# Molarity

**PhET Sim Design Document**

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**Public URL:** https://docs.google.com/document/pub?id=11Vdn8Lwgp0Pe4ozuPJgY_fboV-Vy7srg10BQcGOALPA

This sim is based on the first tab of the Dilutions sim project. The Dilutions sim design doc is: https://docs.google.com/document/pub?id=1H9-ZJznqsh_YFwiRTsPGriqbcKo8AfNMRvq_y9m3dHo

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

in both qualitative and quantitative contexts. 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:

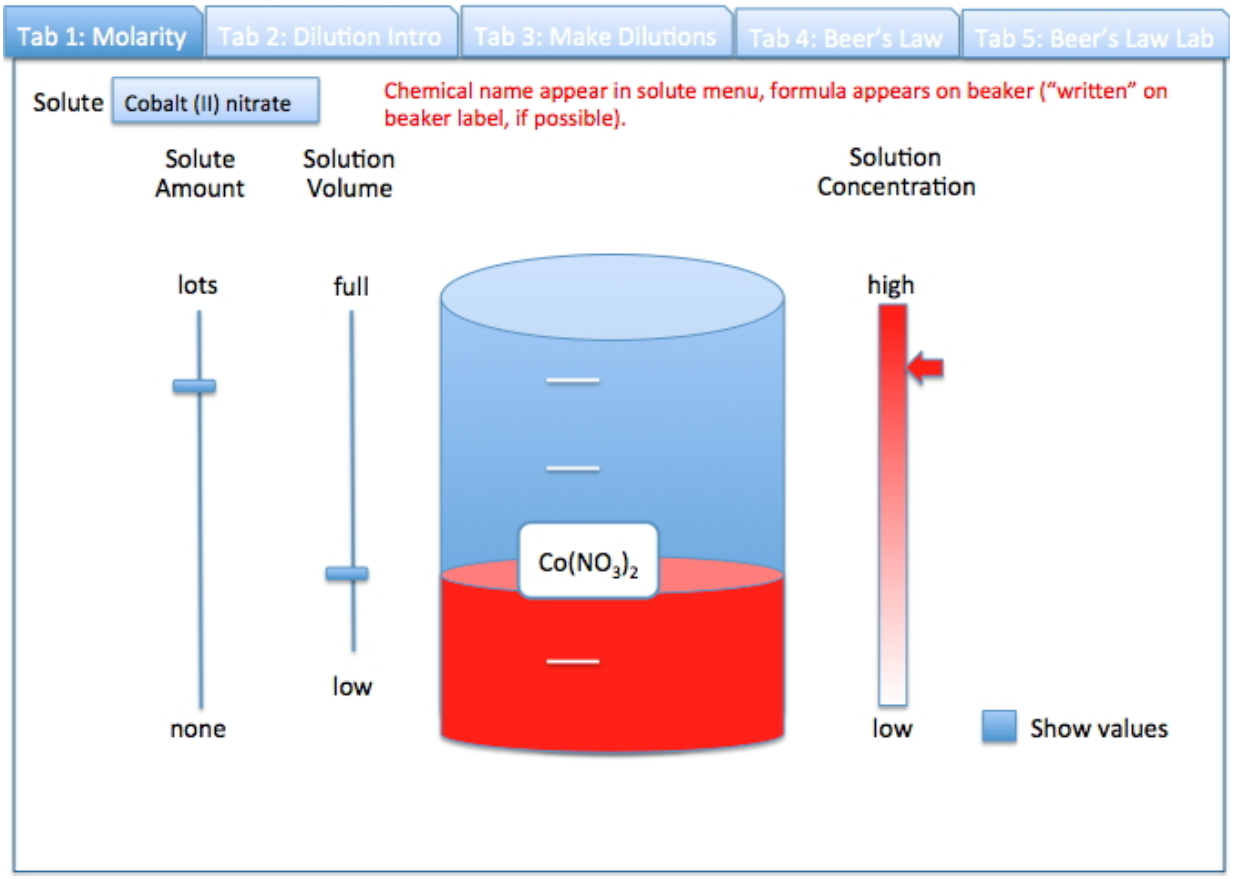
- Describe the relationships between volume and amount of solute to concentration
- Explain how solution color and concentration are related
- Calculate the concentration of solutions in units of molarity (mol/L)
- Use molarity to calculate the dilution of solutions
- Compare solubility limits between solutes

## To Do

Still waiting on response from Kraft on using Kool-Aid registered brand.

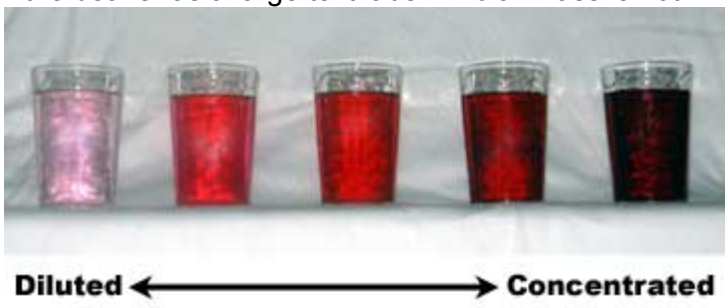
## Mockup

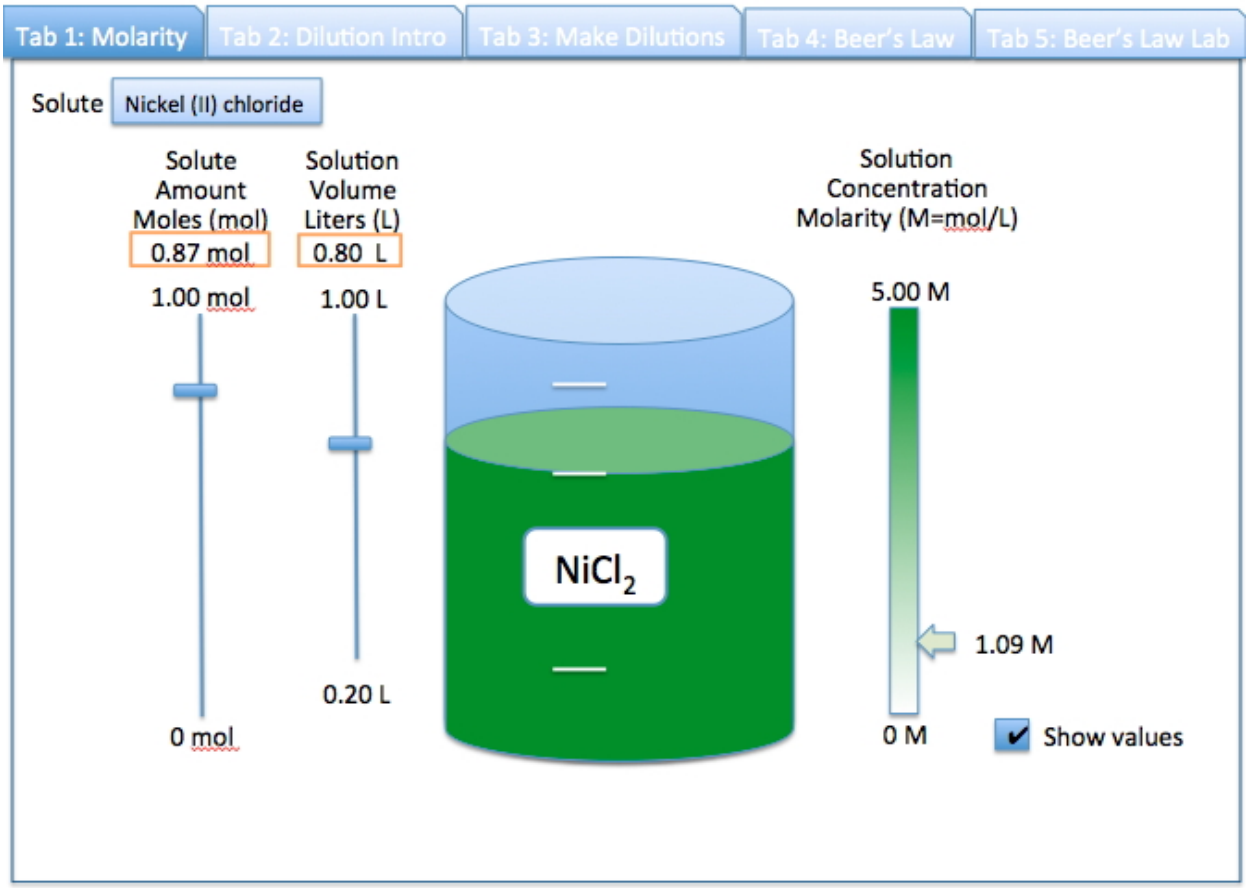
Concentration (Molarity) depends on how much solute is in the glass, and how much water is in the glass. The solute slider controls how many molecules of chemical there are in the solution. The volume slider controls how much water is in the beaker. Concentration is a read-out reflecting the g/mol from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

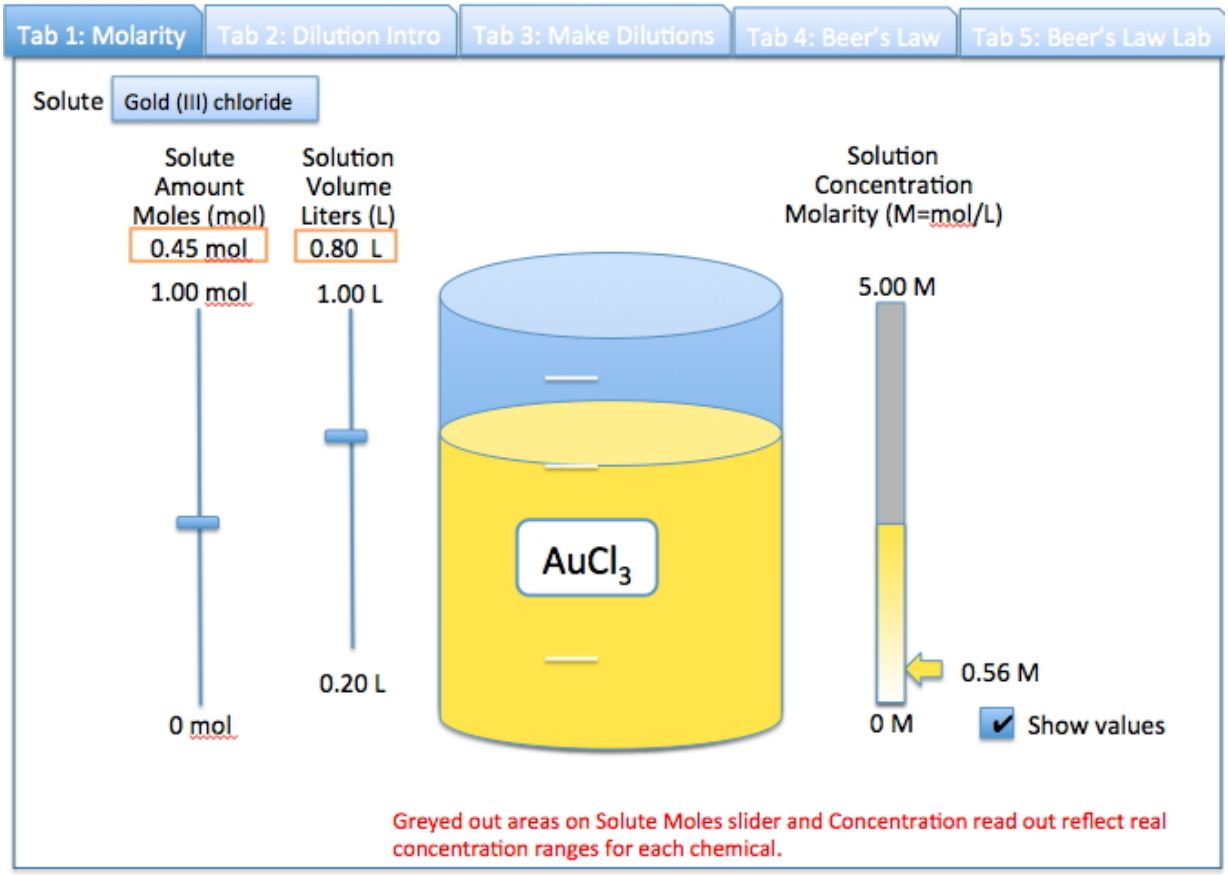
**First Tab Goals:** Students learn the relationship between adding solvent or solute, shown visually through the deepening color of the solution as more solute is added, or the lightening as more solvent/water is added. Students can play with the quantitative relationship between moles and volume, seeing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

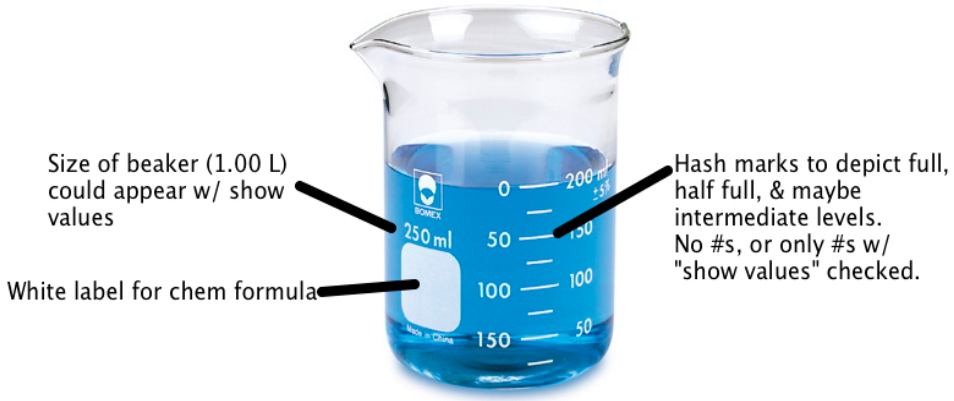
If reincorporating real chemicals:

| 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 |
| $NiCl_2$ | nickel (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



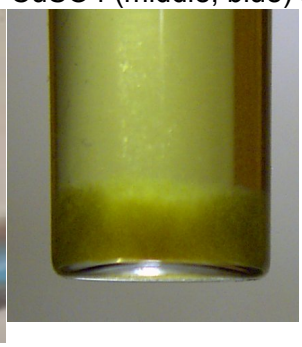

on:

**Examples of solution**

**colors:**
From left to right, aqueous solutions of: cobalt(II) nitrate, Co(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

Cobalt Chloride (left) and potassium permanganate (right)

**Chemical precipitate:** Most chemical solids are the same color as the solutions for this sim, except for KMnO4, which has crystals that are so dark purple, they look almost black (right). Here are some saturated solutions of CuSO4 (middle, blue) and AuCl3 (right, yellow).



## Model txt Document

Model description of Molarity simulation
The basic equation for Molarity is:
  M = mol/L
A chemical solution is a solute dissolved in a solvent.
The solvent in this sim is pure water.
The solutes are shown in the Solutes combo box.
Adding solute to solution beyond its saturated concentration results in formation of a precipitate.
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.
For additional details, consult these model class files: Solution, Solute, Solvent

## Discussion History

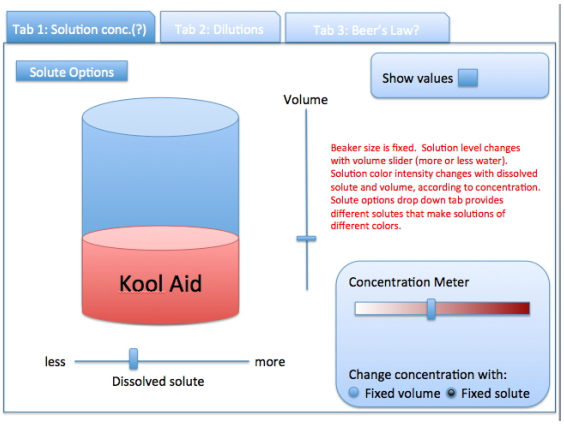
Dicussion and development from the first tab of the Dilutions sim design doc are copied here.

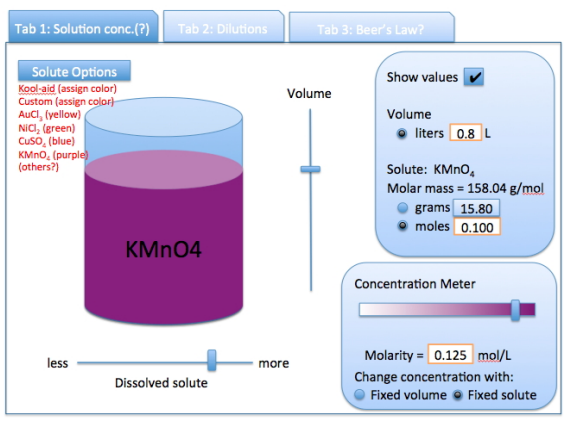
**07/20/11 - *PhET Chem Meeting***
*Ideas to include:*
- Common ion effect?
- Precipitation and solubility rules (probably a good idea for a different sim on this topic)
*Feedback on learning goals:*
TL: Maybe address g/L concept, % concentration and % mass (if mass, need density concept).
RP: Concepts 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.
- 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.

**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.

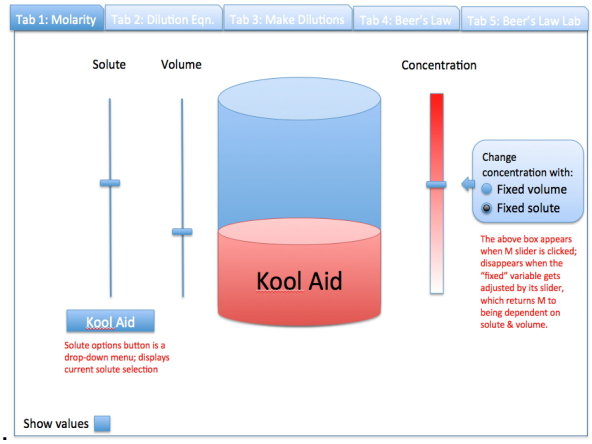
**08/03/11 - *PhET Chem Meeting***
Ideas and feedback from Robert, Trish, and Emily.

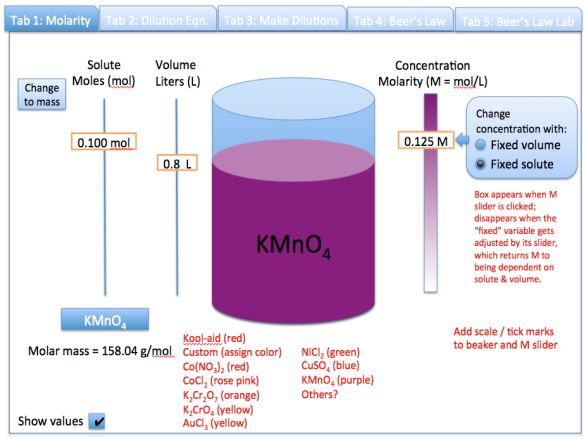
Decided on Design Team Core of Julia, Kelly, and Robert. Emily and Trish will be "consultants" (access and input on google doc, but won't regularly attend meetings on this sim).

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.

***9/21/11 JC and CM Disussion of mockup***
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)<br>5.9583 mol | 0 - 2040 g<br>0 - 5.9583 mol |
| $Co(NO_3)_2$ | cobalt (II) nitrate | 182.942 g/mol | red | 1032.5 g/L (25 C)<br>5.6440 mol/L | 0 - 1032 g<br>0 - 5.6440 mol |
| $CoCl_2$ | cobalt chloride | 129.839 g/mol | rose pink | 562.3 g/L (25 C)<br>4.3304 mol/L | 0 - 562.3 g<br>0 - 4.3304 mol |
| $K_2Cr_2O_7$ | potassium dichromate | 294.185 g/mol | orange | 150.7 g/L (25 C)<br>0.5124 mol/L | 0 - 150 g<br>0 - 0.5124 mol |
| $K_2CrO_4$ | potassium | 194.191 g/mol | yellow | 650.2 g/L (25 C) | 0 - 650 g |

| | | | | | |
|---|---|---|---|---|---|
| | chromate | | | 3.3481 mol/L | 0 - 3.3481 mol |
| $AuCl_3$ | gold (III) chloride | 303.326 g/mol | yellow | 680 g/L (20 C)<br>2.2418 mol/L | 0 - 680 g<br>0 - 2.2418 mol |
| $NiCl_2$ | nickel (II) chloride | 129.599 g/mol (anhydrous) | green | 675.04 g/L (25 C)<br>5.2087 mol | 0 - 675.0 g<br>0 - 5.2087 mol |
| $CuSO_4$ | copper sulfate | 159.609 g/mol (anhydrous) | blue | 219.51 g/L (25 C)<br>1.3753 mol/L | 0 - 219.5 g<br>0 - 1.3753 mol |
| $KMnO_4$ | potassium permanganate | 158.034 g/mol | violet | 75.963 g/L (25 C)<br>0.4807 mol/L | 0 - 75.96 g<br>0 - 0.4807 mol |

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.

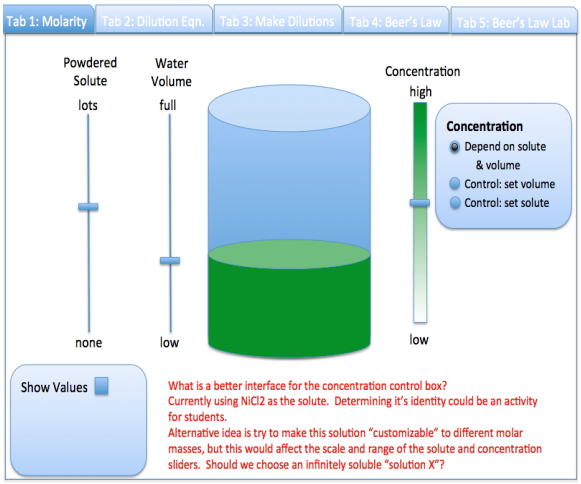
Ranges for the **custom** compound are a current question. It doesn't make sense to allow custom compounds that are physically impossible (I think this would include chemical compounds that are less dense than water, 18 g/mol).
CM: Why doesn't it make sense to allow custom compounds that are physically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

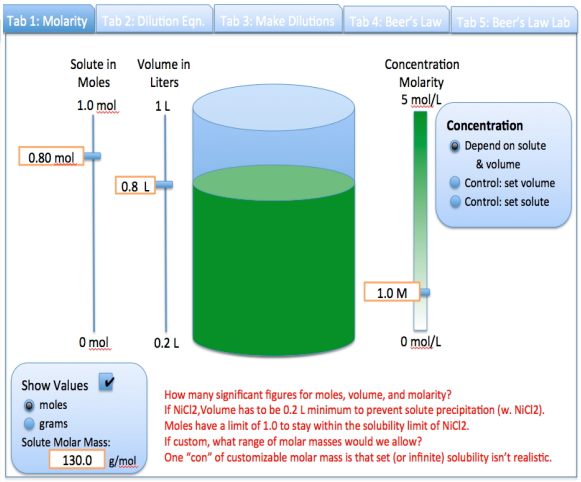
JC: My thinking is that the custom compound option would allow students to enter values for compounds they might be using in a hands-on experiment that we don't offer in the solute options. There would be no need to have this value go below 20 g/mol in this case. I am not sure if teachers would complain 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?

***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?

Discussion:
Tab 1

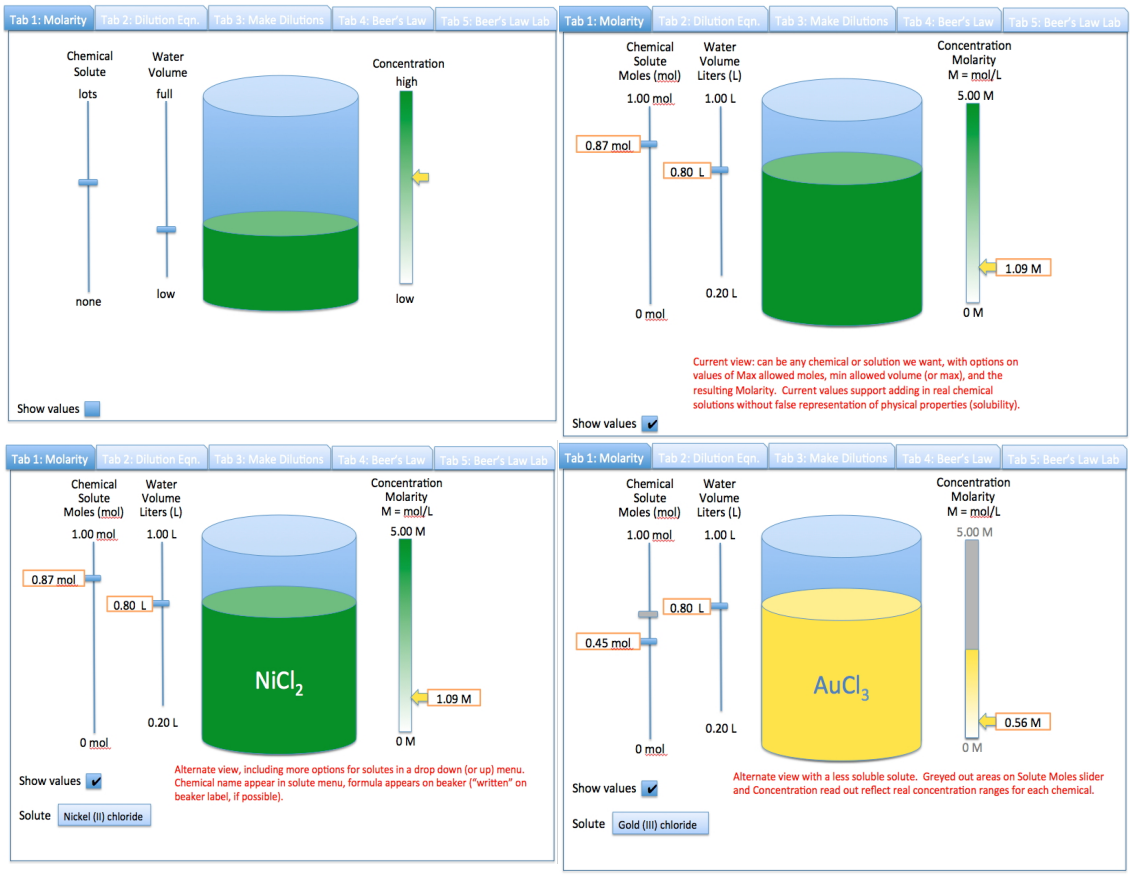



KL: the "Concentration" control box could be renamed "Constant" with 3 options:
1. solute (slider grays out, can only change volume and/or concentration)
2. volume (slider grays out, can only change solute and/or concentration)
3. concentration (slider grays out, can only change solute and/or volume)
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.

***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 circult!" alert in Sugar and Salt Solutions.
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.

***10/20/11 - PhET Chem Meeting***
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)

***10/27/11 - PhET Chem Meeting***
Agenda
Tab 1: Finalize this tab--it's basically done!
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.

***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?

***01/25/12 Remaining issues***
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<br>(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.

***2/14/12 Issues***
- Kool-Aid is a good real-world example for understanding the concept of saturation. However, the 0-5 M range for all solutions with this sim does not allow for Kool-Aid to saturate. If we change the scale of the Molarity read out to 0-6 M, Kool-Aid will saturate. Can we try this change and see how small the ranges for the low-solubility solutes become?
- Still waiting to hear back from Kraft or CU Legal.

***2/16/12 - Chem Meeting Agenda***
- Kool-Aid and saturation. Compare v.18 to v.22.
- Content for website: description and learning goals. Draft of teacher tips. Other items?
- CU Legal says don’t use Kool-Aid without permission from Kraft

## Interview and Classroom Feedback

***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.

***Feedback on Molarity from Courtney Badley 7th Grade Teacher in TX (via Emily)***
Re usefulness for Middle School.
She went through TEKS that might be related. Suggested a tab to combine with balancing chemical equations. Wants to see solution change as you add molecules in a reaction.
If we set up this sim for middle school, we may need different wording for this.

***Feedback from TL on class use with Highschool regular Chem class***
Prefaced with a lab on 2/6/12 about solubility:
The lab experiment involved adding sugar and salt to water (and making a graph of saturation) to predict solubility. However, the lab instructions did not account for temperature, and water temperature was variable, so the results were all over the place.

Tuesday 2/7/12
Prelab about solubility, then played with sim.
They hadn't had molarity concept yet, just g/mL
Time spent on moles was short.
Introduced sim, said yesterday we did g/L, this sim has a different way, mol/L.
First played with sim and figure out which salts you can and can't find the solubility for.
They would notice that the graph of M ended on some, didn't for others.
TL asked students to deign an experiment where you vary 1 independent variable, measure a dependent variable, and graph it to find the relationship.
The sim is simple (only 2 indep variables), so students were able to do this.
Then they had to do the "other" independent variable.
Students were asked to do 3 salts for each experiment., but they ran out of time, so they'll have to finish it outside of class.

Overall: sim worked well for the activity, was simple, students used it with ease but took more time than expected making graphs.

***Student Interview Summary***
(summarize notes)

***Student Interview Notes***

**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.

**Molarity** v. 0.00.18 - **1DD**
(Note: Used Beer's Law Lab tab 1 first)
Start 3:54 (camtasia 13:20)
Fist action: mouses over solute menu, beaker, concentration readout. Clicks "Show Values"
Uses all sliders, seemed like he tried more solutes in this sim than in BLL.

Compared solutions with and without values.
Liked the qualitative view for conceptual learning (his approximate words), and numbers for using in class instead of having to use chemicals.
Describes saturation as a percentage.
Focused a lot more on saturation level.
Finished play after 4 min (3:58, camtasia 17:45)
Q&A:
Liked the beaker visual.
Didn't know what molarity was, recommended terms to explain solute and molarity, more info if you click on the word.
Also thought it would be good to have more information about the chemicals and the reactions with water, seemed to think the name and formula weren't telling all about the chemical.
Overall thought this sim was more straightforward than Beer's.
Finished with sim at 4:07 (camtasia 26:20)
Total time with Molarity (including my questions): 13 min
**Summary**
Said he liked qualitative and quantitative aspects of hide/show values.
Thought it could be used in class instead of chemicals.
Focused a lot on saturation level; described saturation as a percentage.
Played for 4 minutes.
Recommended more information on terms he didn't know (Molarity) and for each chemical included. Seemed to think the name and formula weren't showing everything.
Thought Molarity was more straightforward than BLL.
**Note,** after using Beers and Molarity I forgot to ask student what he thought he had learned from the sim, and I answered questions he had about content during play.

**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.
**Molarity** v.0.00.18 **- 2AP**
Start 4:55
First action was the solute slider.
Used sliders, said that more water means lower molarity. To make molarity go up you need lots

of solute and low volume.
Tried different solutions and was surprised by AuCl3 (first saturated one she choose).
Says “Oh, I see. Saturated.”
Notices the change in the Molarity read out. Says it must be more delicate or something.
Maybe some “go faster”
Clicks “Show Values” and nods, says she likes this view.
Recommends the ability to input values.
Suggests that value input would make it more specific to be like a problem (HW?)
Notices that the scale on the Molarity read out stays the same for different solutions and thinks that’s good for comparing solns.
Doesn’t know what it means that the M bar gets smaller.
Likes the color gradient on the M readout, and that the arrow changes color. Good representation of concentration.
Describes saturation (seen with KMnO4) in terms of Kool-Aid, a solute she knows. Explains that with Kool-Aid it would be like adding more than the water can hold. Solid that doesn’t mix in, homogenize.
Compares saturation levels of Kool-Aid and KMnO4.
Done after 10:30 min (10:40 on camtasia)
Likes M readout, colors, design, and show values.
Thought Molarity part was confusing, not sure about saturation, why the bar gets smaller. Says it “threw me off” Suggests Molarity value input option.
Total time with Molarity: 12:30
Ideas from interview: Benefit to increasing M range so that the familiar solute Kool-Aid can be saturated? Issues of scale would result for compounds like KMnO4.

**Summary**

Talked about relationships between sliders and concentration.
Not sure why molarity read out changes for some solutes.
Described saturation using Kool-Aid as an example while manipulating a different chemical.
Played for 10:30 min.

**Student 3 - KL Interview**

Molarity
02/07/12 v 0.00.18
Did *Beer’s Law Lab* first
Uses all obvious controls
Tries to move concentration readout, says it tells you the concentration
Says “to be more exact, this one works better, but to just experiment and play around with it, I like the other one more… I think the other one is more fun and more interactive”
Compares solubility of different compounds
Likes adding solute herself rather than using slider
Says you can use sim to *check* how much water you need for it to be soluble
On NiCl2, says it does not tell you if you can put less water in it

Says “the other one makes me want to learn it more,” but likes the numbers
Done after 5 mins

**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.

**Molarity** v.0.00.18 **- 4MB**
Start time 4:06
First action: click the menu. Says it looks just like the other sim.
Describes the relationships between sliders: As volume increases, Molarity decreases. As moles increase, Molarity increases. Says this makes sense.
Comments on conceptual with values hidden, values there if you want to measure it.
Comments on good control of values with sliders.
Comments that at zero molarity it’s just water.
Comments on volume range, start point being “halfway” for both sliders.
Comments that Molarity isn’t a slider, just a graph.
Says the sim tells you if different solutions are saturated. Goes through all solns, says only 2 are saturated.
4:10: looks at saturation. Says more mores = more solid.
Says either less water or more moles makes it more saturated.
Wonders why Molarity stays the same (at saturation).
Says KMnO4 has a “short range” of molarity compared to others.
Says they all look different.
JC asks what part looks different.
Student says scale (of Molarity). Different chemicals have different molarities.
Says as Vol goes up, Molarity goes down.
Says directly proportional mol-M, and inversely proportional L-M.Looks at different solutions with same settings, not sure why orange and purple are saturated at the start settings and other chemicals aren’t.
Looks at data log, scrolls up a bit. Closes it.
Looks at all solutions going down the list.
Comments that the solutes aren’t ordered by molarity, or alphabetically, not sure why ordered that way.
4:11 Notices the change in color as solutions become more concentrated. Says diluting makes it lighter.
Likes that she can get the solution level right on the beaker tick marks.

Likes how it's 3D.
Says it makes sense that Molarity = moles over liters.
Says in the last sim, concentration as moles/liters, so the proportional and inversely proportional relationships are apparent.
Describes the fraction relationship with numerator and denominator.
Says it teaches the relationship.
Done with play at 4:18. Spent 12 minutes of play.
Q & A
What did you learn: Show relationship between solute vs. solution, and experiment.
Learned about Molarity = mol/L, and about how it makes sense the relationships between moles, volume, and how each affects Molarity.
What did you think the changing Molarity bar meant? Liters can be the same, but different elements have different molar mass, so it shows that the moles are different, not the liters.
What did you think was the point of different solutions? Maybe to learn about each? Eg. In $KMnO_4$ – not sure why saturated – but you can see the difference. $KMnO_4$ has a shorter "range" of Molarity than $CoCl_2$.
Liked: show and hide values, and how this helps see the relationships. Likes to grasp the concept without a bunch of numbers everywhere.
Likes molarity bar color change gradient that shows how much.
Dislikes: none.
Confusing: Didn't understand why sliders different lengths (mol and L) but says maybe this doesn't matter.
Recommendations: None, I liked it.
Done 4:22
Total Time with sim including Q&A = 16 min

**Summary**

Described the proportional and inversely proportional relationships between mol, L, and M. Referred to Beer's Law sim to cite that concentration is moles / liters, and that this is Molarity. Wasn't sure why some solutes saturated more easily than others, speculated that it might be related to differences in molar mass. Thought the point of the sim was to learn about different solutions, and compare them.

**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)

**Molarity** v. 0.00.18 **– 5HL**

(Used Beer's Law Lab First)
Start 5:00
First action: clicks solute menu, moves molarity slider up, then volume slider up.
Says this sim is more clear about how "the more volume, the less concentrated it is".
Says the less liquid there is, the more molarity and concentration. Says it very clear.
Likes how the concentration bar changes. Says Kool-Aid has a broader range whereas gold doesn't, it can't go as high before it becomes saturated. Says this is cool.
Says the more full the beaker gets, the less… [concentrated].
Says it seems like the larger the compound, the less substance you need to make it saturated.
Says "we haven't done a lot of this stuff yet" [in class].
Says some solutions are really low. (looking at KMnO4)
Likes the colors.
Compares where various solutions saturate.
Shows values.
Says "this sim is definitely more clear. Shows amount to volume and concentration."
Says you can tell how much less one thing needs than the other one (referring to saturation.)
Likes how it shows the numbers.
Done with play at 5:04 (16:50 on camtasia) Played for 4 minutes.
Q&A
Q: What did you think you learned?
A: the things that have more water in it, like Kool-Aid won't become saturated easily, whereas other more strong compounds will. I knew before that more water will dilute it, and make the molecules spread out more. Also I learnd that it doesn't matter the numbers in the chemical formulas, they can be totally different but the numbers don't mean that much.
Q: What did you think the Molarity bar changing was doing/showing?
A: It can't get up to the 5.0, and it's highest… as the solution volume decreases, the concentration increases, so it can only get to a certain level before it gets saturated.
Q: what did you think was the point of having different solns?
A: To tell which ones were more concentrated and which ones have less space between them. Also Kool-Aid isn't a metal whereas gold, copper, are transition metals so you would expect those to be more concentrated.
Likes: This sim was easier to understand. Liked the set up, cites easy to click on different soln. Liked the numbers everywhere, said this made it more understandable. Likes having the units there too.
Dislikes: None.
Confusing: no.
Recommendations: No, liked it. Liked Molarity better than Beer's. Beer's would have been cooler if I knew what I was doing. They were both cool, I liked both, but the first one would be more cool if I understood it.
Done with Q&A at 5:10. Total time with Molarity was 10 min (22:00 in camtasia)
**Summary**
Thought this sim was MUCH more clear than the first tab of Beer's Law Lab.
Explained that with more volume, concentration is less.
Described solutions as having different concentration ranges.
Thought that the larger the compound, the less you needed to make it saturated.
Liked the quantitative view, thought the numbers made it more understandable.
Spent 4 minutes playing, 10 min total with the sim.

## Website

Main Topics
solution, 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
Robert Parson
Kathy Perkins

- thanks to
(consultants?) Emily Moore, Trish Loeblein

- (somewhere should also say)
Kool-Aid (R) is a registered trademark of Kraft Foods Inc.

Description
What determines the concentration of a solution? Learn about the relationships between moles, liters, and molarity by adjusting the amount of solute and solution volume. Change solutes to compare different chemical compounds in water.

Learning Goals
- Describe the relationships between volume and amount of solute to concentration
- Explain how solution color and concentration are related
- Calculate the concentration of solutions in units of molarity (mol/L)
- Use molarity to calculate the dilution of solutions
- Compare solubility limits between solutes

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

Related Sims
Salts & Solubility, Beer’s Law Lab (coming soon)

Teaching Ideas
(upload activity when ready - TL offered to include the one she used with her class)

**Sim completion checklist**

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

2) Add blog entry

3) ADA and other compliance (ON - completed, Ticket #3256)
a. Check for colorblind and other issues (discussed w/ ON, who will test red and green colors; since sim is 1 color at a time, it shouldn't be a problem)

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
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 (in progress)
a. Back up interviews to hard drives
b. Send notes to group or put in Google doc

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) (n/a)

9) Model description (CM done, JC copied to google doc)
a. Developer leads this with team leader

10) Code review
a. Hold 3rd party code review (done, #3233)
b. Make recommended changes (done, #3233)

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

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

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? (yes, done)

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.
Future Beer's Law Lab sim
Sugar and Salt Solutions