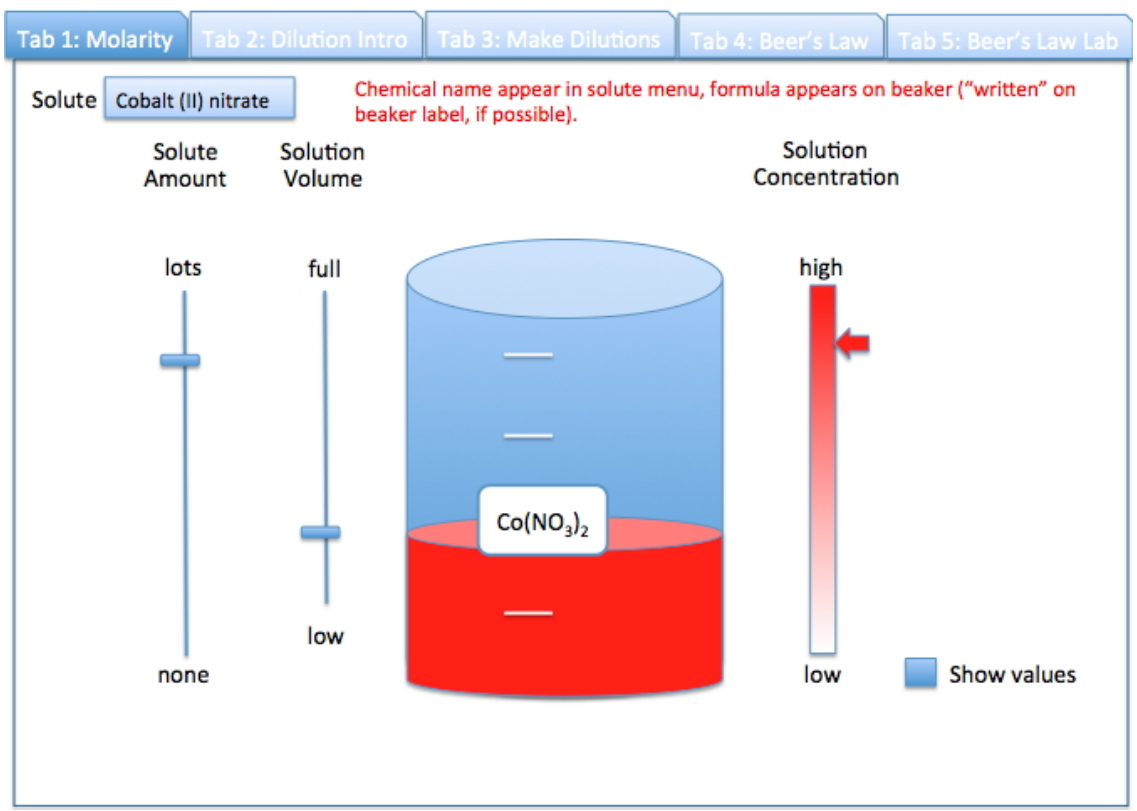
number of moles / volume in L = molarity aka moles/V = M, where units for M are mol/L

2. Calculating a 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
Absorbance = (molar absorptivity)(pathlength...)(concentration)
note: absorbance is also called optical density.

Mockup

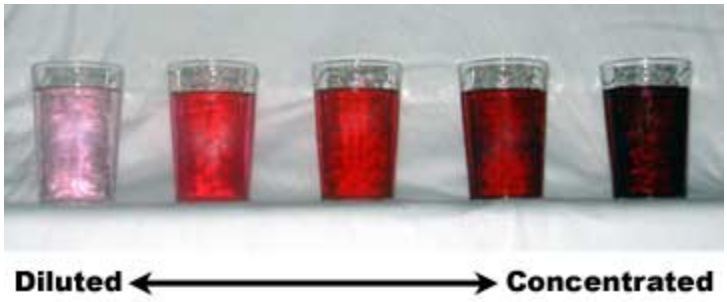
First Tab - Molarity
Concentration (Molarity) depends on how much solute is in the glass, and how much water is in the glass. The solute slider controls how many molecules of chemical there are in the solution. The volume slider controls how much water is in the beaker. Concentration is a read-out reflecting the g/mol from the first 2 sliders.

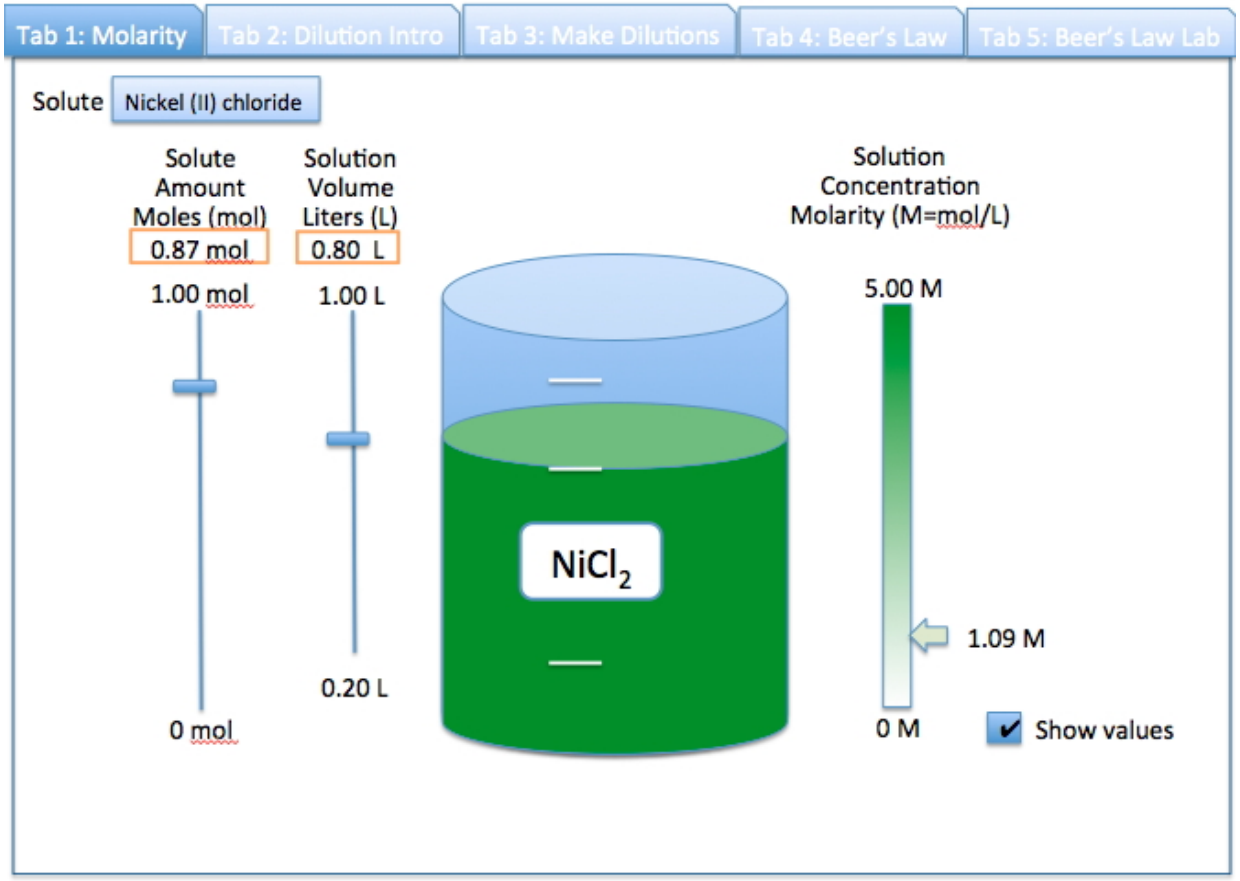


CM: Label Solute range "none" to "lots"; Volume range "empty" to "full".
JC: Volume range shouldn't be able to go to empty. The range should be 0.2 L to 1.0 L in order to avoid solutions that are beyond saturation (a precipitate would form).

First Tab Goals: Students learn the relationship between adding solvent or solute, shown visually through the deepening color of the solution as more solute is added, or the lightening as more solvent/water is added. Students can play with the quantitative relationship between moles and volume, seeing the both the color change and the numerical M value change as they move the sliders.

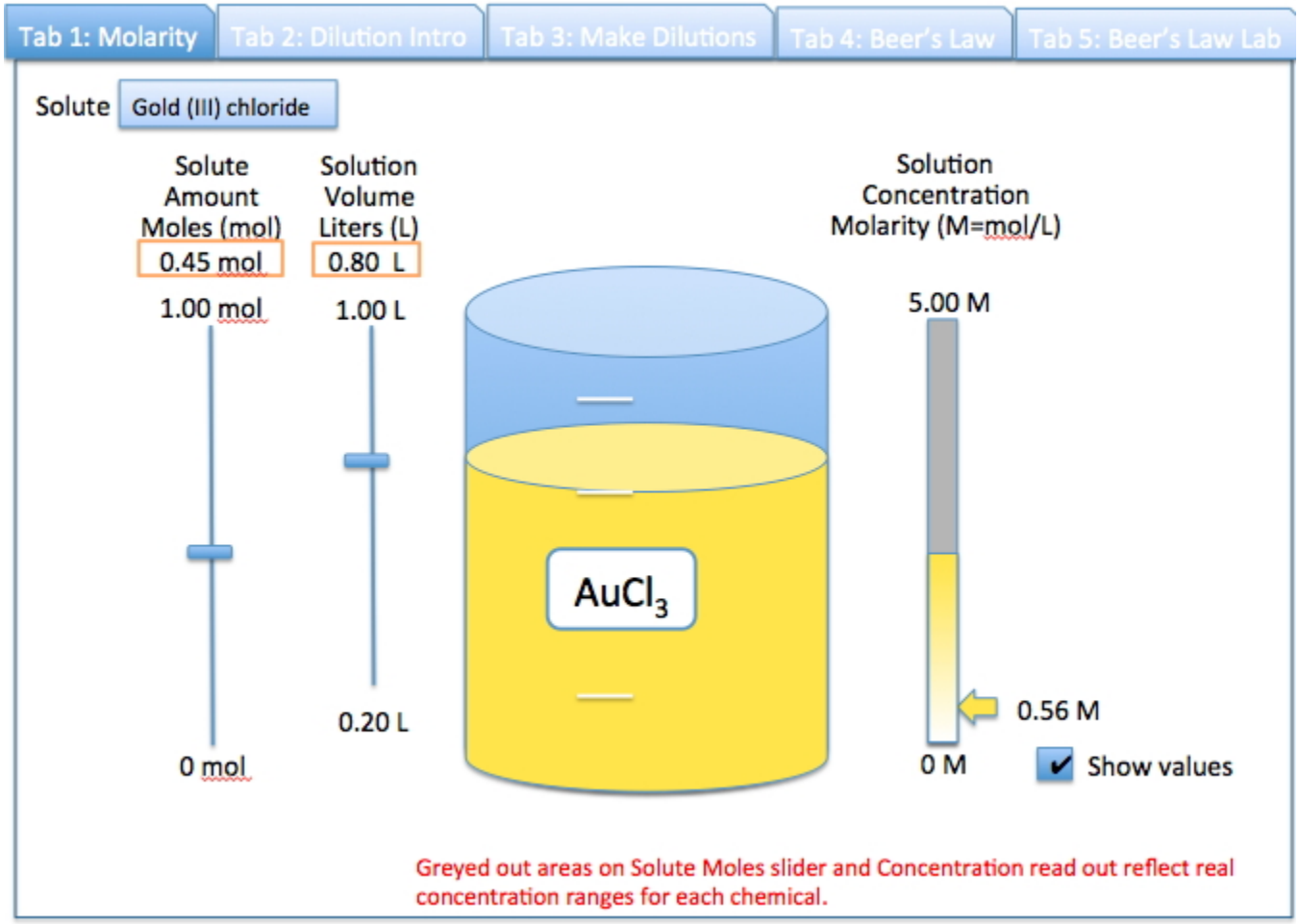
Initial view is qualitative only. The name of the chosen solute will appear on the beaker as a large text label. Molar mass is not provided.





When the "Show Values" box is checked, numerical values for solute (moles or grams), volume (L), and molarity (M = mol/L) will appear, as well as quantitative scale indicators on the molarity slider/read out.

Because of solution constraints (solubility range, over saturation needing to be avoided) the ranges will be 0-1.0 moles, 0.2 - 1 L, and 0 - 5.0 M.



Solute Information:
Here is a table of useful current proposed solute information. The previous table of solute info is saved in the Discussion History from 09/21/11.

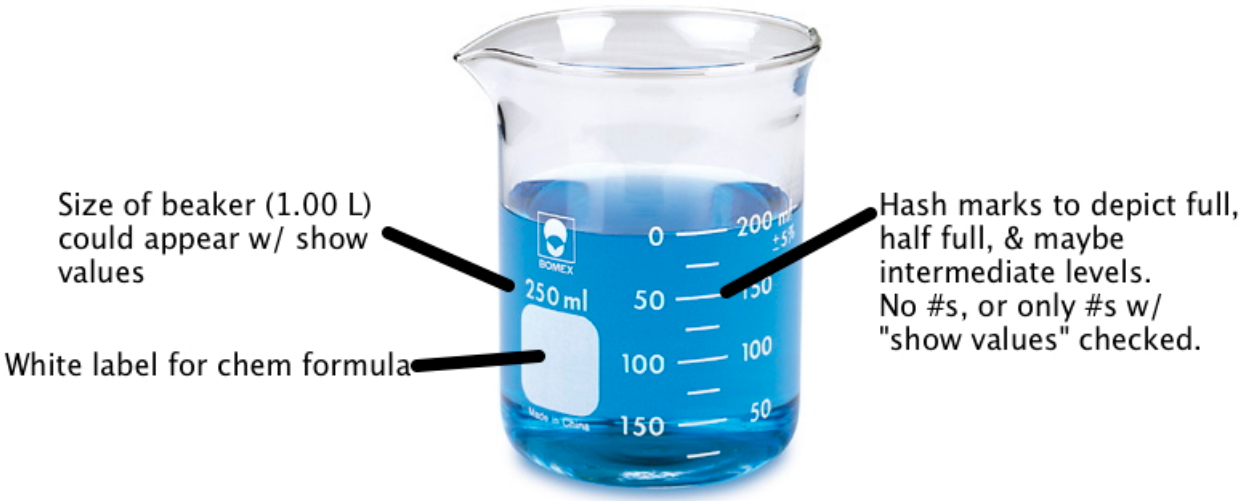
If reincorporating real chemicals:

Solute Formula	Name	Color	Max Moles (real)	Max Molarity (at 0.2 L)	Max Moles for Sim	Max Molarity for Sim (min V = 0.2)
Kool-Aid	Kool-Aid	red	1.192 mol	5.958 M	1.00 mol	5.00 M
$Co(NO_3)_2$	cobalt (II) nitrate	red	1.129 mol	5.644 M	1.00 mol	5.00 M
$NiCl_2$	nickle (II) chloride	green	1.042 mol	5.209 M	1.00 mol	5.00 M
$CoCl_2$	cobalt chloride	rose pink	0.866 mol	4.330 M	0.87 mol	4.35 M
K_2CrO_4	potassium chromate	yellow	0.670 mol	3.348 M	0.67 mol	3.35 M

$AuCl_3$	gold (III) chloride	yellow	0.448 mol	2.242 M	0.45 mol	2.25 M
$CuSO_4$	copper sulfate	blue	0.275 mol	1.375 M	0.28 mol	1.40 M
$K_2Cr_2O_7$	potassium dichromate	orange	0.102 mol	0.512 M	0.10 mol	0.50 M
$KMnO_4$	potassium permanganate	purple	0.096 mol	0.481 M	0.10 mol	0.50 M

Note: **Solubility values** are calculated from mass % values given in the CDC Handbook of Chemistry and Physics 91st edition, online. http://www.hbcpnetbase.com/

Beaker appearance:
If multiple solutes are implemented, a cartoon version of a beaker similar to this one would be nice. Important features are hash marks to indicate levels (full, ¾, half, ¼ would be fine, with no number labels) and a white area to label what chemical it is, possibly with a hand-writing-like font. Here's an example that I wrote notes on:



Examples of solution

colors:
From left to right, aqueous solutions of: cobalt(II) nitrate, $Co(NO_3)_2$ (red); potassium dichromate, $K_2Cr_2O_7$ (orange); potassium chromate, K_2CrO_4 (yellow); nickel(II) chloride, $NiCl_2$ (green); copper(II) sulfate, $CuSO_4$ (blue); potassium permanganate, $KMnO_4$ (violet).
Image & legend: http://commons.wikimedia.org/wiki/File:Coloured-transition-metal-solutions.jpg

Cobalt Chloride (left) and potassium permanganate (right)

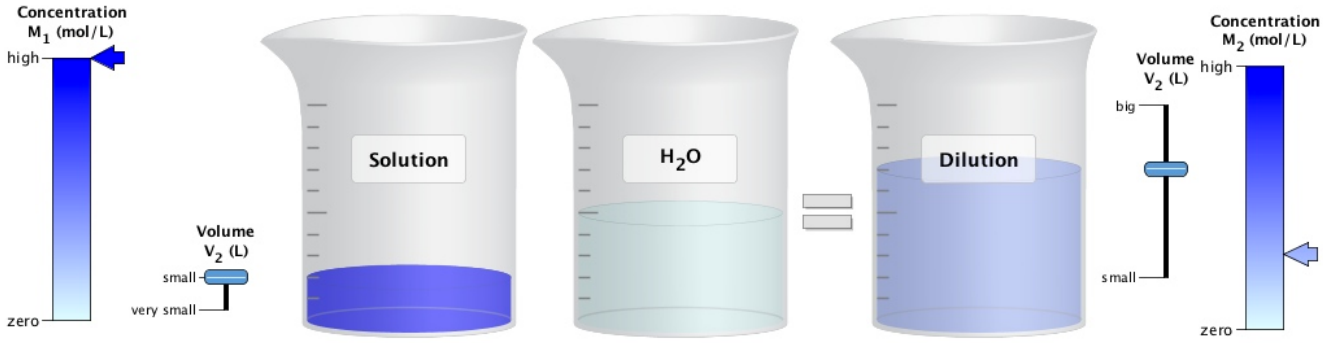
Chemical precipitate: Most chemical solids are the same color as the solutions for this sim, except for $KMnO_4$, which has crystals that are so dark purple, they look almost black (right). Here are some saturated solutions of $CuSO_4$ (middle, blue) and $AuCl_3$ (right, yellow).

Tab 1 Remaining Questions:
(none at the moment)

Second Tab - Dilutions

This tab allows students to play with the (M1)(V1)=(M2)(V2) equation qualitatively, to see the relationships and how molarity and volume affect each other in dilutions. The goal is to provide a framework for students to understand the relationships needed for calculations in the Make Dilutions tab (Tab 3). Currently, we do not intend for Tab 2: Dilution Equation to be quantitative--we want to focus on the relationships of proportions, not numbers.

Given: Slider controls for M1, V1, and V2. See how these 3 affect the readout of M2.



Current view: Beakers of fixed size and variable volume and concentration. Water volume adjusts automatically to compensate for the difference between V1 and V2. The V1 and V2 beakers are the same size; the sliders emphasize that V1 is smaller.

By omitting the pipettes and volumetric flasks, I hope to focus on the relationships between molarity and volume, rather than the procedure of making a dilution (which will be the third tab.)

Let's start with blue solution in this tab. Is there benefit to including other colors?

Deciding on sizing.
M1 and M2 scaling is equal (for the sake of discussion, say 0-1 M.)
3 beakers are the same size (for the sake of discussion, say 0-1 L, each tick mark is 0.1 L.)
Maximum M1 = 1 M.
Maximum V1 = 0.2 L
Minimum V2 = 0.2 L (water beaker empty)
Resulting M2 = 1 M (max on slider)

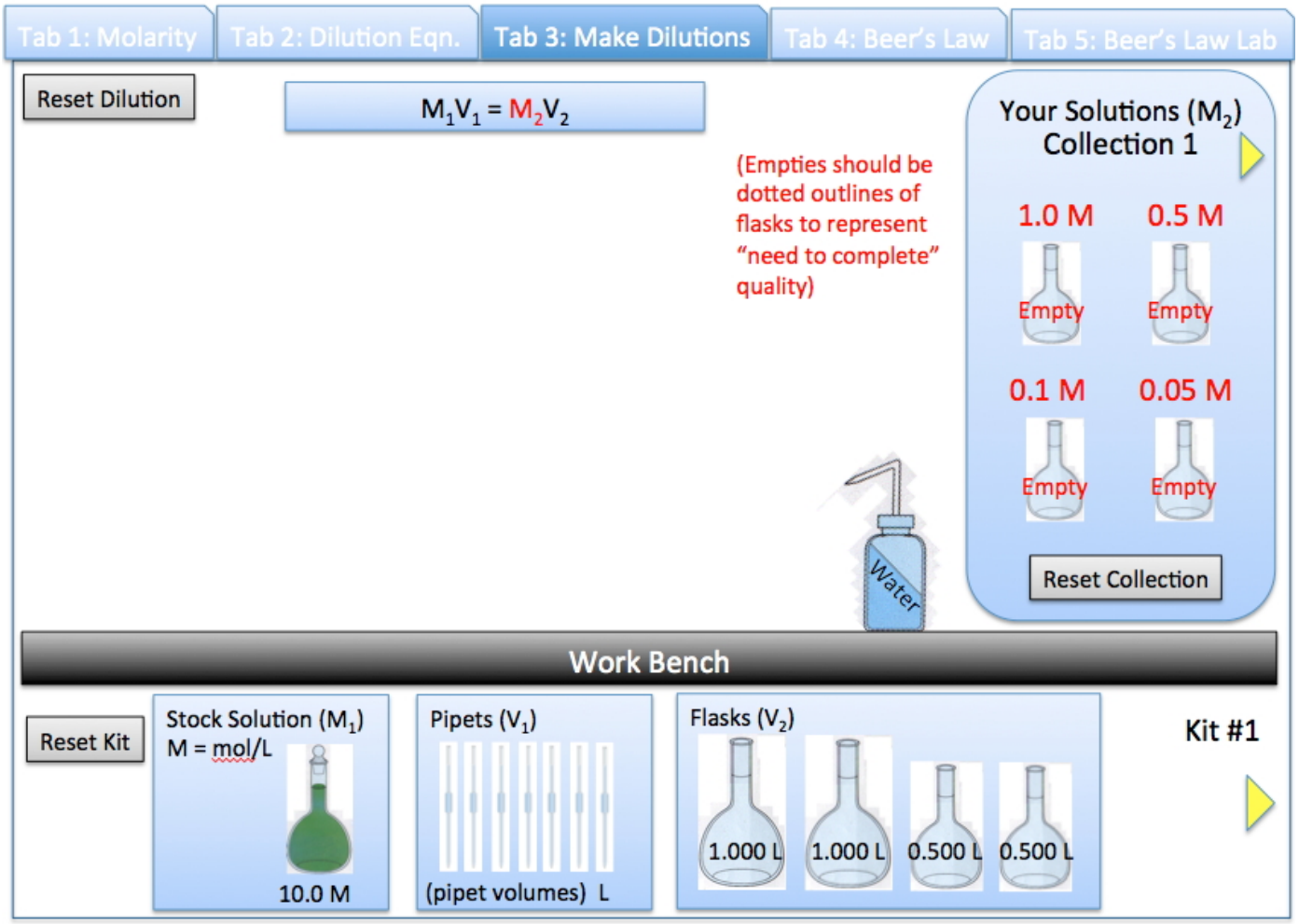
Maximum M1 = 1 M.
Maximum V1 = 0.2 L
Midrange V2 = 0.4 L (water beaker = solution beaker volume)
Resulting M2 = 0.5 M (halfway point on M2 slider)

Minimum M1 = 0 M, resulting in 0 M on M2 and water in all beakers. (Important: when M1 concentration is zero, all beakers should read H2O.)

Minimum V1 = ? How small of increments make a difference on this slider? No point going to smaller increments than could be manipulated with the slider. Would 0.01 L work? Is that what we have on the Molarity Tab, or are the increments smaller than they numbers were when we had them included?

Third Tab - Make and Compare (multiple) Dilutions

This tab provides the tools to make multiple solutions side by side to compare them both qualitatively and quantitatively. This tab will ask students to use the (M1)(V1)=(M2)(V2) equation and the relationships they learned about in Tab 2. Currently, the plan is for students to use an unnamed solution in this tab, since concentrations for stock solutions exceed the solubility limits for most of the colored solutions in the Molarity Tab (Tab 1).



Student have kits for each variable: M1, V1, V2, and M2 (the goal). We still need to consider which combinations of kits students should be able to access at once. There will be a lot of combinations, some of which are more challenging than others (and some of which won't work well at all--like the large flasks kit with the smallest pipette kit, for example.)

Current Kit Ideas (Each Kit is a set of M1, V1, V2, not interchangable).

	M1 Stock Solutions	V1 Pipettes	V2 Flasks	M2 Solution Goals
Kit A	10.0 M	L	1.000, 1.000, 0.500, 0.500 L	5.0, 4.0, 2.0, 1.0 M
Kit B	6.0, 4.0 M	L	2.000, 1.000, 0.800, 0.500, 0.250 L	1.4, 1.2, 0.8, 0.6 M
Kit C	5.0, 3.0, 1.0 M	L	0.100, 0.050. 0.025, 0.010, 0.005 L	0.4, 0.2, 0.1, 0.05 M

Initial Kit Ideas (all interchangable)

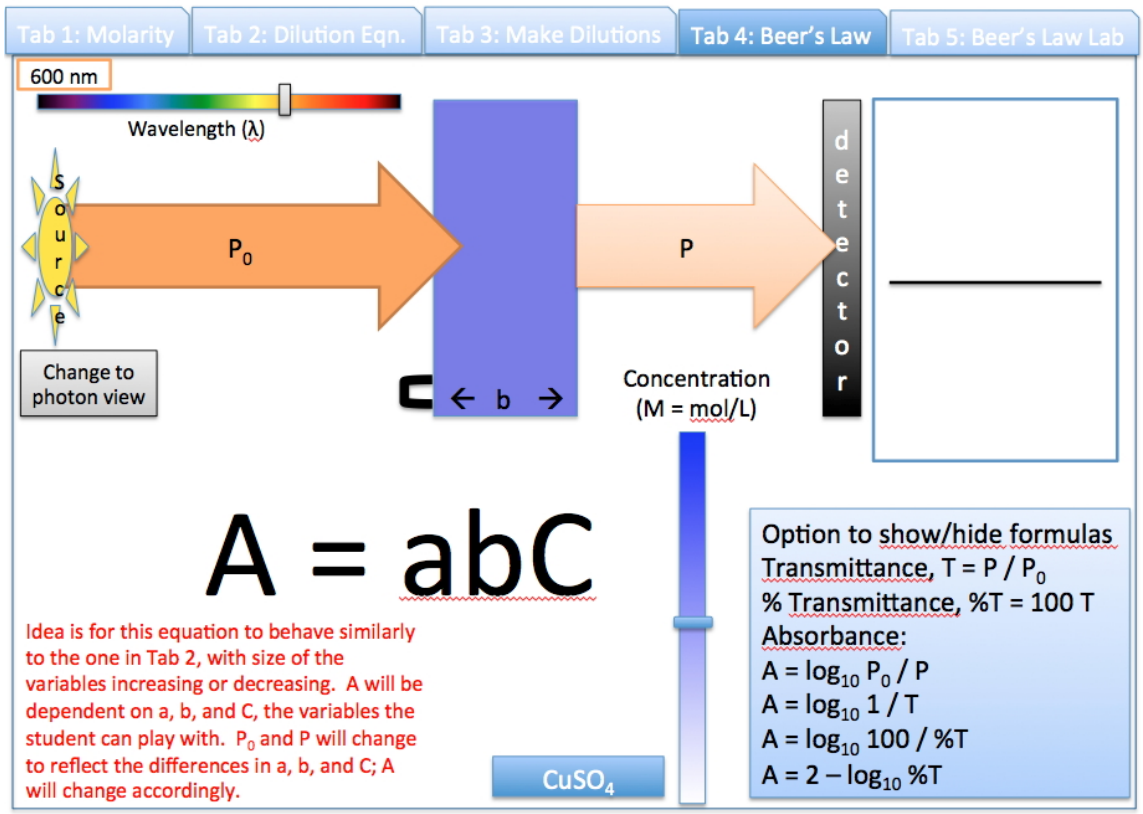
	M1 Stock Solutions	V1 Pipettes	V2 Flasks	M2 Solution Goals
Kit A	10.0, 5.0, 2.5, 1.0 M	0.01 - 1.00 L	1.000 (x2), 0.500, 0.250, 0.100 L	1.5, 1.0. 0.5, 0.25 M
Kit B	12.0, 6.0, 3.0, 1.5(?) M	0.001 - 0.100 L	2.000, 1.000, 0.800, 0.500, 0.250 L	1.4, 1.2, 0.8, 0.6 M
Kit C	16.0(?), 8.0, 4.0, 2.0 M	0.0001 - 0.0100 L	0.100, 0.050. 0.025, 0.010, 0.005 L	0.4, 0.2, 0.1, 0.05 M

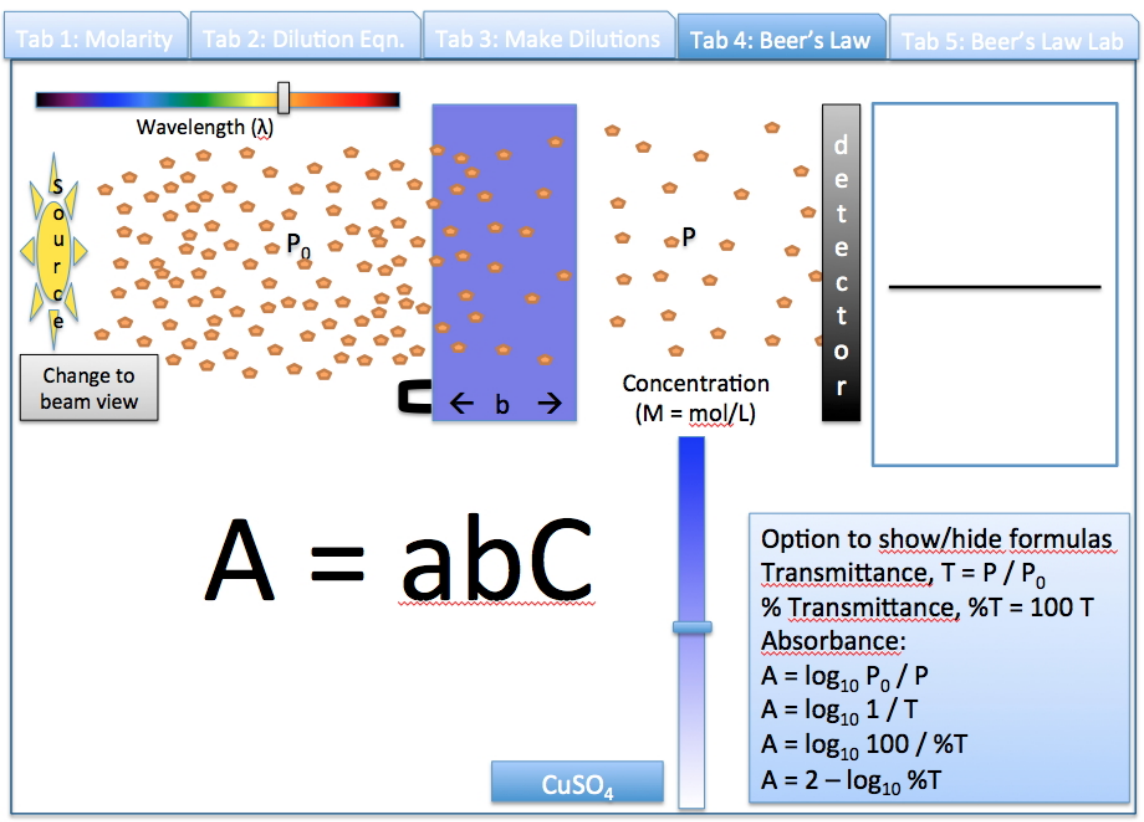
With this kit format, students cannot manually change the concentration of their stock solution. Should we make a “custom” option? I am still thinking about how to present and order the kits and challenges so that they start easy and get harder as the students go along. The collection box from BAM is a good model for how we might structure this.
NOTE: Solutions in Tab 1’s Solute Options do not have high enough solubilities to make 12 M stock solutions. Be aware when planning the options and constraints in this 3rd tab. Currently the best solution (to the problem) is to have Tab 3 be with an unnamed solution (solution X) that can have concentrations up to 12 Molar.

Possible Challenge activity: Complete increasingly difficult kits with different constraints on glassware and stock solution concentration.
Virtual Lab concept: In at least one of the kits, students will make a set of standards that can be used to make a calibration curve in Tab 5. When they have successfully made the range of standards they need, a “Send for Analysis” button will appear, with some cue that their solutions will be waiting for them in Tab 5.

Fourth Tab - Beer’s Law Equation: Virtual Spectrophotometer

Main idea: Let students play with all the variables in Beer’s Law to learn what each is/does.
Note: May need to set wavelength, or specify absorption max for each solute.


Tab 1: Molarity
Tab 2: Dilution Eqn.
Tab 3: Make Dilutions
Tab 4: Beer's Law
Tab 5: Beer's Law Lab
600 nm
Wavelength (λ)
Source
P_0
P
detector
Change to photon view
b
Concentration (M = mol/L)
A = abC
Idea is for this equation to behave similarly to the one in Tab 2, with size of the variables increasing or decreasing. A will be dependent on a, b, and C, the variables the student can play with. P_0 and P will change to reflect the differences in a, b, and C; A will change accordingly.
$CuSO_4$
Option to show/hide formulas
Transmittance, $T = P / P_0$
% Transmittance, $\%T = 100\ T$
Absorbance:
$A = \log_{10} P_0 / P$
$A = \log_{10} 1 / T$
$A = \log_{10} 100 / \%T$
$A = 2 - \log_{10} \%T$


Tab 1: Molarity
Tab 2: Dilution Eqn.
Tab 3: Make Dilutions
Tab 4: Beer's Law
Tab 5: Beer's Law Lab
Wavelength (λ)
Source
P_0
P
detector
Change to beam view
b
Concentration (M = mol/L)
A = abC
$CuSO_4$
Option to show/hide formulas
Transmittance, $T = P / P_0$
% Transmittance, $\%T = 100\ T$
Absorbance:
$A = \log_{10} P_0 / P$
$A = \log_{10} 1 / T$
$A = \log_{10} 100 / \%T$
$A = 2 - \log_{10} \%T$

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:
Transmittance, $T = P / P_0$
% Transmittance, $\%T = 100\ T$
Absorbance:

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

Absorbance (A) is also equal to abC (molar absorptivity)(path length)(Concentration)

Molar absorbtivity is a measure of the amount of light absorbed per unit concentration. It is for a particular substance, so if the concentration of the solution is halved so is the absorbance, which is exactly what you would expect.

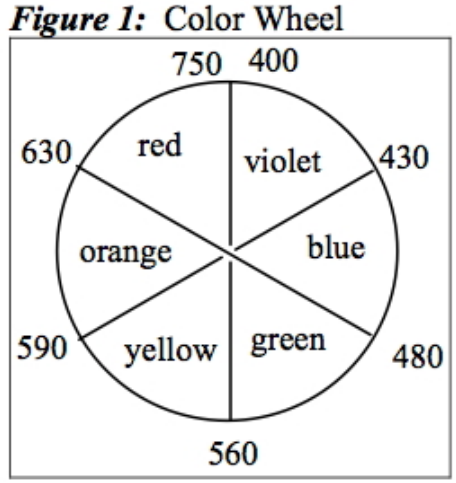
A=abC tells us that absorbance depends on the total quantity of the absorbing compound in the light path through the cuvette. If we plot absorbance against concentration, we get a straight line passing through the origin (0,0). (Note: this doesn't hold at high concentrations because there is a limit to how much light can get absorbed--namely, all of it. This is the detection limit.)

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

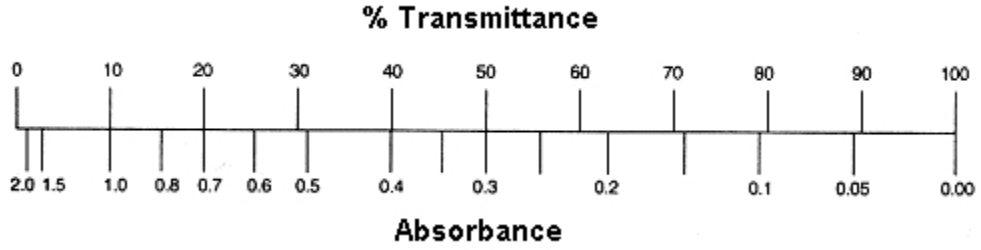


Some info on chemical color, but not lambda max: http://en.wikipedia.org/wiki/Color_of_chemicals

Solute	Name	Color	Absorption $_{max}$ in nm	Molar Absorptivity (a) units = $M^{-1}cm^{-1}$	Solubility Limits (per L)
Kool-Aid	assume=sucrose $C_{12}H_{22}O_{11}$	red	490 ?		0 - 2040 g 0 - 5.9583 mol

$Co(NO_3)_2$	cobalt (II) nitrate	red	490 ?		0 - 1032 g 0 - 5.6440 mol
$CoCl_2$	cobalt chloride	rose pink	560		0 - 562.3 g 0 - 4.3304 mol
$K_2Cr_2O_7$	potassium dichromate	orange	480 ?		0 - 150 g 0 - 0.5124 mol
K_2CrO_4	potassium chromate	yellow	450 ?		0 - 650 g 0 - 3.3481 mol
$AuCl_3$	gold (III) chloride	yellow	450 ?		0 - 680 g 0 - 2.2418 mol
$NiCl_2$	nickel (II) chloride	green	650 ?		0 - 675.0 g 0 - 5.2087 mol
$CuSO_4$	copper sulfate	blue	600 (?) 610 (?) 650 ?	2.2 (?)	0 - 219.5 g 0 - 1.3753 mol
$KMnO_4$	potassium permanganate	violet	530 ?		0 - 75.96 g 0 - 0.4807 mol
Custom	n/a	?			0 - 10.0 moles
$Fe(SCN)_3$??	iron (III) thiocyanate*	redish brown			
others?					

Thoughts and issues with Tab 4:
The most important relationships to show are that A and T change as pathlength (b) and concentration (C) are varied. Could represent this with bar graphs similar to sugar salt solutions. Would be good to include a %T compared to A chart like this one:

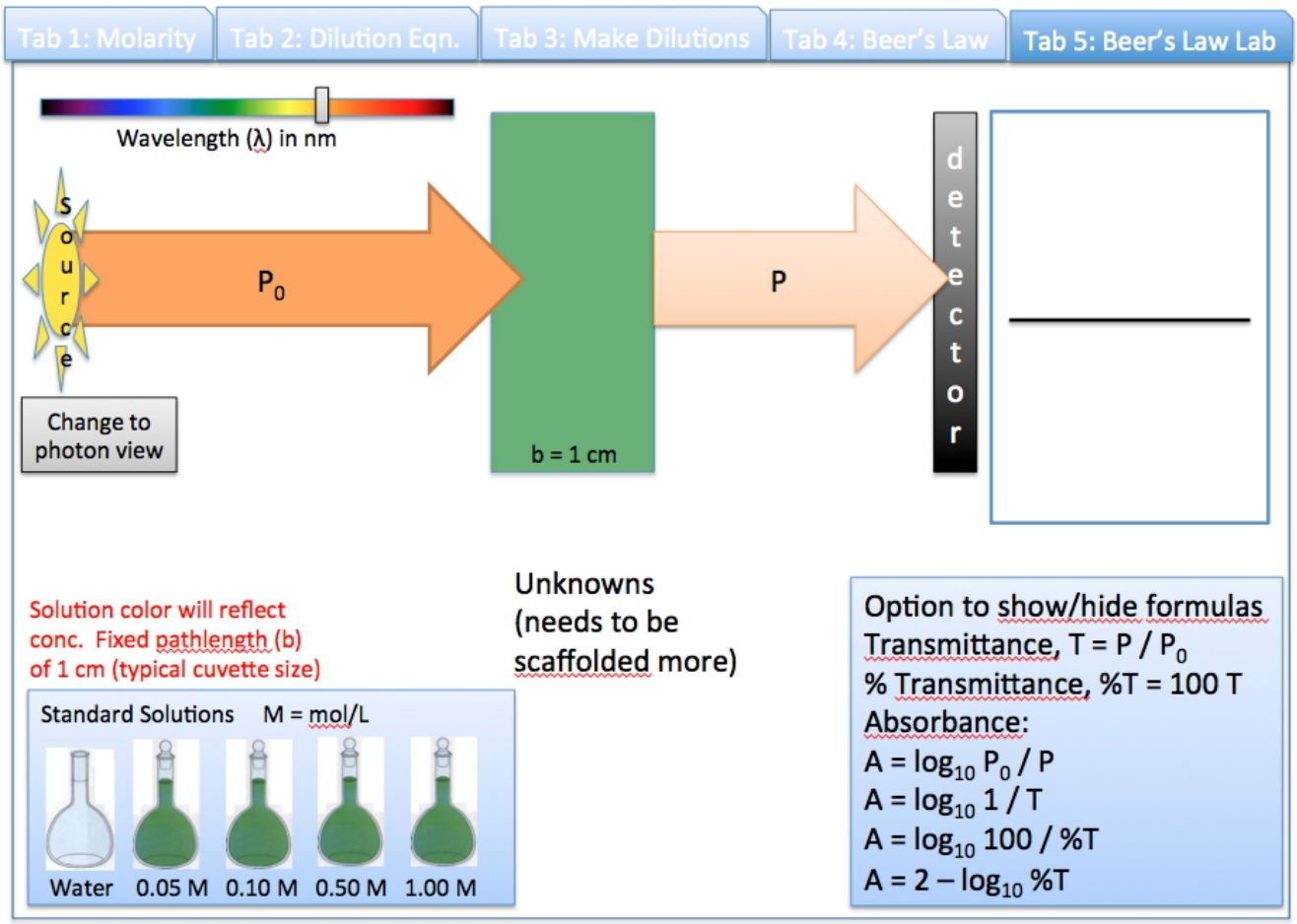


It would be neat to include changing wavelength, so that students can see the affect of using wavelengths that are not the max (maximum absorbance wavelength). This would potentially be much harder for real chemicals--would need to look up and incorporate the individual absorbance spectra of each one. (Maybe that would be doable?) Could try to simplify by using colors instead, with a somewhat arbitrary absorbnce spectrum for each, but this detracts from changing the concentration (since in my mind, a color is not a solution).

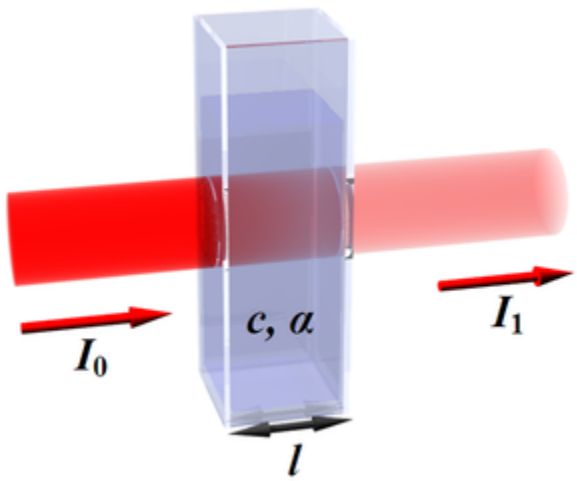
It's also important what results and relationships we show graphically on this tab, to communicate the most important learning goals. This is very different from the first 3 tabs in terms of what tasks the sim will perform and what information the students will need to easily see by using it.

Tab 5: Beer's Law Lab: Measurement with Virtual Spectrophotometer

A virtual data collection interface to measure absorbance of different concentrations of solution to construct a calibration curve and use it to determine the concentration of a solution with unknown molarity.



Idea 2 Notes: (Virtual Spectrophotometer, calibration curve, measuring an unknown)
Interface idea: have students drag and drop cuvettes of solution to the spectrophotometer, which would show the light beam source, the space for the cuvette, and the detector. Here's where A=abC comes in. This tab should also have the ability to open an extra graphing window to make the calibration curve.



The spectrophotometer should help demonstrate and visualize the absorbance of light by the colored solution.

Pathlength and wavelength (max) will be fixed in this tab--students can play with them in Tab 4. Here the goal will be for students to measure their standards, make the calibration curve, and calculate the unknown concentration. It may also be a goal for them to see that different chemical compounds have different molar absorptivity values (a). When they change chemical solution, the maximum absorption wavelength will change to be the correct value.

Discussion History

This section is intended to capture the feedback that we get on early versions and the decisions that are made in response to it.

Optional content ideas:
- Serial dilutions vs. dilutions from stock solution: pros and cons? (applicable to chem & bio)
- How to calculate molar absorptivity (probably include) from slope? Or just provide it.
- Different chemical solutions with different molar absorptivities?
- Different ideal absorption wavelengths (lambda max) for different chemical compounds? Maybe start with one as a model, with others for comparison? Will our spectrophotometer be variable wavelength? How will students find the max absorption wavelength?

07/20/11 - *PhET Chem Meeting*
Ideas to include:
- Common ion effect?
- Precipitation and solubility rules (probably a good idea for a different sim on this topic)
Feedback on learning goals:
TL: Maybe address g/L concept, % concentration and % mass (if mass, need density concept).
RP: Concepts of direct and inverse proportional reasoning.
EM: Important to keep the chemistry flavor in this sim.
TL: Density and parts per million (ppm).

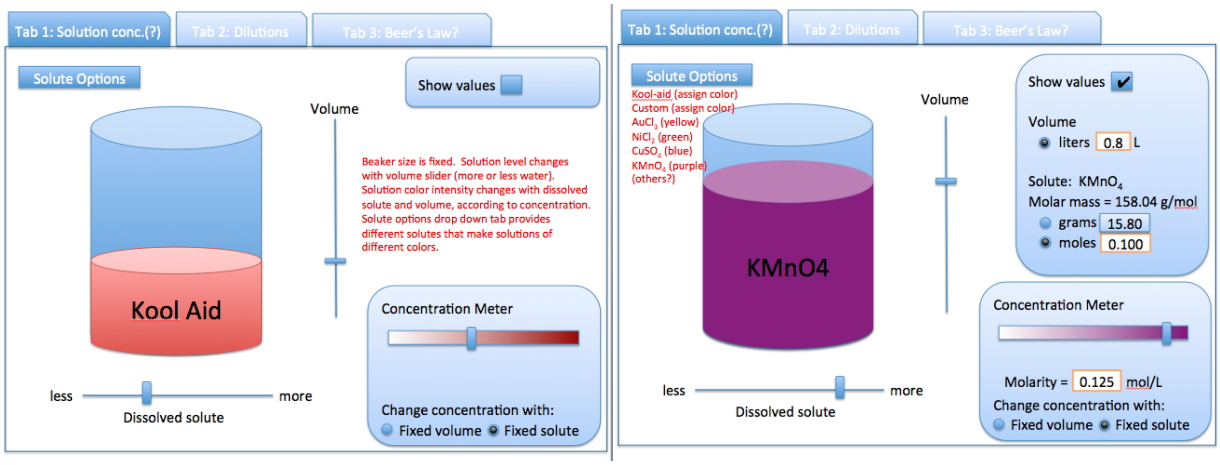
KL: Be able to change units (g/L, mol/L) mass and density seem procedural (factor labels)
KP: Are you keeping it generic enough? Allow vary mass of X but not moles to see what changes.
EM: KP's idea is cool, but may not fit this context.
KL: First 2 learning goals sound similar to Sugar and Salt Solutions sim?
JC: Dilutions will be a different representation, and also have more quantitative scaffolding.
EM: A teacher has requested this!
RP: Get lab manual for Chem 1113 dilution lab, a specifically developed lab with learning goals, which may be helpful.

07/22/11 - *JC & KL discussion*
- Look to Density sim for ideas on how to show the relationship between moles, volume, and molarity (in density it's mass, volume, and density). Good example of sliders interacting and constraints on what the student can control in this type of relationship.
- Consider a challenge goal for the dilutions tab to encourage students to figure out the mathematical relationship, rather than giving students the equation. This could have a completion score or tally box of number of correct dilutions made.
- "Send for Analysis" button on the "make dilutions" tab to send prepared solutions to the analysis tab (spectrophotometer) to use in the calibration curve.
- Slider to change concentration of stock solution (with numerical entry field as well).
- For Beer's Law, let students play around with all of the parameters of Beer's law to help understand and visualize relationships.
- Solute options front and center in first tab (done)
- Make controller expandable, to hide & show like in Build An Atom.
- Separate "Concentration Meter" (molarity display readout) from the control box. Could have a drag-out tool to use the meter to measure molarity, like the conductivity meter in Sugar and Salt Solutions?
- Will need to figure out how to let students change molarity: decide on fixed volume or fixed moles (or how to make these options).

07/25/11 - *JC & EM discussion*
EM: Show solute options, rather than hiding them in drop down menu?
JC: Good idea, but the different colored solutions are not the focus of the sim, so I don't want it to distract; drop down is probably better in this case, at least for the initial view.
EM: Thinking about density sim, there are different modes, "real objects" and "my objects". In this sim, if there is a custom setting, it's important to make sure which mode the student is in is clear.
EM: In Tab 2, need to simplify procedure. Drag out flasks from a selection menu? Idea of kits to scaffold the complexity of the task.
JC: Difficulty levels could be scaffolded in kits (easy, medium, hard); full free range would allow they to tailor their dilutions to be all easy calculations. They should have the opportunity to be challenged once they understand the process.
EM: Kits could be flasks of different sizes, different numbers of flasks, different challenges in each kit.
JC: Not sure whether to include (M1)(V1)=(M2)(V2) formula, include in a hint box, or not include.

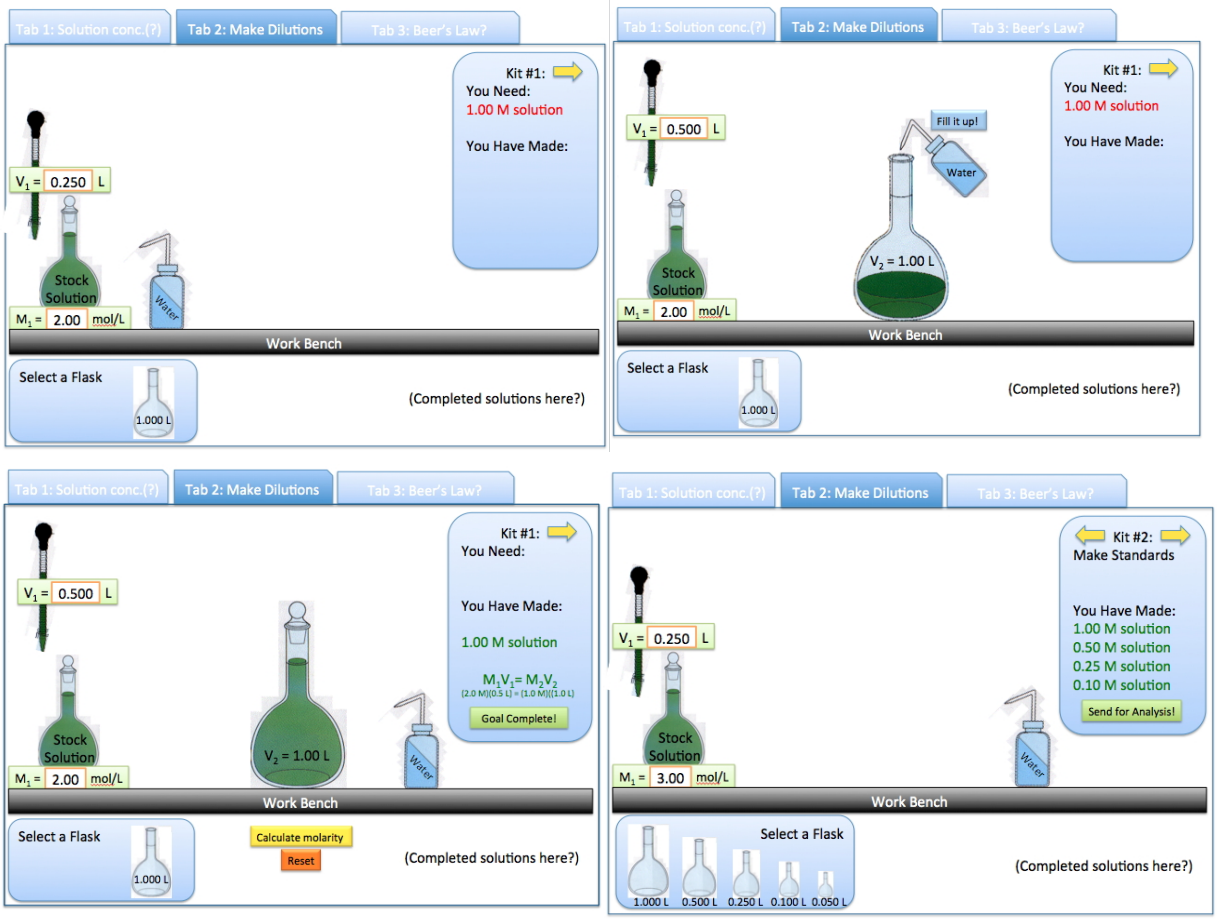
Also not sure whether to provide a calculator type tool. Don't want too much focus on numbers, but also want the quantitative part to stand alone just fine.
EM: Talk to Noah P. for ideas on how to encourage play with this sim.
EM: Maybe you need smaller chunks [of information, tasks, etc].
JC: Could be useful to show the (M1)(V1)=(M2)(V2) equation for completed dilutions in the goal box, for comparisons.

07/27/11 - *PhET Chem Meeting*
Ideas and feedback from Kathy, Robert, Trish, Emily, and Kelly.
Tab 1:



Consider using a faucet to add water rather than a slider.
Don't use the word dissolved--just solute. Connect the solute slider to the drop down menu OR label the solute slider with the name of the solute that has been chosen.
EM: Put concentration meter more front and center (under the beaker maybe?) Or, vertical next to the beaker. Consider having all 3 sliders parallel (vertical) to compare their relationships.
KL: Maybe when the values are showing the readout should be on (or connected to) the slider?
Current question: How does the water go away? Evaporation? Do we show this?
TL: Maybe have an unknown? Use "none" instead of "less" on solute and volume sliders.
When you switch solutes, should the solute go to "none"? (No, that would reset to H2O every time--maybe it should go to a set concentration each time.
TL: molar mass sim idea!
Look at allowed concentrations and solubility for chemicals selected (JC: added chart in g-doc)
Don't choose solutes that are insoluble. Examine and change solubility range later.
KP: Solute slider: grams or moles? In "Custom" should there be a slider for molar mass?
KP: Don't need radio buttons for g and mol. Could make a slider for moles and simplify design.

Tab 2 (Make Dilutions -- now Tab 3) Feedback:



EM: Changes since last time are good! Custom option to edit stock solution #s?
EM: Consider options of stock solution similar to Kit of flasks.
KP: Make collection on the right like in BAM; kits of stock solns and flasks on bottom
EM: can collapse some of the items in the kits so they expand when dragged out or clicked.
RP: get rid of subscripts on M and V on the tools.
KP: can we visually show the proprotional relationship between M and V? eg. Mv = mV? (Maybe bar graphs?)
RP: Hard to convey moles = moles.
KP: Hard to visualize this relationship with numbers only.
KP: Is the squirt bottle too small?
KP: Redesign with multiple stock solutions, collection boxes, and think about what to do for calculations.

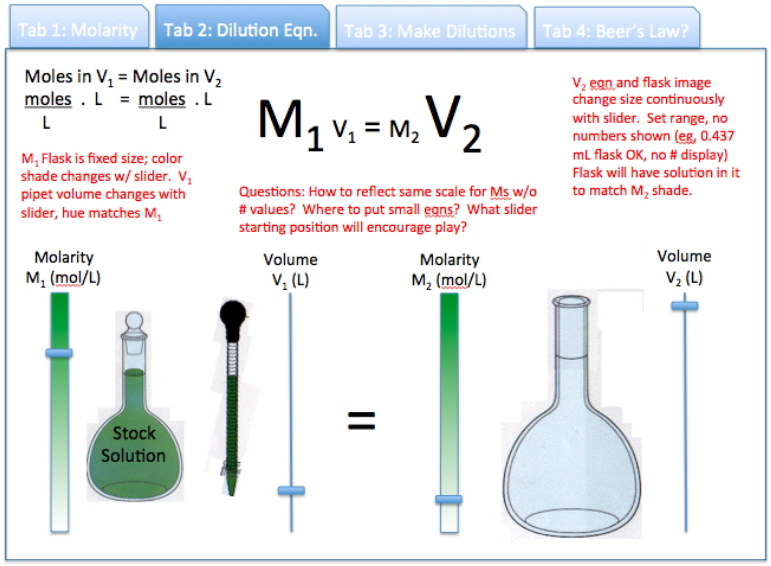
08/03/11 - *PhET Chem Meeting*
Ideas and feedback from Robert, Trish, and Emily.

Decided on Design Team Core of Julia, Kelly, and Robert. Emily and Trish will be "consultants" (access and input on google doc, but won't regularly attend meetings on this sim).

Tab 1:

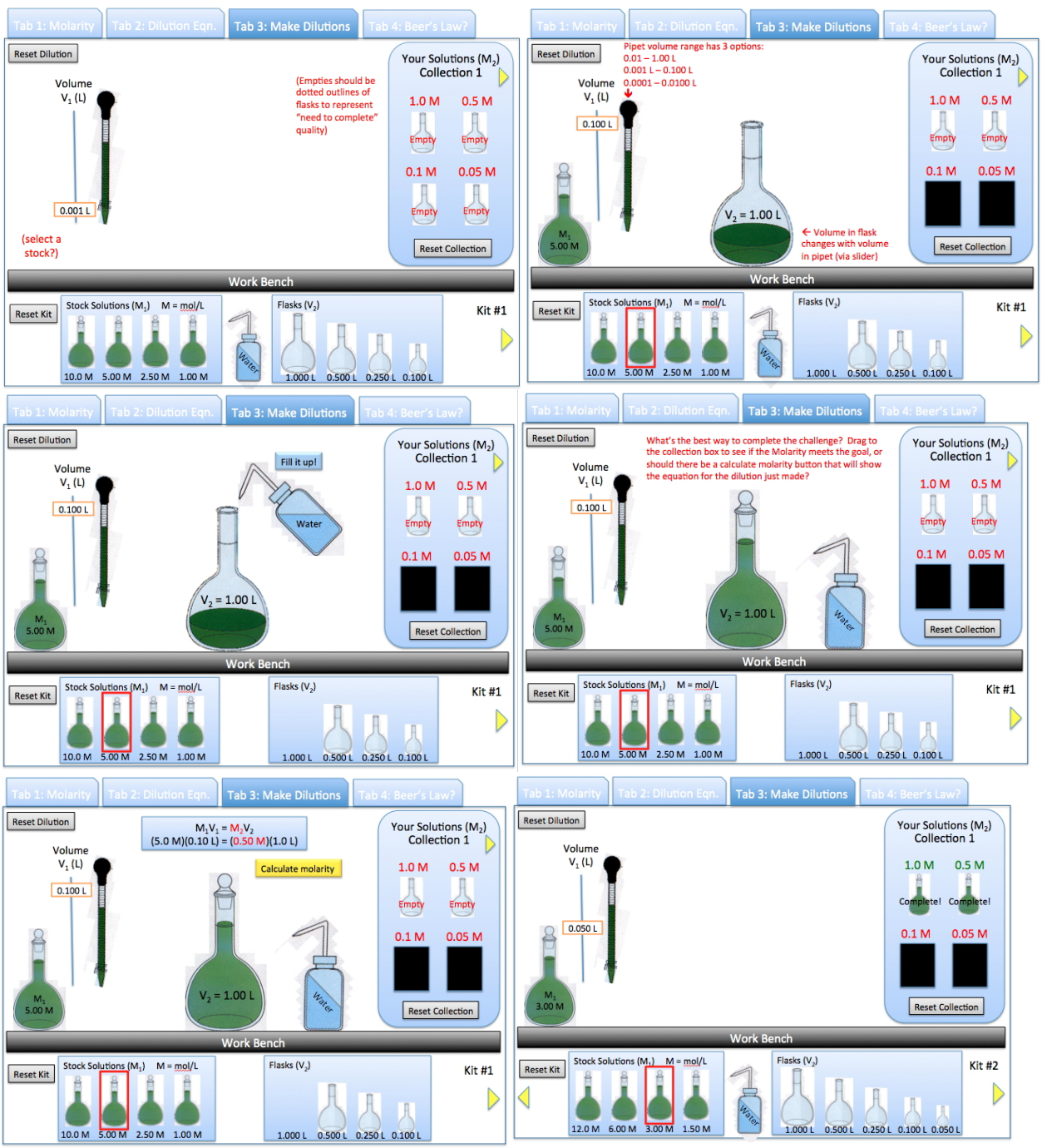
EM: It would be helpful to connect Concentration with M, in the pop up box for editing concentration. One way to do this would be to have the pop up box say “Concentration” instead of M. (done)
TL: Based on how this is set up, the slider magnitude for solute will change with different solutes (to reflect solubility). You’ll want to try having an insoluble and a soluble solute in interviews, and see if the students can process that slider magnitude is changing. Also, ask NP for ideas about changing magnitude.
EM: Ask NP about how we did "autoscale" in capacitor lab in the past, that might help with the rescaling of the solute slider.

Tab 2:



RP: The growing and shrinking characters in the equation didn’t work with the Acid Base sim.
JC: We’ll see how it goes in this sim; shouldn’t be super hard to implement to see and test it.
TL: I want the moles = moles relationship to be more obvious. Maybe show moles on both sides are equal (using numbers?)
RP: This tab addresses the inverse proportion relation well, but could do better on the moles.
TL: I'm wondering if there needs to be something more evident showing what the moles are.
EM: Regarding layout, students can map pretty well from vertical to horizontal sliders. Consider doing horizontal sliders below, with a mole slider below too.
TL: It would be good to interview on this to see what students do and don't see and use. Do they come out of the second tab knowing that the amount of solute (moles) was equal on both sides? (Good question).

Tab 3:

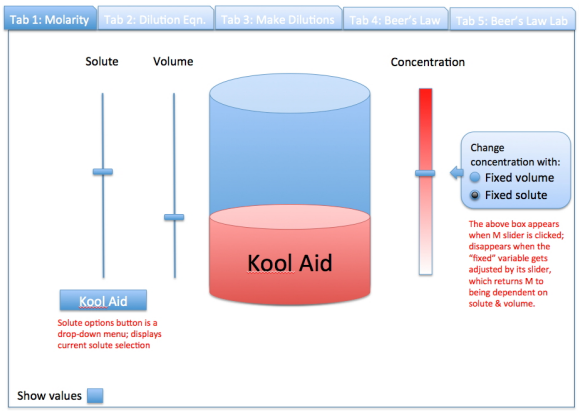


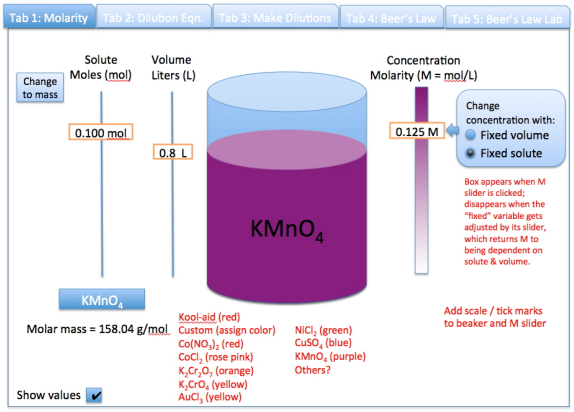
EM: Empty flask outlines in the goal area can visually indicate that something goes there, that it's a goal to fill in, that it can be changed.
JC: I will change it to a dotted outline for empties.
TL: One way of doing it would be that the pipette (V1) is what you select from the kits below, and the flask (V2) is what you're given already.

Question of 1 or 2 sims
JC: These three tabs cover dilutions pretty well; the Beer's law part is feeling different to me, and

could be separate, but I can seem some major advantages to keeping them together. Thoughts?
TL: look at Faraday's Eletromagnetic Lab--it has 5 tabs, but it also is useful broken into smaller separete sims. We could do the same with Dilutions & Beer's Law-- have one big sim, with smaller sims that can be used separately if desired.
RP: the three tabs here are good; it might be helpful to get experience with the whole design process; this could inform your choices on the design of the latter half of this sim.
TL: The three tabs here are good--it would be a full blown yummy sim. (<-- direct quote)

9/21/11 JC and CM Disussion of mockup (first 3 tabs)
Notes and mock ups from the google doc. CM in orange, JC in Purple.





CM: I'm not clear on what the Solute and Volume sliders are doing and they seem poorly labeled. Please describe.
JC: Concentration depends on 2 things: how much solute is in the glass, and how much water is in the glass. The solute slider is the measure of how many molecules of chemical there is (measured in either moles or grams, when "show values" is checked), and the volume slider is how much water is in the glass. The "Concentration" slider will vary with the combination of solute and volume, as in the Density sim, unless solute or volume are set constant.
CM: Label Solute range "none" to "lots"; Volume range "empty" to "full".

CM : I would label the solution combo box, eg "Solute:".
JC: sounds good. I'm open to your ideas on what would look best.

First Tab Goals: Students learn the relationship between adding solvent or solute, shown visually through the deepening color of the solution as more solute is added, or the lightening as more solvent/water is added. Students can play with the quantitative relationship between moles and volume, seeing the both the color change and the numerical M value change as they move the sliders.
CM: The described behavior of the "M slider" is very odd, and has potential usability problems. I think we should investigate other designs for accomplishing what you're trying to do here.
JC: OK. Let's discuss in person.

Given: A beaker of solution, sliders to change volume and amount of dissolved solute. Initial view is qualitative only. (red solution image was here as a demo).
The name of the chosen solute will appear on the beaker as a large text label. The solute for the initial view is Kool-Aid. Students can choose other solutes from the drop down menu (different chemicals with different colors). Changing solutions will reset the concentration to some medium

level. When solute amount is zero, the beaker will read "H_2O".
CM: Doesn't resetting the concentration make it difficult to make comparisons between solutes?
JC: I am not sure what you mean exactly. I guess you couldn't compare a 0.5 M concentration of 2 different solutes by changing only solute, you'd have to reset concentration. But, I think it's important for the concentration slider to demonstrate that the solubility range for different solutes is different.

When the "Show Values" box is checked, numerical values for molar mass of the solute (g/mol), mass (g), moles, volume (L), and molarity (M = mol/L) will appear, as well as a scale indicator on the molarity slider/read out. The scale will change with different solutions based on their solubility range and saturation points (see table below).

CM: By "scale", do you mean the range of M? Will users notice that the range has changed? If they notice the change, will they interpret it correctly?
JC: Maybe it would help to have a readout for "Solubility Range" or "Concentration Range" or something to indicate this more clearly.

CM: What does the "Change to Mass" button do in the above mockup?
JC: It lets students see the value in grams. Trish recommended being able to see that grams and moles are both measures of how much solute is in the beaker. I think it is a good idea. When "mass" (in grams) is selected, the other option would be "change to moles".
CM: Since this affects the value units, it should be colocated with the "Show values" feature. Add 2 radio buttons labeled "grams" and "moles".

Solute Options:
CM: Kool-Aid is a registered trademark of Kraft Food. Will this be a problem?
JC: I will look into it. (9/30 emailed Kraft to ask.)

Solute	Name	Molar Mass	Color	Solubility in H_2O	Per Liter Range for Sim
Kool-Aid	assume=sucrose $C_{12}H_{22}O_{11}$	342.296 g/mol	red	2039.5 g/L (20 C) 5.9583 mol	0 - 2040 g 0 - 5.9583 mol
$Co(NO_3)_2$	cobalt (II) nitrate	182.942 g/mol	red	1032.5 g/L (25 C) 5.6440 mol/L	0 - 1032 g 0 - 5.6440 mol
$CoCl_2$	cobalt chloride	129.839 g/mol	rose pink	562.3 g/L (25 C) 4.3304 mol/L	0 - 562.3 g 0 - 4.3304 mol
$K_2Cr_2O_7$	potassium dichromate	294.185 g/mol	orange	150.7 g/L (25 C) 0.5124 mol/L	0 - 150 g 0 - 0.5124 mol
K_2CrO_4	potassium chromate	194.191 g/mol	yellow	650.2 g/L (25 C) 3.3481 mol/L	0 - 650 g 0 - 3.3481 mol
$AuCl_3$	gold (III) chloride	303.326 g/mol	yellow	680 g/L (20 C) 2.2418 mol/L	0 - 680 g 0 - 2.2418 mol

$NiCl_2$	nickel (II) chloride	129.599 g/mol (anhydrous)	green	675.04 g/L (25 C) 5.2087 mol	0 - 675.0 g 0 - 5.2087 mol
$CuSO_4$	copper sulfate	159.609 g/mol (anhydrous)	blue	219.51 g/L (25 C) 1.3753 mol/L	0 - 219.5 g 0 - 1.3753 mol
$KMnO_4$	potassium permanganate	158.034 g/mol	violet	75.963 g/L (25 C) 0.4807 mol/L	0 - 75.96 g 0 - 0.4807 mol
Custom	n/a	What range makes sense?	?	very high (or no) solubility limit	0 - 10.0 moles
$Fe(SCN)_3$??	iron (III) thiocyanate*	230.092 g/mol	redish brown	soluble (unknown numeric value)	
others?					

Purple text indicates a solubility range that does not meet the range planned for the Make Dilutions tab (0-1.5 M). Consider limiting which solutes can be selected for goals. Also need to consider which solutes can be selected for Stock solutions! None have significantly greater than 5 M capacity, whereas the provided stock solutions were going to range from 1 M to 12 M. Possible solutions to this problem include setting just one solution (of chemical X) for the make dilutions tab; or, limiting/changing the stock solution kits to meet the solubility range of each different solute

chemical.
From left to right, aqueous solutions of: cobalt(II) nitrate, Co(NO3)2 (red); potassium dichromate, K2Cr2O7 (orange); potassium chromate, K2CrO4 (yellow); nickel(II) chloride, NiCl2 (green); copper(II) sulfate, CuSO4 (blue); potassium permanganate, KMnO4 (violet).
Image & legend: http://commons.wikimedia.org/wiki/File:Coloured-transition-metal-solutions.jpg

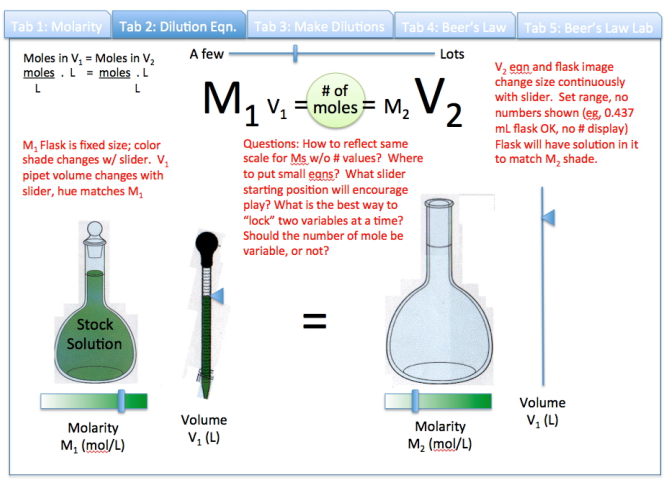
Note: **Solubility values** are calculated from mass % values given in the CDC Handbook of Chemistry and Physics 91st edition, online. http://www.hbcpnetbase.com/
Should we assume all chemicals are anhydrous (not hydrated) for the sake of clear chemical compound names and corresponding molar masses, even if the hydrated forms are more commonly found in the laboratory? Probably yes, since this sim is for General Chemistry, with the goal of teaching concepts.

Ranges for the **custom** compound are a current question. It doesn't make sense to allow custom compounds that are physically impossible (I think this would include chemical compounds that are less dense than water, 18 g/mol).

CM: Why doesn't it make sense to allow custom compounds that are physically impossible?
JC: My thinking is that the custom compound option would allow students to enter values for compounds they might be using in a hands-on experiment that we don't offer in the solute options. There would be no need to have this value go below 20 g/mol in this case. I am not sure if teachers would complain about letting the lower limit be physically impossible.
I don't think it makes sense for the molar mass lower limit be 0--that would be nothing. The molar mass of the lightest molecular compound (H_2 gas) is about 2 g/mol. The next lightest is 4 g/mol (helium). Neither of these are solids though. I think we are going to have to set a lower limit based on some rationale. I'll see what the design team thinks.
The purpose of this setting is to give students a tool that will calculate molarity for them from a given mass in grams, a molar mass they enter in, and the volume they determine. Can we provide this calculation tool without it being an answer factory? What constraints do we need?

Tab 1 Remaining Questions:
Adding and removing water from Tab 1: faucet and evaporation?
CM: Don't the sliders serve the same purpose as faucets?
JC: They do serve the same functions, but the design team wasn't certain if they were OK with water appearing and disappearing from nowhere. The problem is, volume reduction through a drain would also mean solute reduction, which might not fulfill the learning goals of this sim.
CM: So if we add faucets, will be remove the sliders? Having 2 controls that do the same thing is unnecessary and confusing.
Moles/grams/molar mass range limit for Tab 1 Custom compound--what makes sense?

Second Tab - Dilution Equation
This tab allows students to play with the (M1)(V1)=(M2)(V2) equation qualitatively, to see the relationships and how molarity and volume affect each other in dilutions. The goal is to provide a framework (and equation) for students to use in Tab 3: Make Dilutions. Currently, we do not intend for Tab 2: Dilution Equation to be quantitative--it would be too easy for students to enter in the values for their homework questions and not do the calculation themselves.



Given: Slider controls for M1, V1, M2, and V2. Also a silder control for number of moles. One idea is for the green circle representing number of moles to increase and decrease in size as moles change.
CM: slider for number of moles needs to be labeled.
JC: Agreed.

CM: what is the purpose of the equations in the upper left corner of the play area? We don't

typically show equations like this.
JC: They are reminders to myself of things I want this tab to express; should have been in red tex to indicate a note-to-self.

CM: Scaling of terms in equations has been a failure in past sims, not recommended.
JC: I think Kathy wants to try it here; would it take a lot of time to implement a trial version? If you have thoughts on other ways to represent this relationship, I would love to hear.
CM: If we're going to implement something that has failed in the past, we need to identify improvements that we think will lead to success. What are those improvements, and what iis KP's supporting argument for wanting to use it here when it has failed in similar situations?

CM: Scaling the "# of moles" circle is an i18n problem.
JC: I don't know what i18n is. Can you explain?
CM: i18n = internationalization. Guaranteeing that translated text will fit in a circle is difficult, and requires the translator to take unusual care when doing the translation.

Tab 2 Remaining Questions:
How to "map" the variables in the equation to slider effects--for example, will changing M1 only change V1? If not, what settings do we use to show effects on M2 and V2? Should there be a way to "lock" 2 variables so that the remaining 2 affect each other?
CM: This seems like a pretty big issue, and could lead to misconceptions if not handled properly.
JC: Agreed.

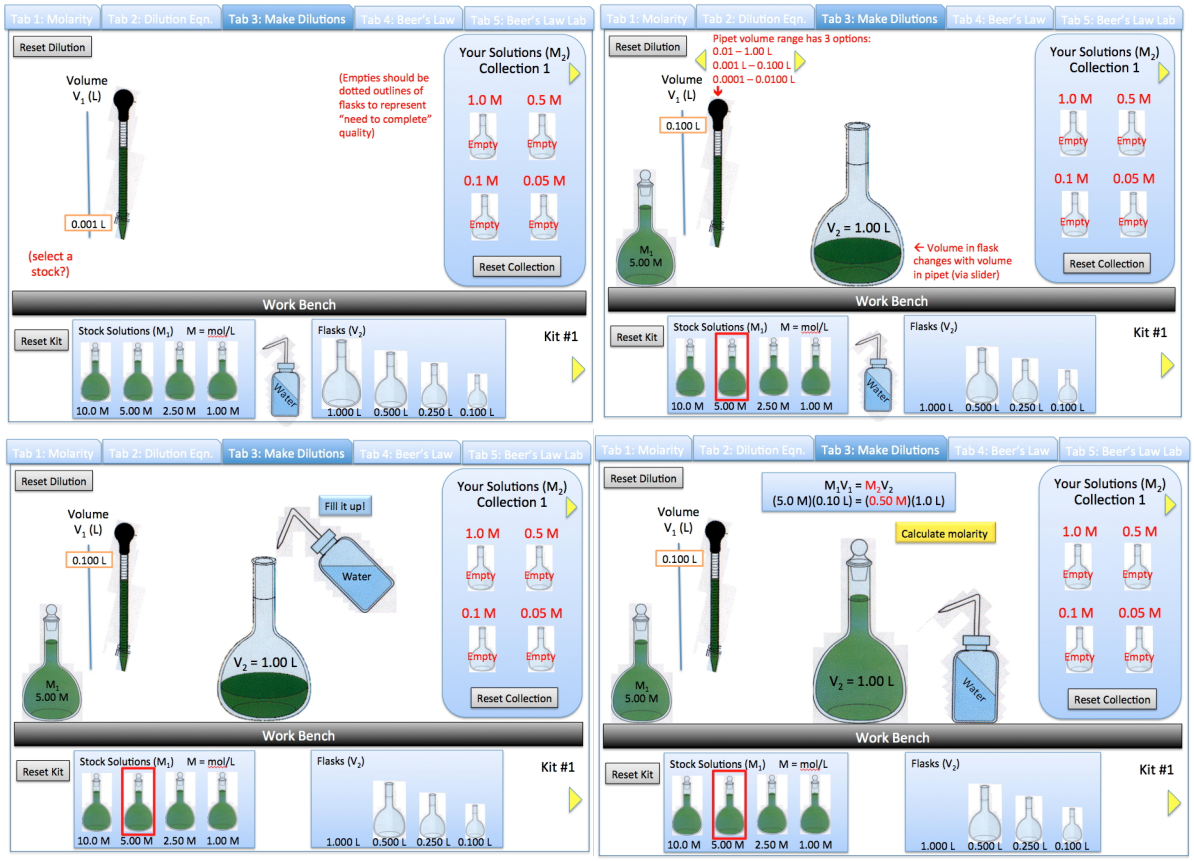
Is this representation of the equations adequate? Does putting # moles in the middle break up (in a bad way) the relationship between Molarities and Volumes in a dilution?
CM: Yes, I think putting it in the middle breaks the equation up in a bad way.
JC: OK, let's try it without moles in the middle. Can we have some indication of moles somewhere else on this tab? The main point is that the number of moles stays constant as M1, V1, M2, and V2 are changed.

How to convey that molarity sliders are the same scale without showing numbers?
CM: Label ends of both molarity sliders with quantities like "little" and "lots".
JC: Alright.

What initial slider starting positions will encourage play?

CM: Doesn't this equation describe the relationship "before" and "after" dillutions? I don't think that's at all clear here. You're showing 2 flasks, and that will likely be interpreted as comparing 2 different flasks, not the same flasks at 2 different points in time.
JC: It is supposed to be two different flasks, one of the "starter" or "stock" solution, and the other of the final solution.

Third Tab - Make and Compare (multiple) Dilutions
This tab provides the tools to make multiple solutions side by side to compare them in both color, and in the numbers that are revealed when "show values" is checked. This tab will ask students to use the (M1)(V1)=(M2)(V2) equation and the relationships they learned about in Tab 2. Currently, the plan is for students to use "solution X" in this tab, since concentrations for stock solutions exceed the solubility limits for most of the colored solutions in the Molarity Tab (Tab 1).



Student have kits for each variable: M1, V1, V2, and M2 (the goal). We still need to consider which combinations of kits students should be able to access at once. There will be a lot of combinations, some of which are more challenging than others (and some of which won't work well at all--like the large flasks kit with the smallest pipette kit, for example.)

(each varible has 3 kits)	M1 Stock Solutions	V1 Pipettes	V2 Flasks	M2 Solution Goals
Kit A	10.0, 5.0, 2.5, 1.0 M	0.01 - 1.00 L	1.000 (x2), 0.500, 0.250, 0.100 L	1.5, 1.0. 0.5, 0.25 M
Kit B	12.0, 6.0, 3.0, 1.5(?) M	0.001 - 0.100 L	2.000, 1.000, 0.800, 0.500, 0.250 L	1.4, 1.2, 0.8, 0.6 M
Kit C	16.0(?), 8.0, 4.0, 2.0 M	0.0001 - 0.0100 L	0.100, 0.050. 0.025, 0.010, 0.005 L	0.4, 0.2, 0.1, 0.05 M

With this kit format, students cannot manually change the concentration of their stock solution. Should we make a "custom" option? I am still thinking about how to present and order the kits and challenges so that they start easy and get harder as the students go along. The collection box from BAM is a good model for how we might structure this.

NOTE: Solutions in Tab 1's Solute Options do not have high enough solubilities to make 12 M stock solutions. Be aware when planning the options and constraints in this 3rd tab. Currently the best solution (to the problem) is to have Tab 3 be with an unnamed solution (solution X) that can have concentrations up to 12 Molar.

Possible Challenge activity: Complete increasingly difficult kits with different constraints on glassware and stock solution concentration.
Virtual Lab concept: In at least one of the kits, students will make a set of standards that can be used to make a calibration curve in Tab 5. When they have successfully made the range of standards they need, a "Send for Analysis" button will appear, with some cue that their solutions will be waiting for them in Tab 5.

CM: I'm totally baffled by this tab, don't know where to begin. You'll need to explain this to me in person. My first reaction is that this is too complicated and unintuitive.
JC: Can do. I think the key will be scaffolding it in a way that students can figure out what to do.

09/29/11 - Discussion w/ CM

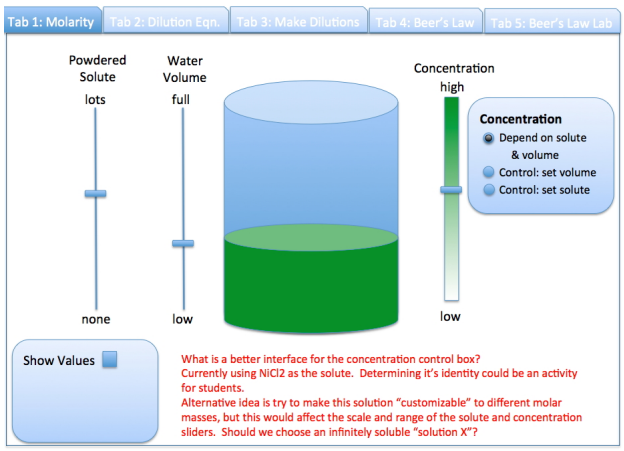
Idea is to have an "Equipment Kit" that includes a set of M1, V1, V2. (3 sets), and 3 collections (goals). Students select stock, pipet (set volume, not variable), and flask. Values in equation appear as M and V are selected.

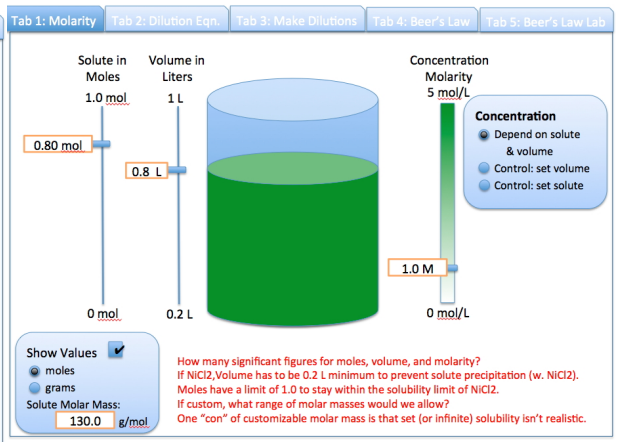
09/29/11 - PhET Chem Meeting
Agenda:
Tab 1: Molarity
CM: This interface doesn't work. Explore other ideas for what we're trying to do here - varying some terms while locking others.
JC: Change: no more solute options.
- Need to choose faucets or sliders.
- Need to either choose a solvent (real or made up) with properties that the sim will reflect
  OR
  make the solute infinitely soluble and let students vary molar mass within a set range.
  - If the second, JC needs to think more about what this would imply for the control sliders. (max concentration, max moles, min volume, how unrealistic is unlimited solubility.)
- When "show values" values is selected, how many significant figures are appropriate?
- What are ideas for a better concentration control box interface?

Tab2: Dilution Equation
CM: Similar problem to first tab, how to "lock" variables in equations. Also, are we willing to rely so heavily on a representation (scaling equation terms) that has shown to be problematic in other sims?
JC: - Changes: removed control over how many moles.
- Will this interface show the relationships I am trying to communicate?
- Tab is qualitative only. Should units be included?
- When to use "Molarity" and when to use "Concentration"?

Tab 3: Make Dilutions
CM: Not at all obvious (to me) how to use this, help me understand. There are dubious/ problematic usages of kits here, take a look at Build A Molecule for a good example.

Discussion:
Tab 1

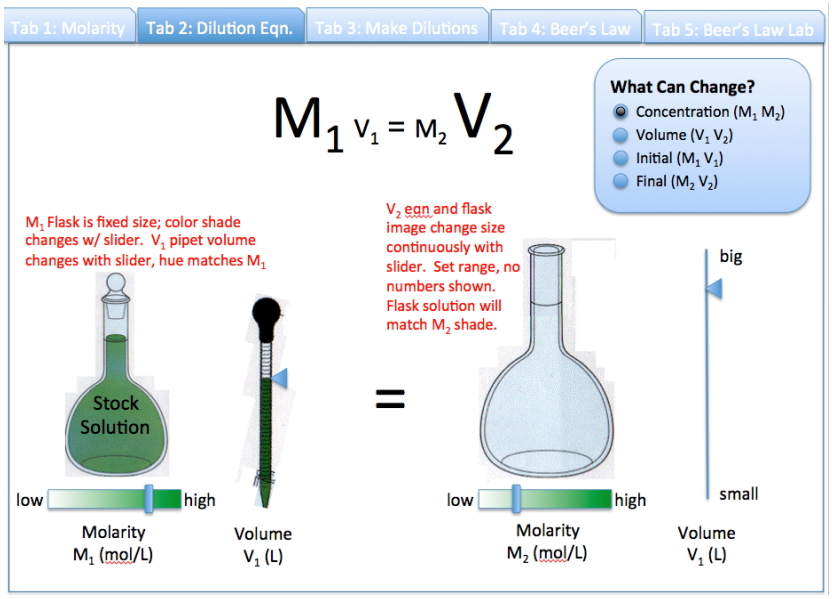




KL: the "Concentration" control box could be renamed "Constant" with 3 options:
1. solute (slider grays out, can only change volume and/or concentration)
2. volume (slider grays out, can only change solute and/or concentration)
3. concentration (slider grays out, can only change solute and/or volume)
Solution to the concentration control problem is to make it a read-out, not a control.

KP, RP: could drop grams to simplify more.
Idea of showing g/mol on a slider, connected to a changing pile of solid chemical.
Decision: remove grams from tab 1 and simplify.
KL: "Constant" for one of three to be kept constant.
RP: Dont' worry about solubility. Fictitious solution with as much solubility as you want it fine.
KP: making concentration a read out is a good solution to this problem.
KL then you don't need any check boxes/radio buttons, only show values.
KP: leave units on the titles in the not-show values view.
KP: Faucet could add water when you increase the liters, remove when you subtract. Could be a fun visual cue.
KL: could have the same thing for the solute.
CM: more concerned about removing real world chemicals (chem advisory board would want these).
KP, CM: could have a second tab for real solutions.
KP: real solutions tab could have other features and not focus on relationships.

Tab 2:



CM: concerned that represention isn't going to work well. Scaling in the eqn.
KP: don't let them change molarity of the bigger flask. Have M2 be the readout, not a variable. The other 3 variables contribute to the readout of M2.
JC: perfect parallel to third tab.
KL: this doesn't feel very interactive. Usually sims are about concepts rather than equations. I feel like we could make it more interactive, that you observe changes rather than linking them to the eqns.
RP: don't want students to focus too hard ont he eqn here. Could we get the students to generate the relationship on their own?
KP: students didn't coordinate M1V1 M2V2 (from a previous conversation), didn't see that moles are equal on both sides of the equation.
RP: moles = moles is still mathematical statement. It's important that matter is being conserved...
RP: if we remove the eqn there's a space to put a visual cue.
CM: what is the action implied? Will students know what's happening with pipet transfer?
KL: tab 1 and 2 could be combined... all you're changing is concentrations.
KP: the other thing is the actions that are implied... One thing that's powerful is dynamically change something and see the result. The actions get in the way of this.
CM: if the student doesn't know this action sequence, will the picture convey it?
KP: Could have a button called "show dilution" where the sim self-animates the process. Could work.

Plan: start in on first tab basic features, with room for added fun.
Mock up potential designs for Tab 2, re-do mock up for changes to tab 3.
Think about mock up for a "real solutions" tab.

10/06/11 - PhET Chem Meeting
Agenda
Tab 1:

- Thoughts on including real chemicals: idea for greyed out region, or leave that part of the slider available and give a “too much!” alert (with ppt forming in beaker) for past-solubility cases. This might look similar to the "short circuit!" alert in Sugar and Salt Solutions.

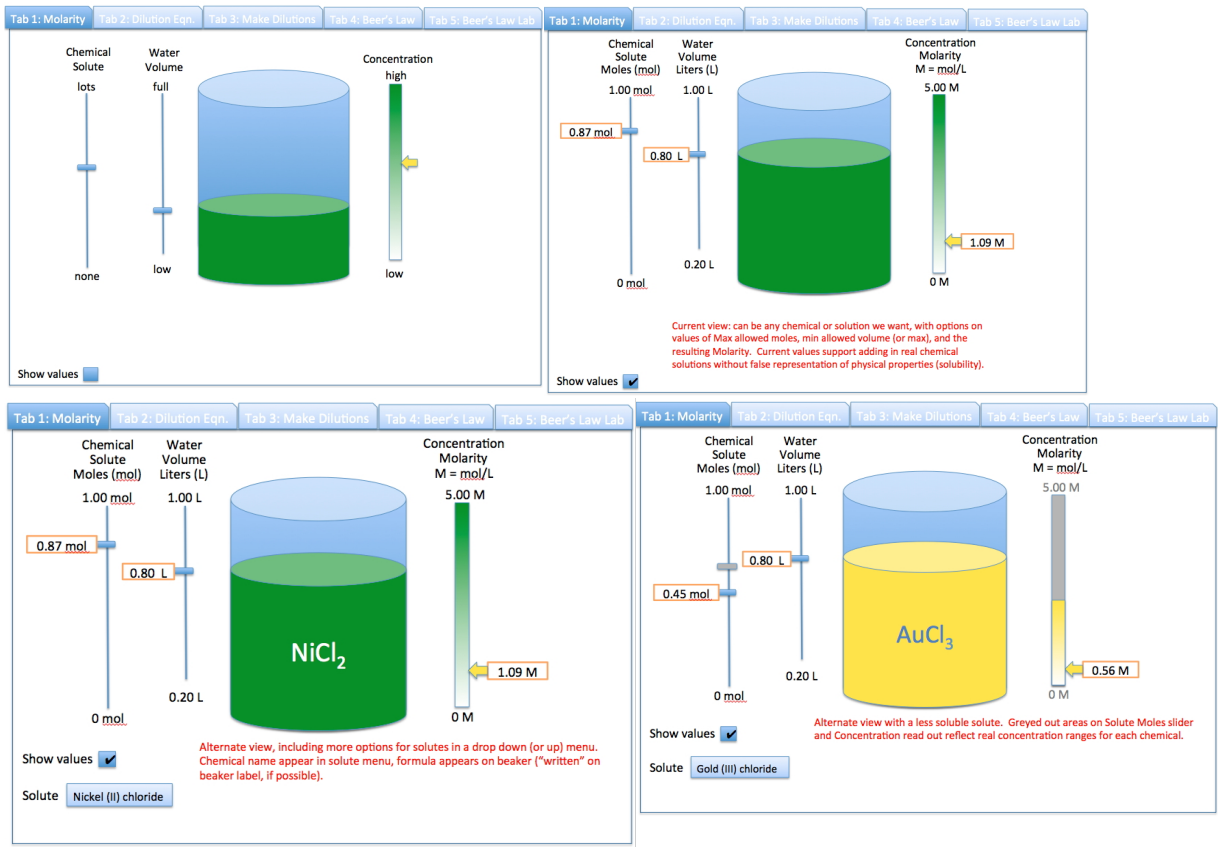
Tab 2:

- Emphasis on relationships rather than procedure.
- Beakers instead of volumetric glassware.
- Currently using a blue arrow as a placeholder for some indicator or equals sign. Other ideas?

Tab 3:

- Equation will show (and fill in) as items from kits are selected.
- New constraints on kits (Each kit is a set of M1, V1, V2. Can’t mix and match kits).
- This tab is procedure oriented. Ideas to make the procedure more understandable or intuitive? Currently it’s pretty obscure. Animation was an idea we discussed last time; maybe that can help.

Meeting Notes



Tab 1:

KP: consider keeping a cue on the amount slider to que saturation.

KL: leave solute amount and water volume normal sliders, and show it with “saturated” indicator (somewhere), greyed out concentration area, etc.

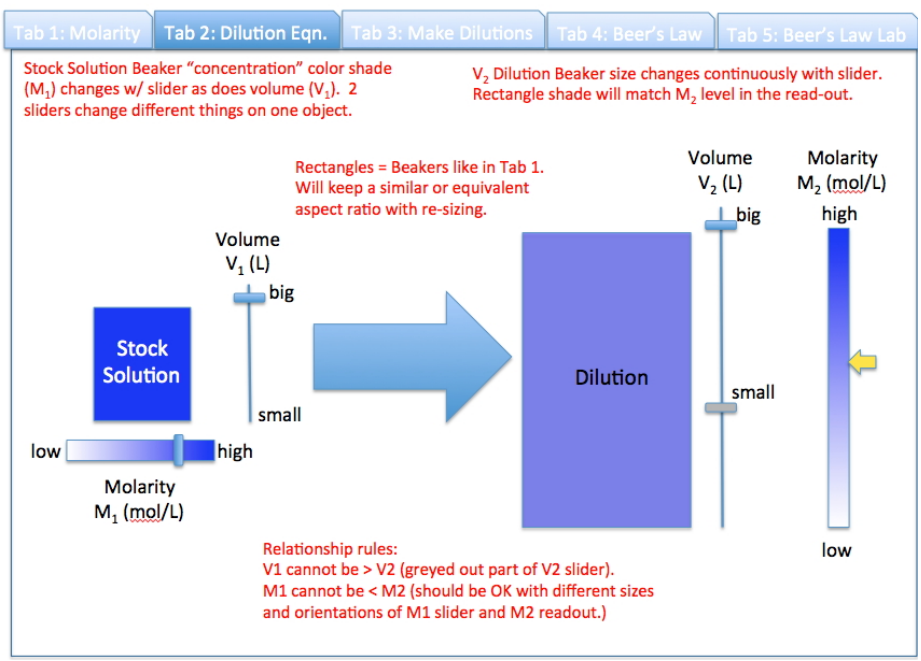
KL: Could have vol min go to zero.

(discussion)

JC: Let’s keep volume minimum as 0.2 L

CM: going to do a basic version w/ volume minimum, with option to go to zero if we want to later (though this would be more complicated).
Solute drop down location: Put it wherever it works.
Change Solute Chemical to Solute Amount. Change check box to be on left of text, move closer to concentration read out.
KP: move it all down, solute top left, shot values lower right. (CM can implement w/o changes to mock up)
KP: include a reset button.
KL: change water to Solution. Concentration to Solution Concentration
JC: when moles are 0, beaker will read “water”.
JC: Think more about how to depict that the solution is water.
JC: Start with mol and L editable number fields at the top of the sliders. Conc, is readout next to arrow (not editable).
KP: make arrow change color to agree with concentration.
Beaker label will be formula, drop down will be chemical name.
What color should water be?
Start with white bkg for sim, water is light blue (possibly with some transparency) to blend into the concentration scale.

Tab 2:



KP questions/suggestions:
- Maybe have M1 scale just “darker” ½ of scale?
- Different custom slider - where not a slider looking knob, but actually greyed out region, or just slider stops there, cannot go below that point.

KP: Discussion of M1 slider: Make stock the more concentrated half of the slider. (pick a range).
KP: Could make vertical. Coud make conc sliders parallel but M1 doesn’t come down as far.

Will volumes be on the same scale?
JC: idea was to keep them proportional
KP: volume per pixel.
V2 slider will have an invisible stop that changes with range of V1 so that V1 is always smaller than V2. (Potential Problem...)
KP: Question on beakers. Are you chaging both width and area, or only height?
Big question / issue: the volumes changing.
Part of the problem here is the underlying assumption of the process (which we're not covering in this tab yet).
Stock solution may not be a good label.
RP: it ties it back to the process, when you want to focus on.
CM: idea to label it Solute (Solution) and Dilution.
KP: Important idea of not letting V1 be larger than V2.
CM: idea of having the arrow read "+H2O" or have the squeeze bottle from the next tab as an icon / indicator.
KP: seems like it would help if the stock solution didn't look so big. It would be clear that a very small amount was being added.
CM: should it look like a pipet? A dilution of a small amount would make more sense in terms of adding such a small volume.
CM: idea of Small volume of stock (controlable) + Water (shows a beaker that you can't control which will always compensate enough water).
RP: this mirrors the idea in textbook questions of always filling to V2.
KP: Likes small volume of V1. Will Conc. be linear or not?
KL; It feels like we cover this already in tab 1.
JC: Tab 1 was about Molarity, Tab 2 is about Dilutions.
KP: like the visual of how much water you're adding.

10/20/11 - PhET Chem Meeting

Agenda
Top Priority: Tab 2 Design (current proposal in the google doc under Tab 2)
Do beakers work as the objects in this tab? (Yes)
Symbols relating the objects (+, =, arrows, or other?) (Get rid of plus, keep equals)
Conveyance of the dilution equation - does this design get the concept across? (TBD, good enough for now)
New name for this tab needed. (Dilution)

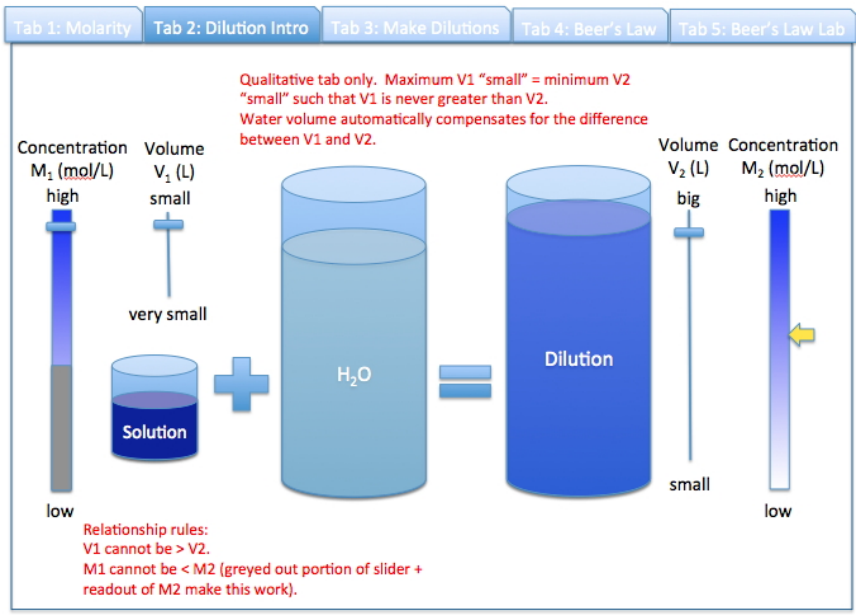
Regular level priority: Tab 1 Molarity
What to show and hide with the Show Values checkbox (remove values for now. No check box)
Moving the volume slider to the edge of the beaker (don't do yet--see how new beaker looks)
Changing the size of the moles and molarity slider/readout (no problem with this happening)
Molecule view ideas (currently not a favored idea--this is a Macro sim)

Notes:
KL: Can check on design of Tab 2 with students in help center for opinions

KL: Put volume control next to V1 beaker like in Tab 1.
Maybe give full concentration range for M1. Would there be any problems with this?
Tickmarks on beakers OK, but no numbers on this tab.

Slider on beaker seems like a strange control at this point in time; might look odd with the 3D beaker.

Plus and equals signs.
KL: plus sign is non-ideal, just remove. Equals sign is good. Keep it.
RP: less clutter. Sounds good.
Current name idea for Tab 2: Dilution



Tab 1:
KL: Recommendation to remove numbers and have units there all the time.
KL: OK to keep the word molarity, but spell out "moles".
KL: have it read "Solution Concentration / Molarity" and let students figure out mol/L relationship.
Make this Tab less of a calculation give-away by removing values.
JC: Could make show values a teacher control/option?
KL: Let's remove for now. Design control affordances/constraints for teachers too so that they focus on conceptual part of this sim.

Moles slider and Molarity read-out resizing seems fine--they don't have to match the beaker.
Grey out the unavailable portion of the concentraton readout in saturated solutions.

10/27/11 - PhET Chem Meeting
Agenda
Tab 1: Finalize this tab--it's basically done!
Tab 2: Ideas for making more horizontal space
Tab 3: Make Dilutions: multi-option kits, or one goal at a time? Maybe a game with different

levels of challenge?

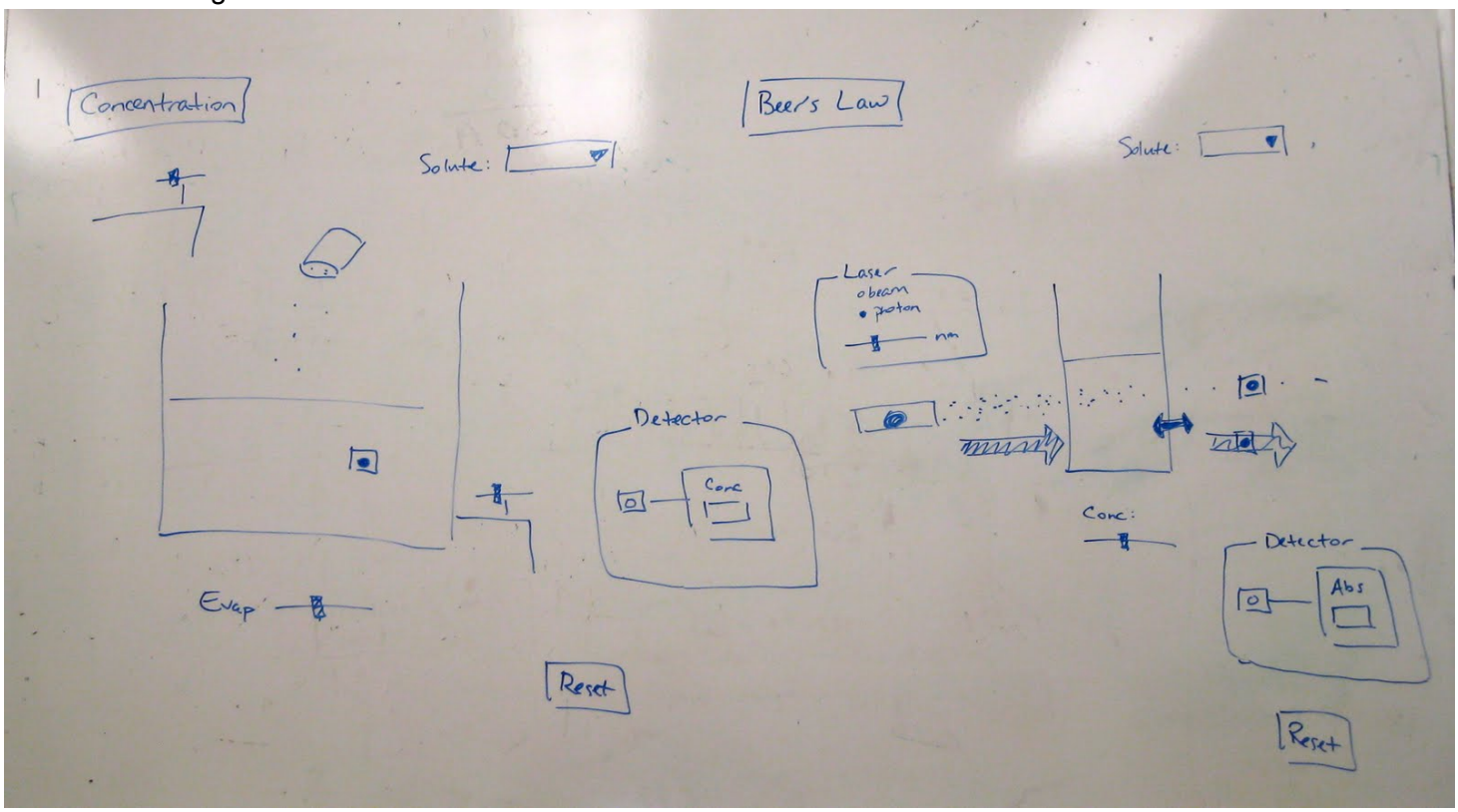
Meeting Notes (KL, RP, KP, JC)
Tab 1:
KL; Change solute order in the list to not be by solubility. Organize by color or formula name.
JC: It's about color, so that's what we should organize the list by.

Tab 2: Bring volume slider for V2 closer to the beaker tick marks (could put slider on the left of the beaker, or tick marks on the right of the beaker.
Ordering of M1V1=V2M2? Seems OK for now, but keep in mind.
If tick marks can be moved to other side, this would help.
Try moving M2V2 control/readout next to = sign, making = a different color to emphasize it a little more.
KL: Potential redundancy of concentration readout with the color gradient on the slider?
KP: but it lets you put a label on it.
Interview on the concentration slider control, and see if students find and make sense.

Tab 3
RP: include a range of difficulties, but not as game levels in this tab.
Try one goal at a time, see how students are interacting with the work bench and how we can use that / where we can go with that.
Idea of getting away from the equation or having deriving it be a goal, vs. students struggling with the equation and figuring out what it actually does.
JC: Maybe have the equation there to help at the beginning, then taking it away at the higher levels.
Maybe make this with a developer option to show or hide the eqn. See if students start understanding this eqn relationship (instead of plug and chug) by using this tab.
KL: Use drag-to-collection as student's way to check result (not giving them the calculation/ answer)
Important to make this not-too-procedural. Concept is the focus.
KP: Once all tools are out, an option to "do dilution" could appear, which would quickly animate the process.
JC: First goal--only the tools they need to solve that first goal, no extras, no choices.
KP: Think about the different mistakes that student make here and come up with tasks that address these or help teach the concepts.
Challenge idea (like BAA) ask for different answers--not always M2.
Could be a different tab called "dilutions game". Very much a game set up, explicitly.
KP: Current layout lets us set up different sets of goals (ratios, etc) and students can devise a strategy to answer them more easily, for example.
Kits and collections let us set up these cases for students to compare and make sense.
KP suggestion: stack pipets horizontally, for easier labeling. (would rotate when pulled out for use)
Have eqn appear and disappear w/ checkbox (which we might remove) It might do this cued off of something (or various things)

To Do: JC mock up new Tab 3, decide on ideas for first 3 or 4 goals. Or, mock up start tab, send out, and if it looks good, CM can start on it.
JC: need to look for student difficulties in the literature to guide the functionality of this tab.

11/03/11 - PhET Chem Meeting
Notes:
Issues with design. KL's idea for Concentration and Beer's Law Lab sim:



01/19/12 - PhET Chem Meeting
Notes on Molarity sim feedback:
- "Saturated" label does not appear when the solute amount is slowly raised above saturation. (Works when Solution volume is lowered past saturation, and works when solute amount is increased fast.)
- Try RGB 225;28;174 for the pink (lower concentration) portion of KMnO4
- Sliders read "none" and "none" for solute amount, and "low" and "low" for volume amount
- on PC, show value has background grey color / box around the control.
- need consistence on Moles and Liters labels. moles should be Moles.
- When show values is on, could label the beaker with the concentration of the solution. Make beaker label size adjust between values shown or hidden.

RP: where do you see in use?
JC: HS, intro chem.

KL could be a good math application sim.
KP. Units and labels blend together here. Could we make the titles bigger font and the label smaller font? Or make units not bold, something to help parse.
EM: could be good to see what HS or MS students think about this.
RP: could interview intro chem students (ask if they have had HS chem)

Question from CM:
The question I wanted to ask the team: This sim is currently part of the "dilutions" project. The project is named "dilutions" in SVN, and the jar file will be named "dilutions_all.jar". If we don't plan to continue with the Dilutions portion of this project, than it may be less confusing in the longterm if we rename the project to "molarity", so that it appears as "molarity" in SVN and the jar is "molarity_all.jar". It will take 1-2 hours to rearrange this. Do we plan to continue with Dilutions as part of this project? And if not, is it OK to spend ~2 hours reorganizing things?

02/02/12 PhET Chem Meeting
Agenda
1. CM's question above.
2. Slider labels - splitting to 2 labels.
I think this is a good idea, but I want you to be aware of what's involved. Our generalized sliders have a single label. Multi-line labels are achieved by using HTML, like "<html>Solute Amount
(mol)</html>". Java's support for HTML is generally lousy, and changing the font size or style (bold) via HTML is not recommended. To give you what you want, I'll need to split the existing label into 2 pieces of text (label and units) so that they can be styled separately. 1-2 hours of work, depending on what else is using these sliders.
3. Beaker label for Molarity: will this detract from attention to the molarity read-out? This would be a redundant feature. What are the pros and cons, and what do we want the sim to show?

Next Step: Student feedback in interviews.
KP: ideas to take this all the way to MS level (or maybe 2 versions) change solute to "salt amount" or get rid of solute amount.
EM: not sure if salt is the best word choice. Will ask MS teachers for recommended words.
EM: would it be confusing if it was "solid"? We can discuss more later for MS level.
KP: for College and HS it should say Solute.

01/26/12 - PhET Status Meeting
- Decided to create a separate SVN project for Molarity
- Decided to remove beaker molarity label and interview on the sim otherwise as-is.

01/31/12 - Feedback from Ingrid Ulbrich, Intro Chem instructor (while meeting KL)
I asked her to look at the Beer's Law and Molarity sims while I was in her office. She used all of the controls in Beer's Law (she moved the concentration meter first, then moved the probe). She tried to move the concentration slider in Molarity and saw that it's only a readout.
She said both sims were doing the same thing, but she liked the explicit adding of solute in Beer's Law. She liked the values in Molarity, since you can't add an explicit amount of solute in Beer's Law.

Still waiting on response from Kraft.
TL to use Molarity in class on 2/6 and report back with reflections on user interface and learning outcomes.

Online Resources

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

Interview and Classroom Feedback

Tab 1:

Tab 2:
Do students come away from this tab realizing that moles = moles? Is this slide too busy / too many controls? Are the controls confusing? Should they be horizontal instead?

Chem 1113 Helproom - 11/30 and 12/01 - 3 students, 1 LA

Student 1: (Got Tab 2 first--accidental use of dev version)
Asked for quantitative, numbers shown.
Would like a calculator to use sim for HW assistance.
Wasn't sure what volume was being added ("what is it -- water or what?")
Thought full parameters for concentration would be better than a cut off.
Thought a display of % to show how close the solution was getting to saturation would be good.
Student 2: Suggests displaying an equation. (Doesn't identify what equation to display for T2.)
Recommends to carry over the Kool-Aid label from T1 to T2.
Thinks beakers next to each other would be better, controls on the far right.

Recommends a plus sign between solution and water beakers.
Recommends quantitative, show numbers.
Doesn't seem to know eqn for T2, but gets eqn relationship for T1 mol/L = M
Student 3: Suggests a dialog to talk you through the sim, with explaination.
Tab 1 eqn - doesn't know, thinks it's like M = 1/V (get the inverse relationship between M and V)
T2: gets eqn for M1V1 = M2V2, but thinks that the sim would be a good supplement to an explaination on the subject (possible the narration with the sim, or the description in class). Sees it as a visual addition to help understanding, not stand-alone tool.
LA: Likes solubility/saturation shown.
Likes the qualitative aspect.
Recommends using Kool-Aid to show dilutions, then tie into solubility later (it's more advanced, and not closely related to dilutions).