Acid-Base Solutions

PhET Sim Design Document

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Public URL: https://docs.google.com/Doc?docid=0Ab-bfyyKuh9uZGR3cmY3cGZfNTAzbWt0ZGNy&hl=en

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Advisory Board Feedback

http://www.colorado.edu/physics/phet/dev/acid-base-solutions/0.00.14/

1) What is your general impression of the sim? Are the learning goals appropriate?

2) On the **Test Solution tab** shown in the *Mock-ups* below.

- Should we include real-world examples of acids and bases? (Right now we just have the generic names of strong acid and weak acid)
- How do you feel about the real-world tests (litmus, conductivity, reactivity) in general?
- Litmus test:
    - Do you recommend including this? If so, is it okay to *dip* the paper into solution? Which type of paper do you prefer - red/blue litmus or pH paper?
- Conductivity test:
        - Do you recommend including this? If so, should we use it in both tabs?
- Reactivity test:
    - We are leaning towards removing this test because of complexity it adds in changing pH.
    - Do you agree with removing this feature?

3) On the **Custom Solution tab** shown in the *Mock-ups* below.

- Strength slider:
    - What is your recommendation: Using separate radio buttons for weak & strong OR using one continuous slider that shows the full range from weakest-weak to strong allowing for continuous exploration of the concept of strength?
- Range of K:
    - What do you think of the selected range for "weak" - is 1e-10 to 1e2 acceptable?
    - Is it okay that we hide the K values for this introductory version of an acid-base sim?

4) Is it okay that we do not show motion (and thus no reactions)?

MC: I got a chance to look at the new acid-base sim and I think this is much better – its much easier to see what is going on.

1. I do think the learning goals are appropriate

2. I like real world examples – this is pretty abstract stuff and any connection to actual acids and bases would be useful.
I prefer universal indicator to litmus – you would need a scale. Its Ok to "dip"
I like to show conductivity – with varying brightness of the bulb

The reactivity test are overkill – if you could get students to understand the difference between weak/strong dilute/concentrated acid/base solutions you would be doing very well. The reactivity is quite different – I notice you were thinking about reaction with

metals (which is a redox reaction) and reaction with CaCO3 – which is an acid base reaction – I prefer to keep these separate – and when I teach them I try to get students to see the differences (between redox and acid base). I think lumping them in together here would muddy the waters even more. (no pun intended). I have a particular horror of the way reactions are treated in intro courses – by surface level features – rather than the underlying chemical concepts. It is very difficult to get rid of this kind of categorization once implanted (its a didaskalogenic idea!)

3. I like the strength slider better – and the range of K is OK

4. For a first look it is ok not to show motion - would it be possible to add motion as another view – I do think its important to emphasize that species are in motion. I do like the ability to show the water – and that the solution is full of water molecules touching!

One thing I was wondering about – and you may have to do student interviews to see what is best – but right now your color coding changes with chemical species. Most visualization keep the atoms coded the same color. I can see that this makes the ionization easier to see – but it might implant odd ideas.

LJ: I'm still reading through the document, but here (finally) are thoughts on the simulation (part A of your list):

1) General impression: The lesson is a nice visualization of the difference between a weak acid and a strong acid. I like the magnifying glass and having the option to show the water molecules. The pH value is not yet showing up, so I can't tell how that will work.

General Issues:
a) A big weakness is that the pH meter immediately shows the pH. It would be good to allow students to predict/estimate the pH before seeing it.
b) The program may induce a misconception about bases, because it shows strong bases as hydroxides and weak bases as neutral molecules. Not all strong bases are hydroxides. Oxide ions, for examples, are strong bases. So is the amide ion. Also, some weak bases are ionic. Some are even hydroxides.
c) The molecular view show a solution that is much too concentrated.
d) The graph is logarithmic and that fact should be noted, as students may not read the y- axis labels carefully.
e) The colors of the hydronium ion (red) and the conjugate base of the acid (orange) are too close together. I had trouble distinguishing them. Also, why does the base have a "bite" taken out of it?

2) On the Test Solution tab shown in the *Mock-ups* of the design document.
* Should we include real-world examples of acids and bases? (Right now we just have the generic names of strong acid and weak acid)
++ It is a good idea to have a few real systems, particularly systems students are likely to encounter in the lab, such as ammonia, acetic acid, NaOH, and HCl.

* How do you feel about the real-world tests (litmus, conductivity, reactivity) in general?
++ Real-world tests would be good, especially ones students are likely to do themselves in lab. However, litmus would not distinguish between weak and strong acids or between weak and strong bases. Universal indicator would be better.

* Litmus test:
Do you recommend including this? If so, is it okay to *dip* the paper into solution?
Which type of paper do you prefer - red/blue litmus or pH paper?

++As mentioned above, do not use litmus; use universal indicator. Indicators are used different ways. Either add a drop of the indicator to the solution or place a drop of the solution onto a piece of paper.

* Conductivity test:
Do you recommend including this? If so, should we use it in both tabs?
++This is a very appropriate test and can be very convincing.

* Reactivity test:
We are leaning towards removing this test because of complexity it adds in changing pH. Do you agree with removing this feature?
++Yes. You would have enough with pH meter, conductivity test, and indicator.

3) On the Custom Solution tab shown in the *Mock-ups* of the design document.
* Strength slider:
What is your recommendation: Using separate radio buttons for weak & strong rather OR using one continuous slider that shows the full range from weakest-weak to strong allowing for continuous exploration of the concept of strength?
++Right now you have only two acids, a strong and a weak. The distinction between them is made clear. Having a slider introduces a new option, the ability to control the dissociation of the weak acid. I like this option, but it is a more advanced one, a true custom solution. If you have that option, you might have three tabs. The current "Custom Solution" could become "Sample Solutions". Then you could use the real-world examples here. The Custom Solution would then be one for which students could change the strength. However, that sort of option would be much more meaningful at a more advanced stage, when students indicate values of *K*a and *K*b.

* Range of K:
What do you think of the selected range for "weak" is 1e-10 to 1e2 - is this acceptable? Is it okay that we hide the K values for this introductory version of an acid-base sim?
++The values are OK and it is fine to hide them, as often the concepts of weak and strong acids and bases are introduced well before the acidity and basicity constants. However, it might be helpful for teachers to know the values used.

4) Is it okay that we do not show motion (and thus no reactions)?
(We think this reaction level view is best suited to be a separate simulation).
++Yes, it is easier to keep track of the relative numbers when it is a "snapshot" rather than a motion picture. You might also mention this somewhere. You could also have a special button to show a movie of the ions exchanging from one water molecule to another. You would need only one of them. LJ

The full design document
++Later...

JB:
1. Right now I think the sim nicely shows the difference between strong/weak and concentrated/dilute. I like the magnifying glass and ability to show water molecules. Looking through your list below and reading some of the comments from Melanie/ Loretta, I fear that too many things will "creep" into the design and clutter or complicate things. Would the group not be happy with a simple sim that reflects a basic, fundamental concept? This could then be the basis for an acid-base reactivity sim.
I did not get a chance to review the learning goals yet.

2. Adding real-world examples would be nice, I think we had a decent list from the last time. As noted above, the tests might complicate things too

much. If anything I might suggest adding a “universal indicator” option and nothing else.

3. I like the radio buttons! This removes the ambiguity of the continuous slider. I think the range is fine and that for simplicity sake leave the K-values out.

4. Yes, I am not sure what added learning gains this would provide anyway. As it would always be nice to show motion and ions exchanging partners, it might negate the simplicity and clarity of what is there.

GW: I’ve entered some comments into the design doc. I like the learning goals. I think a lot of the “real world” tests would be confusing to include in this sim at this time. The working model that you have, which I played with, works nicely. In fact, I very much enjoyed seeing the continuous changes that are possible with the “custom solution” tab. One item of note: It took me a little while to figure out that I needed to grab the pH meter and lower it into the solution. The dashes make it appear as though I needed to enter a number. Once lowered, it can stay there and the numbers change in response to my selection on the right side menu. So, what is the point in having to lower it?

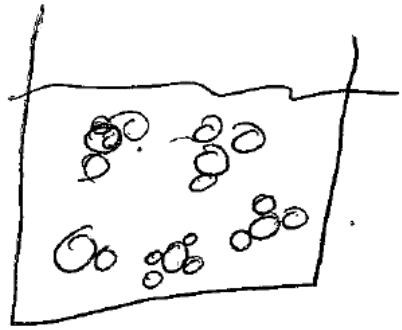
I like the idea of including some real world acids and bases in this sim. I would suggest that these could be put into a third tab which looks like tab 1 (“test solution”) but lets you select the different acids/bases. Maybe you could change the concentration in a slider bar like the second tab (but obviously not the strength, since that is determined by the identity of the acid/base.)

Strength slider: I like the way the development doc is right now, with a radio button for “coarse” control and the slider for fine control. I really like the slider.
Range of K: This range is fine.
Hide K values: Yes. I am in favor of hiding the math on this version.
Show motion: I think it is fine that there is no motion shown. In fact, I think it helps because then students could count the relative concentrations more easily.

Learning Goals

Primary learning goals: Students will be able to...

1. illustrate the major species in a *strong/weak acid/base* solution What does "illustrate" mean in this context? -Chris Malley 5/12/10 8:47 AM Here is an example of a weak base (NH3) solution drawn by a general chemistry TA in an interview: -Kelly Lancaster 5/12/10 3:16 PM



NH_3

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

2. differentiate *concentration* (amount of acid/base) and *strength* (ability of acid/base to donate/accept protons)

Other learning goals:
Below are some other goals to consider from the old goals doc made by Laurie and I that I think still apply -pat loeblein 6/16/10 11:49 AM
These are basically good goals. In part 2 you might add showing that the concentration of a solution is the same no matter the size of the sample. LJ

1. **Given acids or bases at the same concentration, demonstrate understanding of acid and base *strength* by:**
    - Relating the strength of an acid or base to the extent to which it dissociates in water (and thus whether the reaction goes to completion or is at equilibrium in the aqueous solution)
    - Comparing the relative concentrations of molecules and ions in weak versus strong acid (or base) solutions
    - Explaining how the terms *strong* and *weak* are used when describing aqueous solutions of acids or bases
    - Describing the similarities and differences between:
  - Strong acids and weak acids
  - Strong bases and weak bases

2. **Given a particular acid or base (thus constant strength), demonstrate understanding of solution *concentration* by:**
    - Describing the similarities and differences between concentrated and dilute solutions
    - Comparing the concentrations of molecules and ions in concentrated versus dilute solutions of a particular acid or base

3. **Use *both* the strength of the acid or base and the concentration of its solution in order to:**
    - Describe in words and pictures (graphs or molecular drawings) what it means if you have a:
  - Concentrated solution of a weak acid (or base)
  - Concentrated solution of a strong acid (or base)
  - Dilute solution of a weak acid (or base)
  - Dilute solution of a strong acid (or base)
    - Investigate different combinations of strength/concentrations that result in same pH values <u>(This may not be possible depending on what ranges we select)</u>

4. **Use and produce multiple representations that describe what's happening within a particular acid or base solution** <u>(These could be incorporated into the other three; we just decided it might look repetitive)</u>

- Use bar graphs to illustrate differences in concentrations of molecules and ions between strong and weak acids (or bases), or between dilute and concentrated solutions of a particular acid or base
- Use the molecular beaker view to describe what is meant by acid strength
- Interpret single or double reaction arrows in terms of the extent to which an acid or base dissociates in water

How this sim differs from the advanced sim:

1. ignore the autoionization of water
   - if acid, do not show OH- ions in solution
   - if base, do not show H3O+ ions in solution
2. less emphasis on equations
   - do not show equations for Ka, Kb or Kw
   - do not animate the reaction equation

Milestones

08/01/10 - sim in a state where it can be shown at BCCE
08/23/10 - classes begin at CU - ready for student interviews
09/06/10 - acid-base recitation in Robert's class

Sim Operation

<u>1st tab: to address LG1</u>
Students can interact with strong/weak acid/base solutions as they would in lab, but they can also do things *not possible* in lab (e.g. they can see the particles in solution)

<u>2nd tab: to address LG2</u>
Students can interact with acid/base solutions as they would in lab, but they can do so *more readily* (e.g. they can continuously vary the concentration and/or strength of a solution)

The following parameters are always fixed:

- V = 1 L (as indicated on beaker); this is so we can show concentration as more particles in the same volume
- T = 25 C; this is because equilibrium constants depend on temperature Not sure if thermometer is necessary - just one more thing for students to pay attention to, and it never changes -Kelly Lancaster 5/12/10 3:09 PM However, it is useful to remind students that the temperature of interest is 25 C. I would leave it in. LJ

Tools

Students can use radio buttons in the control panel to select different tools. When selected, the tools appear in the play area. Only one tool can be selected at a time, but the tool will remain in the play area as the solution is changed. The *default* tool is the magnifying glass.

The tools either appear where they need to be when chosen, or they appear above the beaker. In the later case, the student can click-and-drag the tools into and out of solution (but they cannot move the tool right or left).

1. Litmus test

To answer the question: Is this necessary? I think so. I do hope you add the pH paper and conductivity, so students are more invited to interact and so they relate the sim to their lab
experience. Why was it decided that these should only be on the first tab? It is important to decide because then the conductivity tester would need more than just low and high on the second tab. Also, on the second tab, it would be nice to have universal pH indicator paper which is widely used in labs so students could relate the molecular images, bar graphs, and nomenclature to their own lab experience. I believe both of these would really help with the relating to real-life component necessary for learning. -pat loeblein 6/16/10 2:25 AM
I do not think that litmus is appropriate here. LJI agree that litmus test is not necessary -GCW 8/3/10 5:26 PM

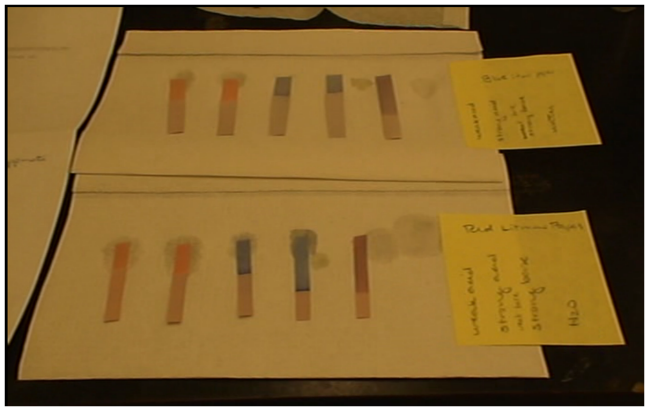
Students can dip litmus paper into solution (but not proper technique!) It does not bother me that it is poor technique to "dip" pH paper. -pat loeblein 6/16/10 2:27 AM The student may test the other solutions with the pH paper, or the student may keep the same solution and proceed through the other tools. In the former case, the pH paper returns to its original color if left out of solution, or to the appropriate color if left in the solution. In the later case, the pH paper disappears.

<u>Red litmus paper:</u>

- If acid, turns more red
- If base, turns blue

<u>Blue litmus paper:</u>

- If acid, turns red
- If base, turns more blue

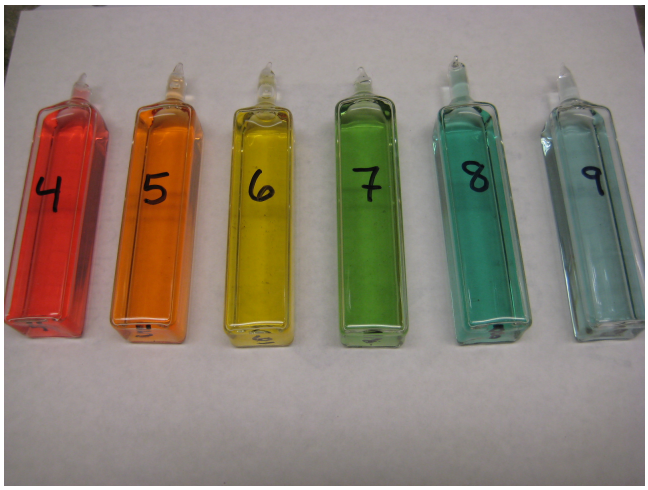


left-to-right: weak acid; strong acid; weak base; strong base; water
front-to-back: red litmus paper; blue litmus paper

<u>pH paper:</u>
Color is dependent on pH; need a color chart

left-to-right: strong base; weak base; strong acid; weak acid

<u>Universal indicator:</u>
Color is dependent on pH; need a color chart



2. Measure pH

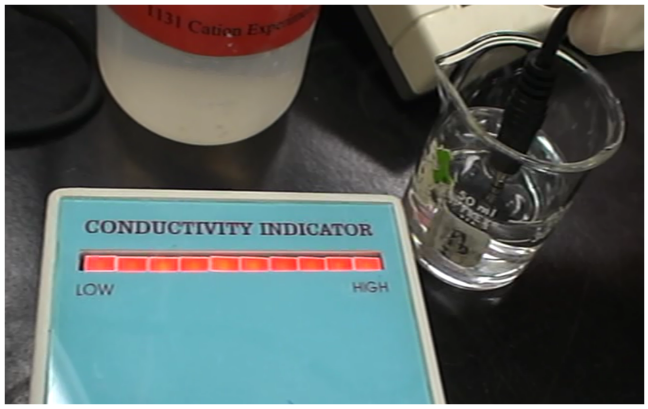
Students can lower probe of pH meter into solution; will get digital read-out of pH to two decimal places (x.xx)It took me a little while to figure out that I needed to grab the pH meter and lower it into the solution. The dashes make it appear as though I needed to enter a number. Once lowered, it can stay there and the numbers change in response to my selection on the right side menu. So, what is the point in having to lower it? -GCW 8/3/10 5:27 PM

How to calculate pH?
See model.

3. Conductivity test

Only available in 1st tab
I disagree, see comments about relating the sim to students lab experience in the Litmus test section -pat loeblein 6/16/10 2:28 AM

Students can place the electrodes in solution; when circuit is complete, bulb will light (similar to Faraday sim)



Luminance of bulb depends on strength:

- If *strong* acid/base, bulb is *bright*
- If *weak* acid/base, bulb is *dim*

Are there multiple levels of brightness, or only 2 levels (bright and dim)? If multiple levels, describe factors that affect brightness. -Chris Malley 5/12/10 8:55 AM Only 2 levels -Kelly Lancaster 5/12/10 3:29 PM If we use the test on the second tab there will need to be variation -pat loeblein 6/16/10 2:33 AM
Pat makes a good point. On the first tab you can have video of two test solutions: strong acid (or base) and weak acid (or base). Once you can change the concentration or acid strength the conductivity test might give different results
What Learning Goal does this address? Could it be left out? -GCW 8/3/10 5:29 PM

4. Reactivity test (removed)

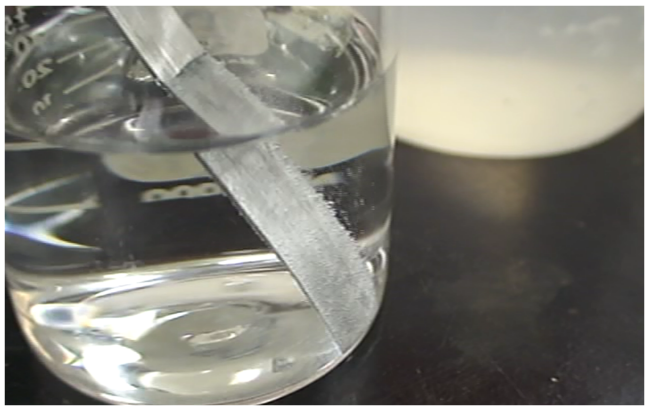
We decided to drop the reactivity tests because it's a huge can of worms: no one can describe what it should look like, the student might think they can use tools post-reaction, and it will be a bear to implement. -Chris Malley 6/16/10 10:47 AM

Students can place objects in beaker to determine if reaction occurs.

<u>Nail</u>
Zinc metal reacts with acids to produce H_2 gas: $Zn(s) + 2H_3O^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g) + 2H_2O(l)$

- If strong acid, reacts *rapidly*
- If weak acid, reacts *slowly*
- If base, no reaction

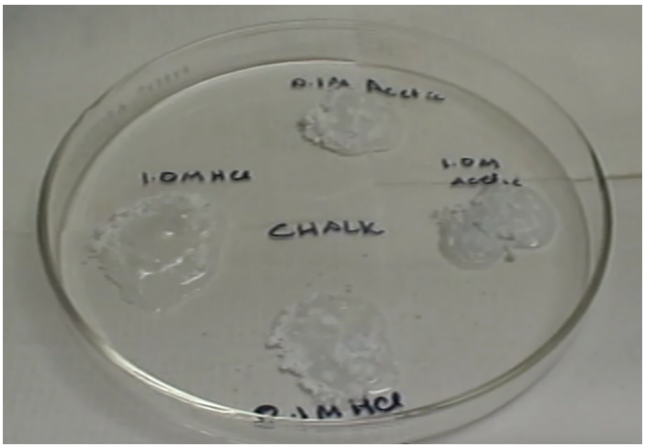
Are there multiple levels of speed, or only 2 levels (rapid and slow). If multiple levels, describe factors that affect speed. -Chris Malley 5/12/10 8:55 AM Only 2 levels -Kelly Lancaster 5/12/10 3:28 PM



<u>Chalk</u>
Calcium carbonate reacts with acids to produce CO_2 gas: $CaCO_3(s) + 2H_3O^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + 3H_2O(l)$
(this is similar to the classic baking soda + vinegar volcano)

- If strong acid, reacts *rapidly*
- If weak acid, reacts *slowly*
- If base, no reaction

Same question for speed as above. -Chris Malley 5/12/10 8:55 AM Same response -Kelly Lancaster 5/12/10 3:28 PM



How do the reactions look/sound? See lab video.

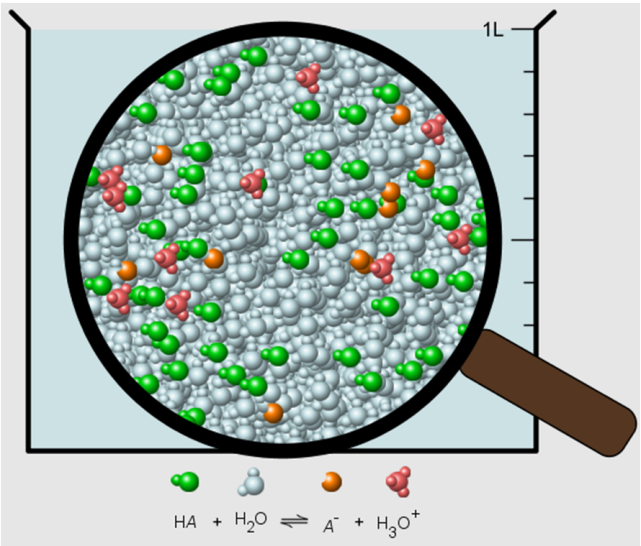
My understanding is that the problem with using reactivity is the changing pH. I think we should provide good links for teachers to videos that are freely available in the teaching guide or make some of our own and include them with the guide. -pat loeblein 6/16/10 2:34 AM
Links would work. LJ

5. View particles

Magnifying glass

Students can place magnifying glass over beaker to see at the microscopic level

Do we show H2O?
YES, but students can elect to show/hide the H2O molecules. The *default* state is to hide the H2O molecules, so as not to overwhelm students.



Do we show equilibrium?
NO; this would show difference between weak & strong, but motion could be too difficult to see/code. Can represent by arrow in reaction equation instead.

1. If *strong* acid/base, no equilibrium, one-way arrow (→)

2. If *weak* acid/base, equilibrium, two-way arrow (↔)

How to color particles?

Option 1. Can make molecules/ions same color to more readily see if solution is acidic/ basic (will do this for now)

Color scheme:

acidic	basic
H3O+ red	OH- blue
HA orange	B purple
BH+ yellow	A- green

Option 2. Can make atoms same color to show that atoms do not change, only connectivity

Color scheme:

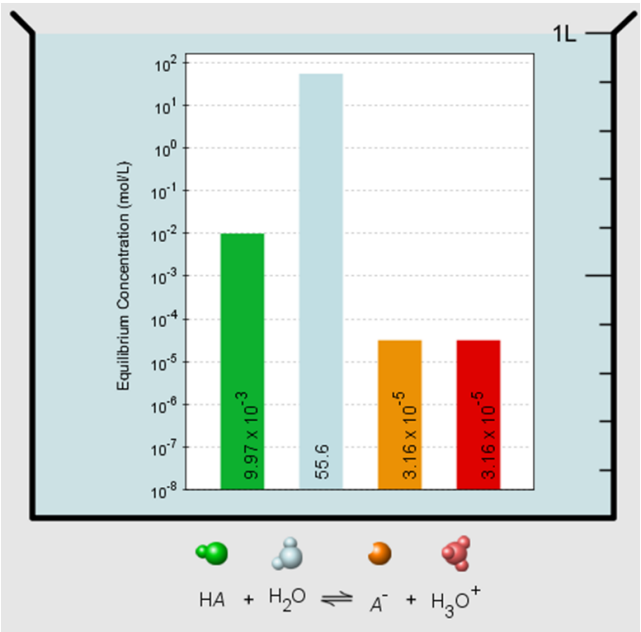
H white	A orange
O red	B purple

A few comments on option 2: (1) It's a more expensive implementation than option 1. (2) Not advisable to use white, it will disappear this sim's backgrounds. (3) You'll also have to color the symbols this way. Eg, H3O+ will be white and red,and what color do we make the + sign?-Chris Malley 5/12/10 9:03 AM
Something to consider is to color-code ions so that negative ions are similar colors and positive ions are a different set of similar colors. Neutral molecules could be more neutral colors such as gray or beige. Once students learn this color code they can use it throughout equilibrium studies. LJ

How many particles to show?
See model.
There might actually be too many ions now. LJ

Bar graph

Students can see the equilibrium concentrations of the *major* species in solution. The order of bars matches the reaction equation, and the color of bars matches the molecule color. Range of bar graph: 1e-8 to 1e2 mol/L.



In advanced sim, will also show [OH-] for acids and [H3O+] for bases (*minor* species). Graph should be identified as logarithmic. LJ

Sliders

Only available in 2nd tab

Students can use sliders in control panel to change *concentration* and *strength*. If tool is also selected, it will change with the slider.

1. Concentration

Slider ranges from 0.001 to 1 mol/L on log scale
Textbox is editable and shows value of slider (to 3 decimal places, x.xxx)

2. Strength

This control has *separate* radio buttons for "weak" and "strong" regimes; when weak is chosen, a slider from "weaker" to "stronger" is visible (K values range from 1e-10 to 1e2 on log scale); when strong is chosen, no slider is visible. K values are hidden.

Physical Model

Concentration of particles

All concentrations are in M (mol/L)

Ca/Cb = initial concentration of acid/base
Ka/Kb = strength of acid/base
Kw = 1e-14

[X] = equilibrium concentration of X

pH = -log[H3O+]

Water

[H2O] = 55.6
[H3O+] = 1e-7
[OH-] = 1e-7

Weak acid

[HA] = Ca - [H3O+]
[A-] = [H3O+]
[H3O+] = (-Ka + sqrt(Ka^2 + 4*Ca*Ka))/2

Strong acid

[HA] = 0
[A-] = Ca
[H3O+] = Ca

Weak base

[B] = Cb - [OH-]
[BH+] = [OH-]
[OH-] = (-Kb + sqrt(Kb^2 + 4*Cb*Kb))/2

[H3O+] = Kw/[OH-] (for pH calculation only)

Strong base

[MOH] = 0
[M+] = Cb
[OH-] = Cb

[H3O+] = Kw/[OH-] (for pH calculation only)

Note: the weak acid model gives the correct [H3O+] (and thus the correct pH) for a "strong" acid, but since [HA] is *defined* to be 0 in the strong acid model, we'd need *huge* values of Ka for the weak acid model to work for a "strong" acid. We treat the two cases separately in the current sim, so the model is fine as is.

Number of images

As the strength of an acid (Ka) increases, the equilibrium concentration of A- (and H3O+) increases, and the equilibrium concentration of HA decreases. The sum of [HA] and [A^-] *must* equal the initial concentration of the solution (Ca).

Our current model for the number of images shown in the sim is given by:

- # images = a*y^x
- y = (b/a)^(1/log(1/c))
- x = log(z/c)

where *a* is the base number of images (not to be confused with *that* base), *b* is the maximum number of images, *c* is the base concentration (again, not *that* base), and *z* is the equilibrium concentration of the particle (be it HA, H3O+, A-), which depends on the concentration of the solution (Ca) and the strength of the acid (Ka).

- a = 2
- b = 200
- c = 1e-7

For dilute weaker acids, this model gives too many A- (and H3O+) images:

Ca = 1e-3, Ka = 1e-7	Equilibrium concentration	# of images displayed
HA (99% intact)	9.90e-4	28
H3O+	9.95e-6	7 (too many)
A-	9.95e-6	7 (too many)

Note that [HA] + [A-] is not equal to Ca (28 + 7 = 28)

For concentrated stronger acids, this model gives too many HA images:

Ca = 1e0, Ka = 1e2	Equilibrium concentration	# of images displayed
HA (99% dissociated)	9.80e-3	53 (too many)
H3O+	9.90e-1	199
A-	9.90e-1	199

Note that [HA] + [A-] is not equal to Ca (53 + 199 = 200)

Luminance of bulb

Below is a way to map pH to luminance (L):

For acid (pH = 0-7):
L = -(1/7)*pH + 1

For base (pH = 7-14):
L = (1/7)*pH -1

For water:
You can use either equation, or just define L = 0

Mockups

1st tab: Test solution

Students can choose water (the default) or strong/weak acid/base. Once chosen, the reaction equation appears below the beaker:

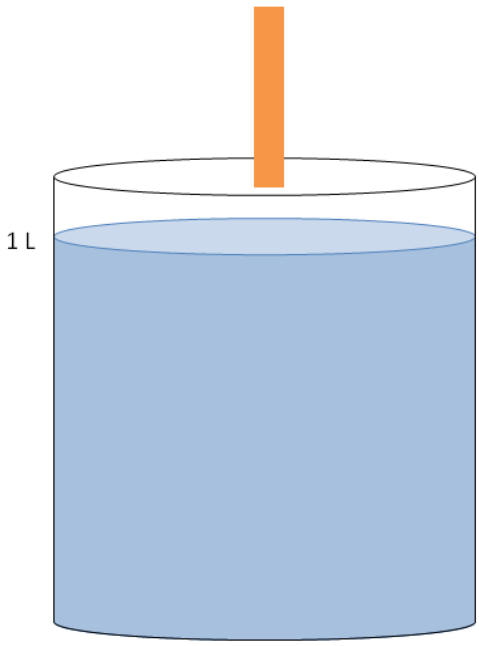
- Water: $2H_2O \leftrightarrow H_3O^+ + OH^-$
- Strong acid: $HA + H_2O \rightarrow A^- + H_3O^+$ (note *one*-way arrow)
- Strong base: $MOH \rightarrow M^+ + OH^-$
- Weak acid: $HA + H_2O \leftrightarrow A^- + H_3O^+$ (note *two*-way arrow)
- Weak base: $B + H_2O \leftrightarrow BH^+ + OH^-$

The concentration is fixed and is not shown - this is so the student must focus on strong vs. weak. The K values for the weak acid/base (also not shown) are chosen so that we can show partial ionization. Because the concentration and strength are fixed, the pH is also fixed.

User scenario

In the default state, water is in the beaker, and the pH meter and magnifying glass are both selected. The student dips the probe into the solution. The student then selects different solutions, and finds that the pH changes (the pH meter remains in the play area as long as it is checked). The student spends some time making sense of the change in pH. The student also spends some time making sense of the particles. The student again clicks through the other solutions to compare (the magnifying glass remains over the beaker until a different tool is chosen).

1st tab | 2nd tab



$H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$

Solution

- Water
- Strong acid
- Strong base
- Weak acid
- Weak base

Tools

pH paper

Test conductivity

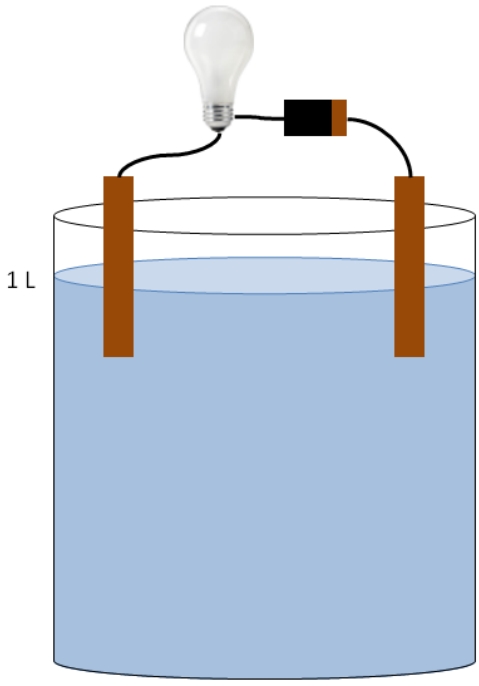
Measure pH

View particles

Show water

Reset

1st tab | 2nd tab



$H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$

Solution

- Water
- Strong acid
- Strong base
- Weak acid
- Weak base

Tools

pH paper

Test conductivity

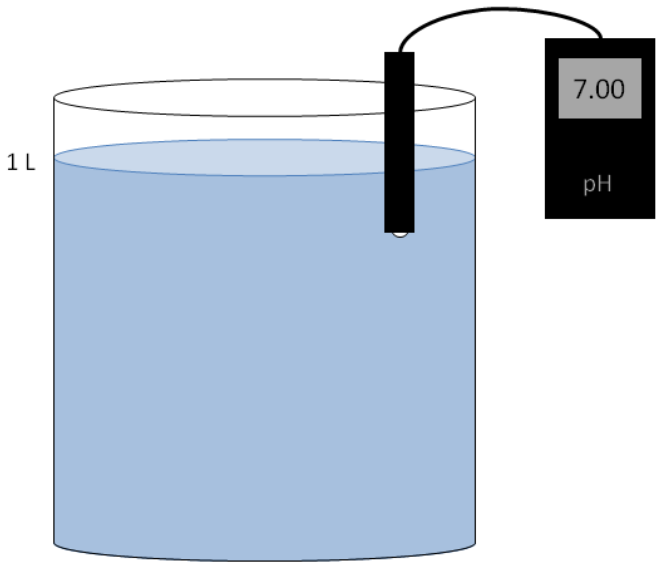
Measure pH

View particles

Show water

Reset

1st tab | 2nd tab



$H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$

Solution

- Water
- Strong acid
- Strong base
- Weak acid
- Weak base

Tools

pH paper

Test conductivity

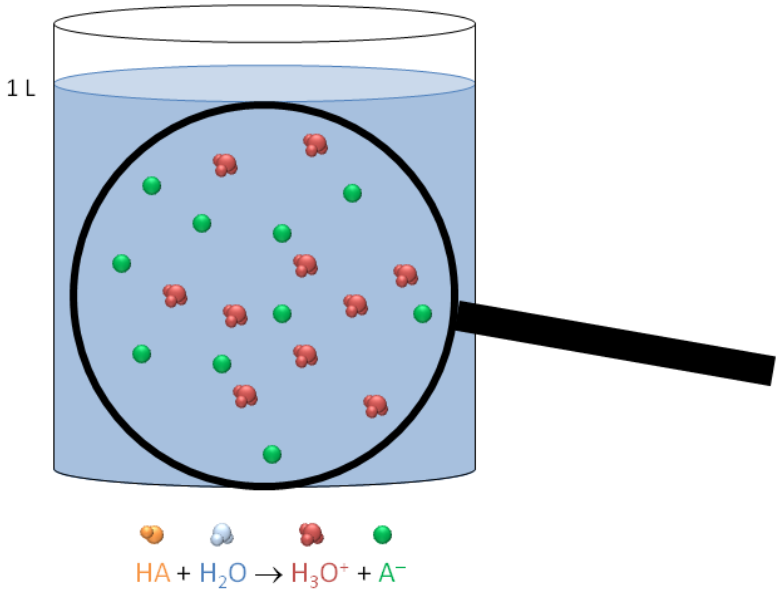
Measure pH

View particles

Show water

Reset

1st tab | 2nd tab



Solution

- Water
- Strong acid
- Strong base
- Weak acid
- Weak base

Tools

pH paper

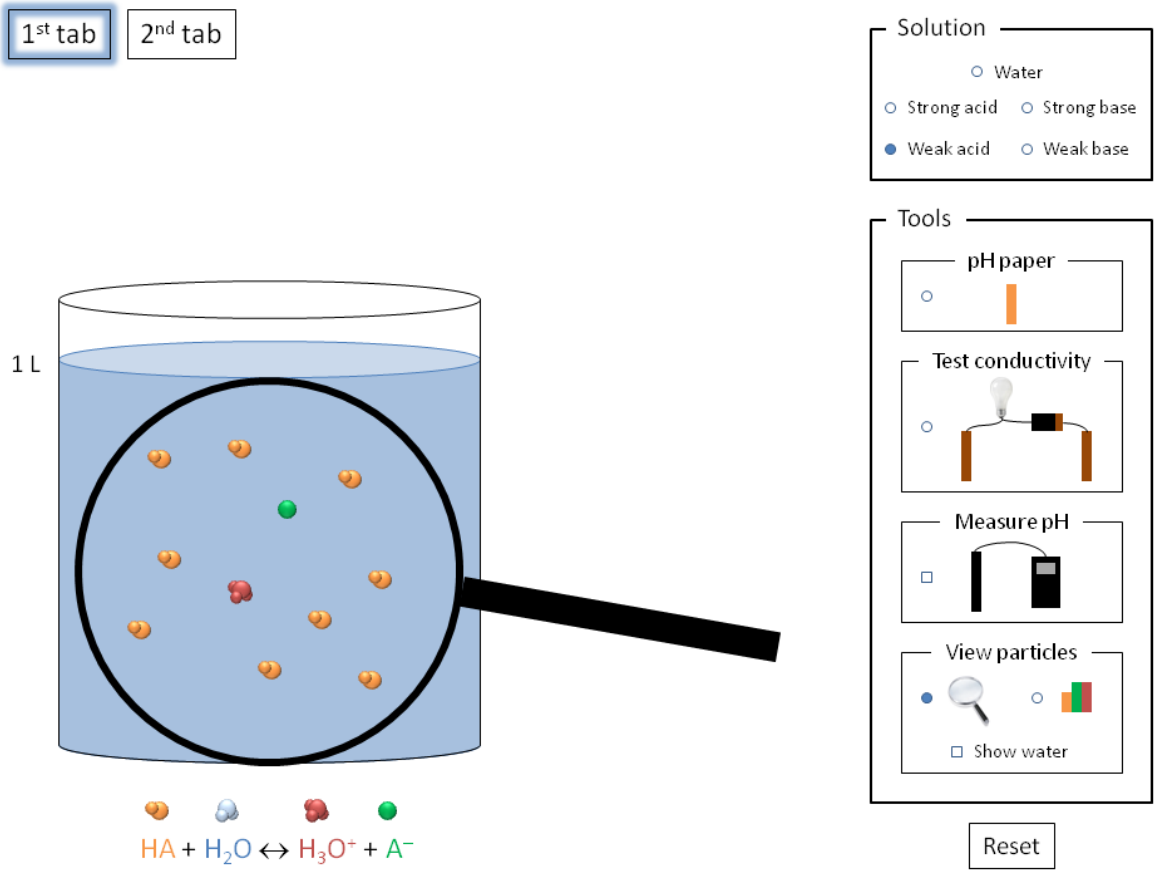
Test conductivity

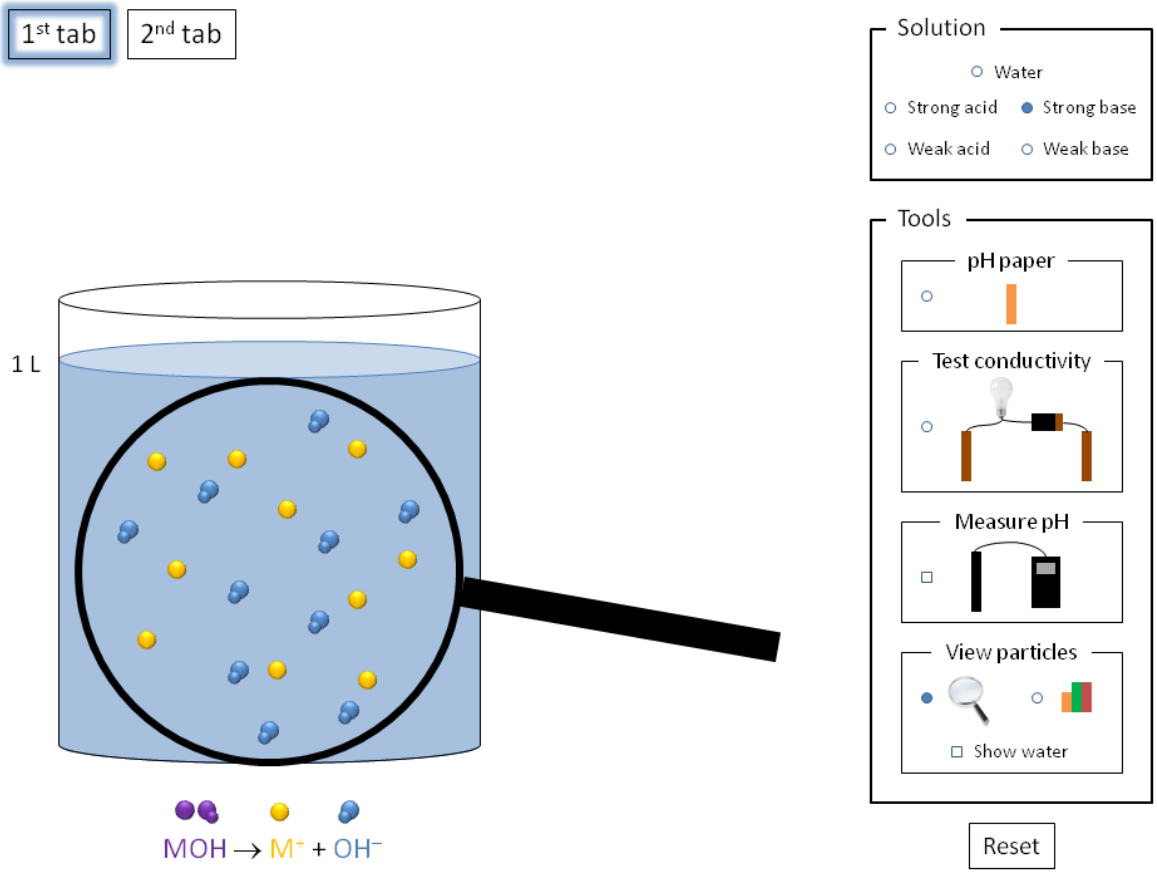
Measure pH

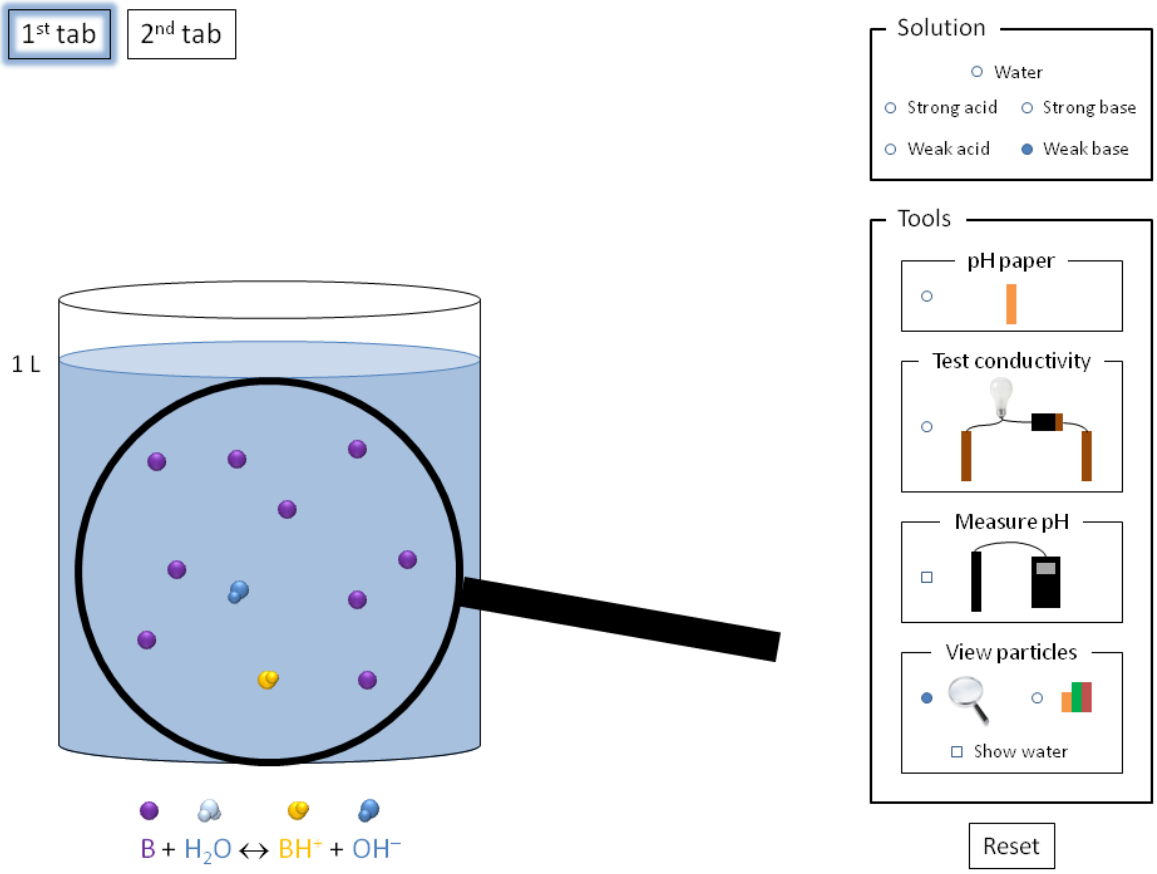
View particles

Show water

Reset


1st tab
2nd tab
Solution
Water
Strong acid
Strong base
Weak acid
Weak base
Tools
pH paper
Test conductivity
Measure pH
View particles
Show water
1 L
HA + H2O ↔ H3O+ + A−
Reset


1st tab
2nd tab
Solution
Water
Strong acid
Strong base
Weak acid
Weak base
Tools
pH paper
Test conductivity
Measure pH
View particles
Show water
1 L
MOH → M⁺ + OH⁻
Reset



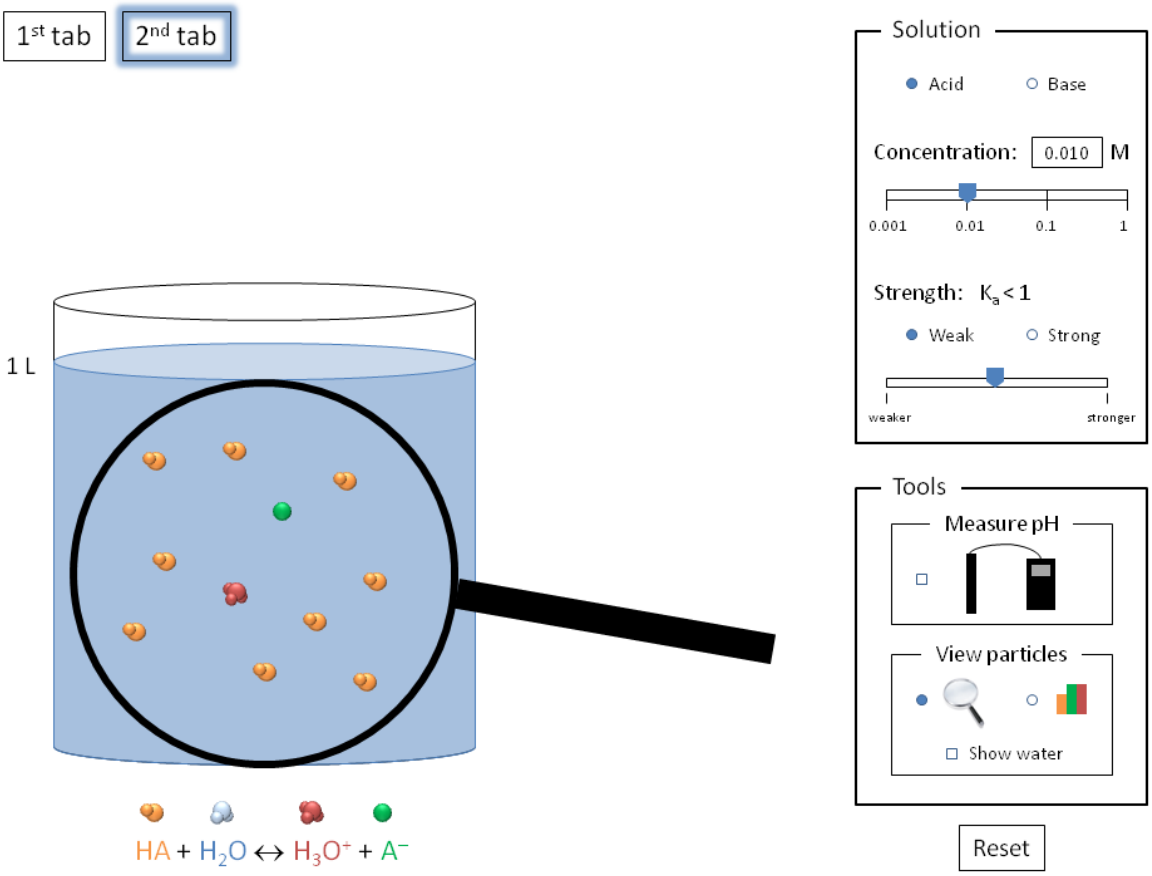
After the student has used every tool with each solution, they click on the next tab.

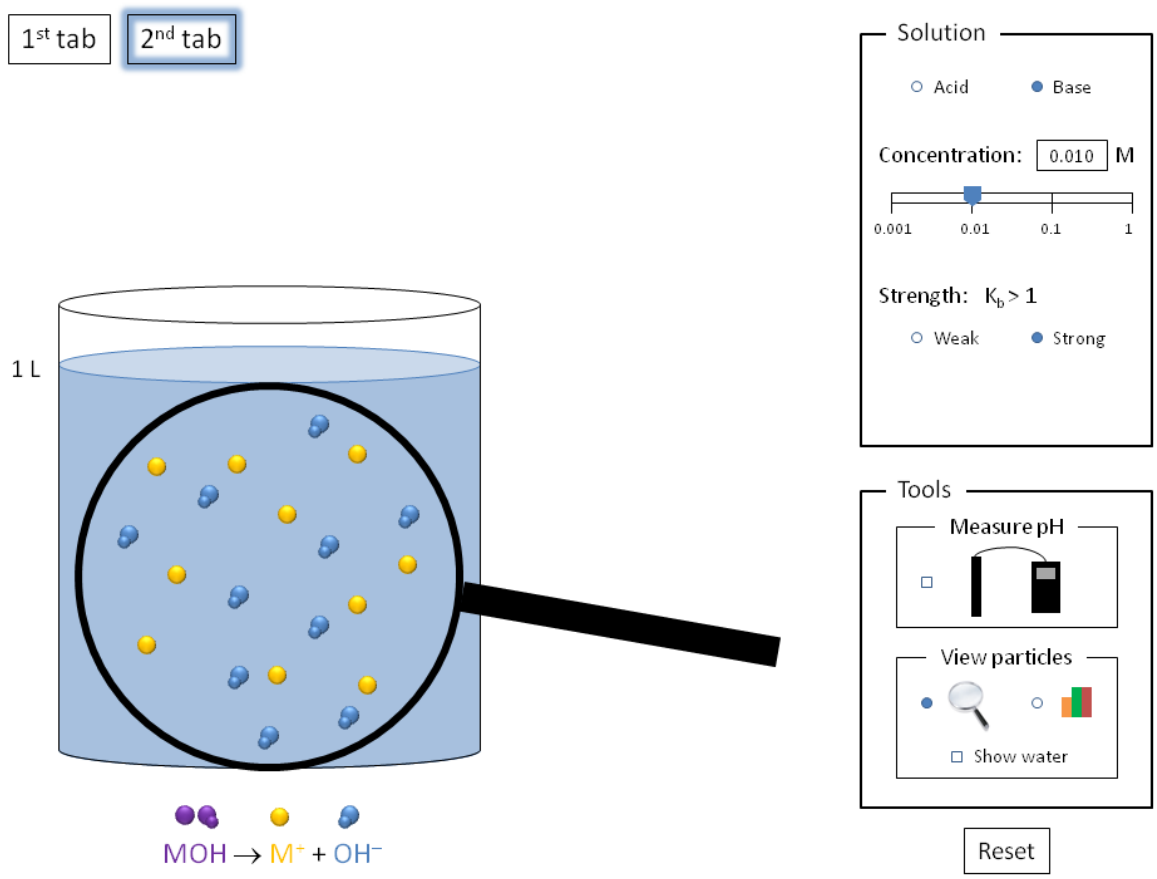
2nd tab: Custom solution

Students can select an acid (the default) or a base. Once chosen, the reaction equation appears below the beaker. Students can also use sliders to change the concentration and strength. To begin, the sliders are at the same settings as for the weak acid/base in the 1st tab.

User scenario

In the default state, weak acid is selected, along with the pH meter and magnifying glass. The student moves the sliders for concentration/strength, and sees the number and type of particles change. The student spends some time making sense of the change. The student may then select the base solution, or they may keep the acid solution and proceed through the other tools. Either way, once a solution/tool is chosen, the student moves the sliders and observes the effect on the tool.


1st tab
2nd tab
1 L
HA + H2O ↔ H3O+ + A−
Solution
Acid
Base
Concentration:
0.010
M
0.001
0.01
0.1
1
Strength: Ka < 1
Weak
Strong
weaker
stronger
Tools
Measure pH
View particles
Show water
Reset



After the student has used every tool with both solutions, they are done.

Magnifying Glass Prototype

At our 01/21/10 design meeting, we decided that we needed to prototype the magnifying glass view before we could finalize some of the other design elements. This is an important view, and we have questions about the feasibility of showing images vs dot, conveying relative ratios, etc. This section documents what we hope to learn, and the features that will be in this prototype.

http://www.colorado.edu/physics/phet/dev/acid-base-solutions/0.00.07/

What we hope to learn from this prototype:
- how many particles to show
  - min # of particles needed to see effect of sliders
  - max # of particles we can show in allotted space
- how to vary # of particles w/ concentration & strength sliders
- what range to use for strength slider
- how many water molecules to show, and how they should look

Features in the prototype:
model:
- weak acid model only, taken from advanced-acid-base-solutions

view:

- magnifying glass, positioned on top of beaker
- HA, A-, H3O+, OH- molecule representations: dots or images
- H2O molecule representations: dots, images or solid color

beaker controls
- sliders for width and height

magnifying glass controls:
- slider for glass diameter
- radio buttons for HA, A-, H3O+, OH- representation: dots, images
- check box to show/hide H2O dots or images

solution controls:
- sliders for concentration and strength
- color chooser for solution color

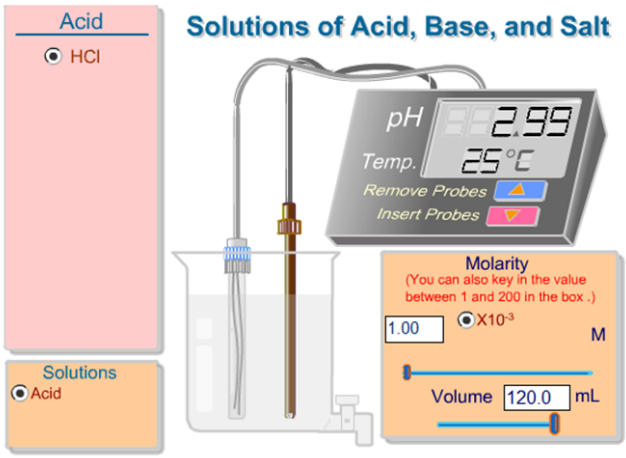
dot controls:
- slider for dot diameter, applies to all dots
- slider for max # of dots shown
- color choosers for HA, A-, H3O+, OH-, H2O dots
- one slider that controls HA, A-, H3O+, OH- transparency
- separate slider that controls H2O transparency

image controls:
- slider for image size, applies to all images
- slider for max # of images shown
- one slider that controls HA, A-, H3O+, OH- transparency
- separate slider that controls H2O transparency

misc controls:
- read-only display showing the number of molecules of each type (displayed vs actual)
- color chooser for play area color

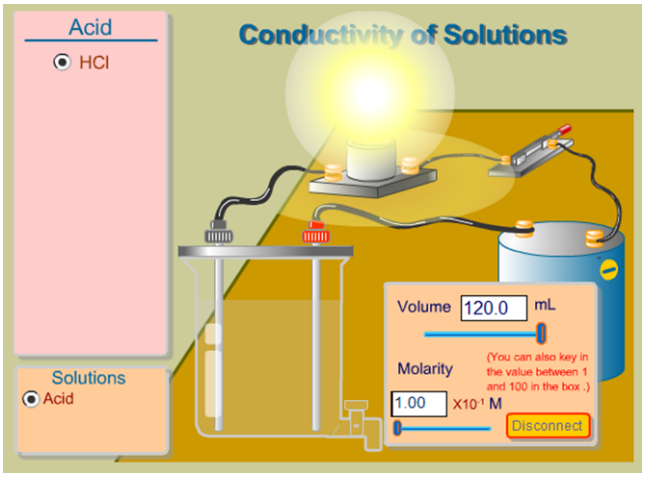
Online Resources

1. http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/acidbasepH/ph_meter.html
Interactive simulation; choose acid, base, or salt solution; change concentration and/or volume; insert probes for pH and temperature; **no molecules**

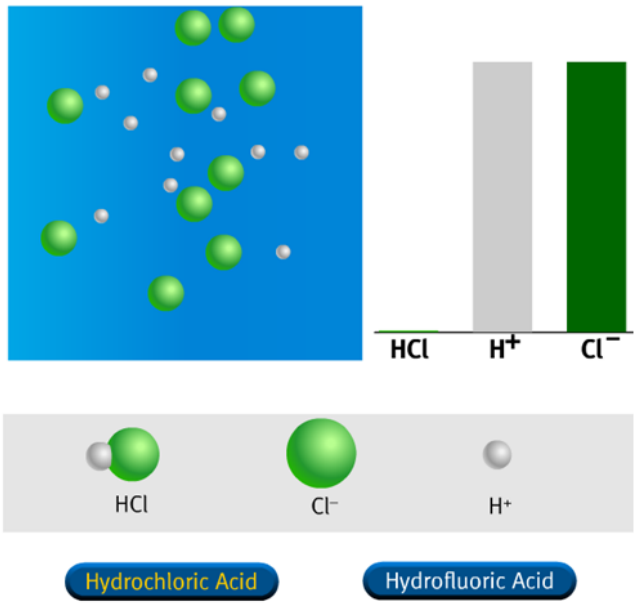


2. http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/electroChem/conductivity.html

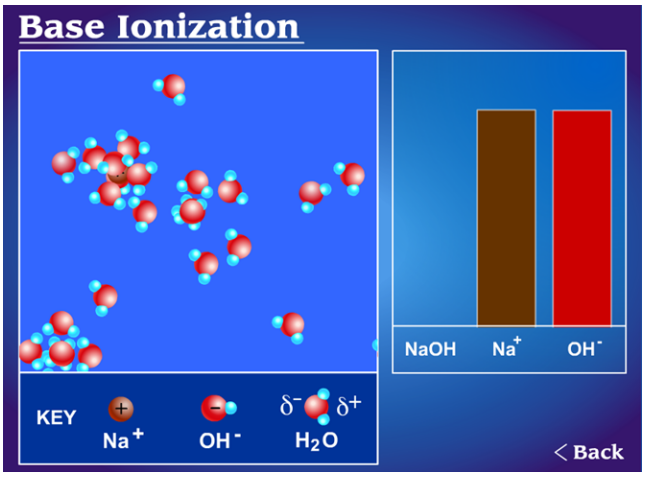
Interactive simulation; choose acid, base, or salt solution; change volume and/or concentration; connect circuit to test conductivity; **no molecules**



3. http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/acid13.swf
Animation with narrator; compares strong acid (HCl) to weak acid (HF); shows ionization with dynamic molecular view and bar graph; **no H2O molecules**

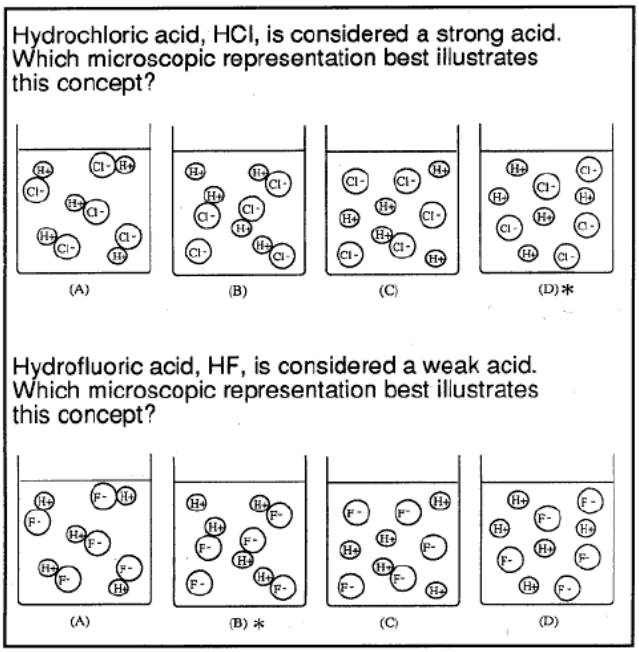


4. http://www.mhhe.com/physsci/chemistry/chang7/esp/folder_structure/ac/m2/s2/acm2s2_1.htm
Similar to animation above; compares strong base (NaOH) to weak base (NH3); **some H2O molecules**



References

1. Smith, K.J; Metz, P.A. J. Chem. Educ. 1996, 73, 233.
Title: Evaluating Student Understanding of Solution Chemistry through Microscopic Representations
Students can define strong/weak acid but cannot visualize strong/weak acid; students think strong acid has strong bond, weak acid has weak bond



Research Ideas

Biennial Conference on Chemical Education, August 2010
Symposium: **Research in Chemistry Education**

1) Motivation for the research and type of problem investigated, 2) methodology chosen to gather and interpret the data collected

When a sim works: An interview study of two PhET simulations on acid-base solutions
The goal of the PhET project is to develop a suite of interactive simulations to improve the way science is taught and learned. Central to every sim design is the question of how to create an environment that will encourage student exploration. Here we present results from an interview study of two PhET sims that address the same learning goal – acid-base solutions – but differ in the amount of implicit scaffolding given to students. We perform a qualitative analysis of the interviews, focusing in particular on how sim complexity affects student engagement and learning of acid-base chemistry. In sum, PhET sims are not only tools for learning science, but they are also tools for the study of how science is learned.

ACS National Meeting, August 2010
Topic: **Teaching Acid-Base Concepts in General and Organic Chemistry: Current Approaches to Improve Conceptual Understanding and Retention**
"In this symposium, speakers will share recent attempts to address difficulties encountered by students in learning acid-base chemistry. Rich experiences of instructors who teach general and/or organic chemistry to enhance learning and facilitate student success and retention as majors, especially in the physical and biological sciences, will be presented."
Organizer: **Margaret Asirvatham**

Do microscopic representations help students develop conceptual understanding?
As follow-up to Faraday "invisible" research, can study students who can see particles in the sim and those who can not.
(Chris would need to make version in which the only option under "View particles" is the bar graph)

Potential collaborator: UBC chem professor **Laurel Schafer** (schafer@chem.ubc.ca)
01/13/09: Instructor Sophia Nussbaum (our laboratory instructor) would be interested in the acids and bases sim. Also the course coordinator Prof. John Sherman, who actually coordinates the half of 1st year chemistry that teaches Acids and Bases, would be interested in working with you on the Acids and Bases sim. He may even be able to have it tested with our first year students, if you have a version that will be ready to go soon.

Discussion

12/10/09 - *Chris, Kelly*
How to implement dynamic microscopic view? How to change # of particles w/ concentration & strength sliders?

12/28/09 - *Robert, Wendy, Noah P, Kelly*
WA: How about a 3rd tab w/ *fun* solutions (similar to pH scale)?

01/11/10 - *Kathy, Kelly*

1. If show motion, need play/pause button
2. Should we show more water molecules?
3. Need to reconsider range of K slider

<u>01/12/10</u> - *Chris email to team*

Comments:
o Looks generally good, much simpler, much more focused on a few basic learning goals.
o If we can really keep it this simple, development should proceed relatively quickly.
o Your "rough sketch" mockups are totally fine for a document of this type, don't really need anything fancier.
o Very little code will be reused from the existing Acid Base sim. I don't think this fact should influence the design. But I want everyone to be aware that we're not salvaging much from the previous 8 months of development.

Questions:
o Are the tools mutually exclusive? (only one selectable at a time?) Yes, for two reasons: 1) the tools would overlap if more than one was in the play area, and 2) some tools (like the reactivity test) change the solution, so we need a way to start over.
o All tools are moveable except magnifying glass and bar graph, correct? Yes. That way, students are not allowed to place the magnifying glass over anything other than the solution, and there is no need to move the bar graph.
o Where does the bar graph appear, and is it moveable? Inside the beaker, and no.
o Describe what we see for the reactivity tests. Do the objects (nail/chalk) change, dissolve, end up in solution, disappear,...? Good question! Never seen this myself, so not sure. What we need is a field trip to a chemistry lab!
o How are the molecules moving? Simply jiggling in place? Random walk? Interaction/ collisions?... This is a liquid, so most likely random walk (but with small steps).
o When molecules are visible, are we showing any reaction taking place, or just molecule movement? Not sure if we should show reactions. It would be nice to show that the solutions are in equilibrium (at least for *weak* acids and bases), but it may just be overload for the student. The animations above show equilibrium, and they either highlight or point to the molecule undergoing a reaction (and even pause the motion), but it is still very hard to see.
o I don't understand the algorithm for how many molecules to show. The number of molecules is determined by the concentration. We need a lower limit for the smallest concentration (1e-3 M), and an upper limit for the largest concentration (1 M). Once we determine the two limits, the number of particles will vary linearly with the slider. This is before ionization. How many of those molecules remain *after* ionization is determined by the percent ionization (which depends on concentration and strength). So, *none* of the molecules could be ionized (0%), or *all* of the molecules could be ionized (100%).

Implementation concerns:
o Can we show a convincing/useful number of molecules, especially while the user is varying concentration and strength? This was a difficult problem in the pH and the previous Acid-Base sim, because the number vary by many orders of magnitude.
o Showing molecules instead of simple circles increases the graphics requirements. We'll need to use image files, and there will be a scaling cost. Whether the cost has any impact depends on how many molecules we'll be drawing, the type of movement/ interaction, etc.
o Using a magnifying glass gets rid of the "counting all the molecules" issue, but it provides less space in which to draw things. And since the molecules are larger than in previous sims, we'll have space for fewer molecules.
o How to implement the reactivity test? Depending on what you want to see, this could be as large a problem as showing molecules.

01/14/10 - *Chris, Kathy, Kelly, Robert, Trish, Wendy*
1. Do not show motion, and thus do not show reaction
2. Make water molecules more dense; need a show/hide H2O button

01/14/10 - *Laurie email to team*

A few comments, if they're useful:
I'm wondering if using a drop of Universal Indicator instead of the litmus paper would be useful. It would be more dynamic as students change concentrations and Ka or Kb values (which would also add to the cost of the sim, I'm sure). It just seems more interesting and engaging to me than litmus paper.

For either the chalk or nail test, I would expect to see bubbles form and for the solid to start dissolving. The difference between putting a piece of chalk in 0.1 M strong acid and 0.1 M weak acid is the RATE at which the reaction takes place. Since the calcium carbonate is reacting with free H+ ions, there are more readily availably immediately when you put the chalk into the strong acid solution. Not as many in the weak acid solution, so it doesn't go as quickly. But as the chalk reacts with the H+ in the weak acid (removing it from solution), it pulls the weak acid equilibrium to produce more H+, which reacts, and so forth. Ultimately, the same amount of chalk would react with a 0.1 M strong acid and a 0.1 M weak acid, it just wouldn't be as vigorous and would take longer in the weak acid.

I like the idea of all these tests, though!!

Oh, and for the conductivity meter, consider having more than one bulb. The chemistry department had the machine shop fabricate some conductivity meters using 10 LED lights, so students could take readings from 0 - 10 lights lit up. Or, you could have the choice of a single bulb (in which case, it's the difference in brightness) or an LED strip.

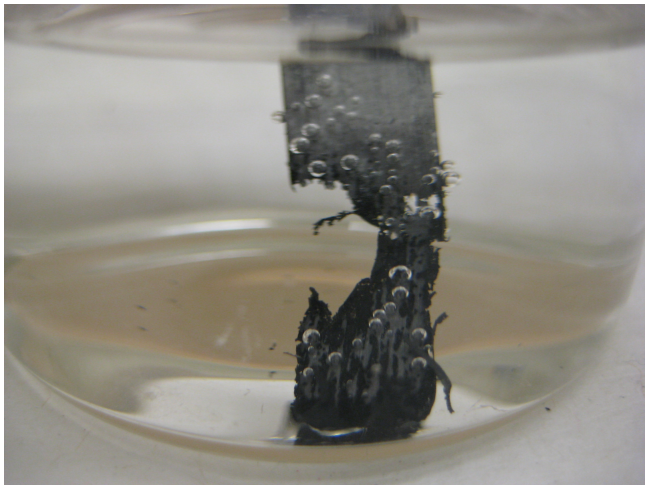
Just some initial thoughts. I think this might also be a good starting template for a more general "Making Solutions" sim.

I have an amendment to my previous comments, concerning the Universal Indicator. It would be useful to have on the second panel, when students can dynamically change concentration and strength. Probably not quite as useful on the first panel. I'm not sure.

01/21/10 - *Chris, Kathy, Kelly, Robert, Trish*
1. Tools: Use pH paper (rather than red/blue litmus paper); thus need a key. Also use smaller pH meter.
2. How do tools work? If users must move the tools, need to have room in play area. Or can just appear in beaker.
3. Need to determine size of beaker/magnifying glass. Chris will mockup with developer controls.
4. What is range of K? Some want weak to strong, others want weaker to stronger (but still "weak"). Ask advisory board.
5. KP: pie chart w/ fraction of HA/A-?

01/27/10 - Kelly, Laurel
Fun in the lab!

KL: I wanted to see what happens to a metal in acid over time, so two days ago, I left a strip of Zn in 1M HCl solution. I went back to the lab today, and this is what I saw...



04/09/10 - *Chris, Kelly, Robert, Trish*

CM: Here's a version of the Magnifying Glass prototype for discussion:
http://www.colorado.edu/physics/phet/dev/acid-base-solutions/0.00.04/

The biggest outstanding issues are:

(1) The representation of H2O using images

CM: Each different type of molecule is drawn in its own graphical layer. H2O is always in the background layer. After reviewing the design document, I believe we want the H2O molecules to look like they fill the background, and (as the doc says) "the molecules will fade into continuous blue background". This tells me that a single layer of H2O images (like we have now) is not going to cut it, since they all have the same transparency. We probably need multiple layers of H2O molecules, with each layer getting more transparent (and possibly smaller?). Implementing this using the same approach as the HA/A/H3O/OH molecules may be expensive, but it's probably doable. The least expensive approach would be to simply create a single image (using Photoshop, etc.) that we then display for the water shown through the magnifying glass, but that approach also has drawbacks. Before proceeding with any changes here, I'd like to get everyone's input on the desired "look".

TL: The prototype seems very good to me. I tried a wide variety of the sliders and thought that many options would provide a good model for students. Adding more layers doesn't seem necessary for me. My class is just four days into the Acid base unit, so I could ask some students what they think. I would want to write some open ended questions that directly address our concerns. I know we are not to this point yet, but I think that the students being able to change from molecule to dot view would be helpful to their understanding if we can include it as an option. If not, maybe just a simple sim that lets them go back and forth would be helpful.

(2) The algorithm for calculating # of molecules to display

CM: Kelly has commented that the current behavior is confusing and not what she expects. The prototype currently uses the same algorithm as Advanced Acid Base Solutions. That algorithm was specified by Kathy, and a copy of her specification document is attached here. Kathy described this as the "HA/A- ratio model", but we also used it for the H3O+/OH- ratio, since it would be confusing to have these 2 ratios visible at the same time with different models. And according to my notes, we changed "Base concentration" to 1E-7 "so that pure water shows some dots". So we need to decide

whether to tweak this algorithm further, or whether to try something different. I've made it easy to plug new algorithms into the prototype.

KL: For instance, starting at Ka = 1e-10, the number of HA images is constant as you move the slider to the right (until Ka = 1e-5), while the number of A- images increases. I think HA should decrease as A- increases - otherwise, what is the source of the A- ions?

TL: I am unsure about how to judge the quality of the algorithm. It seems like we really need to test some very specific chemicals and see if students come up with the right idea/answers. I am afraid that my own experience and knowledge may interfere with judging how a novice would interpret the representations. One thing that I noticed from the clicker questions that I used with pH Scale was the the bar graph with the Molarity showing was most helpful in helping students understand how much more water there is than ions and also we were able to talk about significant digits and why the water didn't appear to change concentration. Some students asked if the pH could be negative or greater than 14. That helped us talk more about significant digits and why the sim stayed in the traditional range. I attached my clicker questions.

KL: At a very basic level, this is what we want the sim to show:

I. as students move the <u>strength</u> slider from left to right, we want them to see:
- the number of HA images decrease
- the number of A- (and H3O+) images increase

II. as students move the <u>concentration</u> slider from left to right, we want them to see:
- the total number of images increase

I attached a pdf of why the current model fails to show part I, but I do not as yet have a solution. (It would help to know the reasoning behind the current model.)

(3) The range of K

KL: In terms of seeing a *change* in the HA and A- concentrations (ie, # of images) with acid strength, here are the optimal ranges of Ka for different values of Ca:

Ca = 1e-3 Ka = 1e-7 to 1e-1
Ca = 1e-2 Ka = 1e-6 to 1e0
Ca = 1e-1 Ka = 1e-5 to 1e1
Ca = 1e0 Ka = 1e-4 to 1e2

Lower bound: There is not much to see below Ka = 1e-7 for any value of Ca; do we need to go down to Ka = 1e-10?
Upper bound: In the prototype, this is set to Ka = 1. But when Ca is large, there is more to see beyond this cutoff.

TL: The small K range was chosen by Laurie and I, but I am not stuck on it. One of the things about the first sim was that we tried to do too much, so maybe increasing the K would be a good simplifying step. In the "advanced acid base" google doc, there is a list of acids and bases that we thought teachers would think is appropriate (I copied it below in this email). One of our thoughts was that students in upper division courses need to see how the structure in "families" of acids or bases demonstrates patterns that can be transferred to other acids and bases. In HS chem, we typically use just ammonia and acetic acid as our examples, so 10-5 would be sufficient. Robert could help with this? And do we need to run this by the advisory board?

NaOH	Kb >> 1

NH3	Kb = 1.8e-5
C5H5N	Kb = 1.7e-9
HClO4	Ka >> 1
HClO2	Ka = 1e-2
HClO	Ka = 2.9e-8
HCl	Ka >> 1
HF	Ka = 6.8e-4
CH3COOH	Ka = 1.8e-5

CM: Do you mean increasing the *lower bound* of K? This would actually decrease the range.

In the Advanced Acid-Base sim, we had a continuous range for K, with 3 "regimes":

weak: 1e-10 to 1
intermediate: 1 to 20
strong: 20 to 30

The intermediate base looks like a weak base (ie, it does not involve a metal).

TL: Thanks for helping me try to make my ideas clear. To help Kelly to understand where the original model came from in terms of learning goals, I wanted to put in the table Laurie and I made when we decided which acids and bases to include. To help clear up what I want to know from Robert or the advisory board: I was asking if using a larger K (increasing lower bound) in the weak section (ie smaller range) would be acceptable as Kelly has suggested or do we need to include the families?

RP: I think we should go with whatever keeps the sim simple.
Understanding the trends in Ka across a family of related compounds is an important learning goal for a 1st year university chemistry course, but not one that we need to address in the sim (and probably not one for which the sim is well suited, since the dynamic range in going from, say, HOCl to HOClO3, is enormous.) If the sim helps students to understand what Ka *means*, then an instructor can build on that foundation using other methods.

<u>04/16/10</u> - *Kelly interviews*

http://www.colorado.edu/physics/phet/dev/acid-base-solutions/0.00.05/

I interviewed 4 students on the magnifying glass prototype this week. Here are my notes:

- 4 students, all in first semester of gen chem, all find it hard
- all took chem in high school, one took intro chem in college
- started prototype w/ images or dots, H2O on or off

- students notice that more conc = more of all molecules
- notice that more strength = less HA, more H3O and A
- but not sure what HA means (not sure about A)
- also not sure what strength means (since no units)
- notice when conc & strength high, pH is low; when conc & strength low, pH is high
- notice when pH high, more HA
- but need to know what pH means to make sense of pH change!

- all prefer images to dots (even when see dots first)
- all like being able to show/hide the H2O images
- want more instruction
- played for 15 mins on average

I also interviewed 8 students on the "advanced" acid-base sim last week - students got closer to the learning goals by playing with the prototype than they did by playing for an hour with the advanced sim.

04/23/10 - *Chris, Kelly*

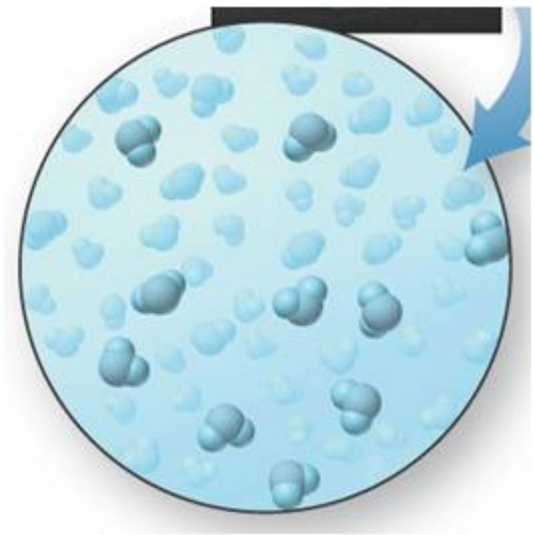
http://www.colorado.edu/physics/phet/dev/acid-base-solutions/0.00.06/

CM: This version improves the "images" representation of H2O molecules. H2O is represented using 3 layers, referred to as back, middle and front.
KL: It may just be my computer display, but I actually prefer the previous representation of H2O molecules. Anyone else have an opinion?
CM: What don't you like about the new representation? And have you played around with the dev controls?
KL: I did play with the dev controls, and it's not that I don't like the new representation - I just like the previous one better!

- the previous H2O representation gives more of a sense that H2O molecules fill the entire space
- if we show depth for the H2O molecules, then it looks funny not to show depth for the other molecules
- the previous H2O representation works for students!

04/29/10 - *entire PhET team*

The H2O molecules will NOT fade into continuous blue background as in Silberberg textbook (see image below), but will fill the entire space. This is to avoid giving students the idea that H2O molecules "float" in water.



05/13/10 - *Chris, Kathy, Kelly, Robert*

Are all the tools necessary?
- use pH paper, not red/blue litmus
- no reactivity test - too hard to implement

How should the tools work?
- measure pH = checkbox (ON by default), all others radio buttons (some tools may overlap)
- tools appear above beaker, can only slide up and down
- for conductivity test, each probe can move separately, bulb and battery can't move

What to do about strength slider?
- separate tabs for concentration & strength?
- use 1e-7 to 1e2 range for now, but ask advisory board if okay
- do we need to show K *values*? ask advisory board

<u>05/20/10</u> - *Chris, Kelly, Robert*

Strength slider
- radio buttons for 'weak' and 'strong'; when weak is chosen, get slider from 'weaker' to 'stronger'; when strong is chosen, no slider
- do not show K values, only show that for weak, K < 1; for strong, K > 1

<u>06/04/10</u> - *Chris, Kelly*

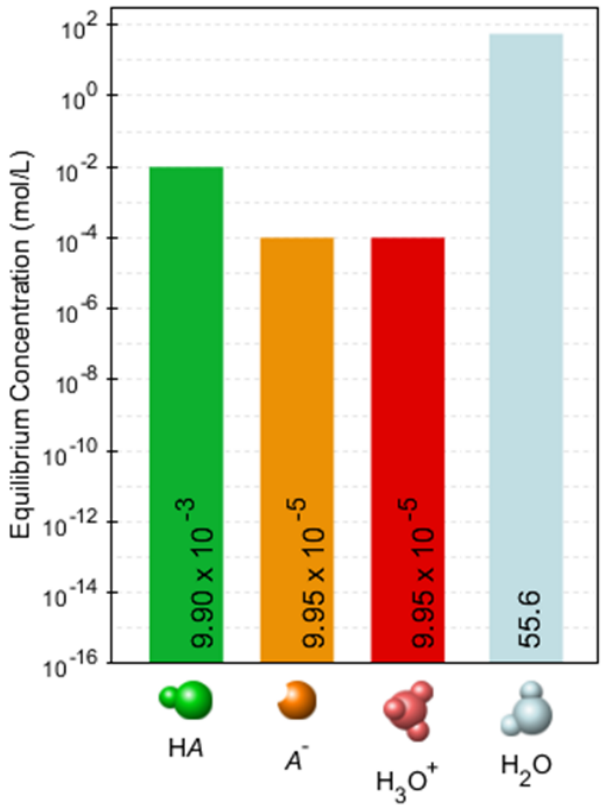
Show water

CM: Acid-Base Solution design doc has a "Show Water" check box. It's placement in the "View" panel leads me to assume that it applies to everything in that panel, ie both the magnifying glass and bar graph. Is this what you want? We hadn't discussed this for the bar graph, and it's not hard to do. But the magnitude of the H2O bar will dwarf the other bars.

KL: I did not intend for the "show water" check box to apply to the bar graph, but it may be good for students to see the amount of water in both representations. If it's not too hard to implement, then let's try it.

CM: Showing an H2O bar is not difficult to implement. But it's going to bring up issues of scale for the graph. Should the graph autoscale to fit everything? Do we need manual zoom buttons? Or do you want a fixed scale, with an arrow at the top of the H2O bar to indicate that it's off the scale? (as in Advanced sim)

KL: I was thinking a fixed scale for the y-axis, and if "show water" is selected, then the bar for H2O would add on to the end of the x-axis. Something like the attached image.



06/14/10 - *Trish, Chris I added my comments about the tools to the sections above -pat loeblein 6/16/10 2:38 AM*

http://www.colorado.edu/physics/phet/dev/acid-base-solutions/0.00.11/

1. I do hope you add the pH paper and conductivity, so students are more invited to interact and so they relate the sim to their lab experience. Why was it decided that these should only be on the first tab? There is no reason in the google doc. It is important to decide because then the conductivity tester would need more than just low and high on the second tab. Also, on the second tab, it would be nice to have universal pH indicator paper which is widely used in labs so students could relate the molecular images, bar graphs, and nomenclature to their own lab experience. I believe both of these would really help with the relating to real-life component necessary for learning. It does not bother me that it is poor technique to "dip" pH paper.

2. I would like to see something real next to the radio buttons on the first tab. Maybe the same common items as pH scale: Weak Base-Blood or Spit , Weak Acid-Milk or coffee, Strong Base-Drain Cleaner, Strong Acid-Vomit or Battery acid. Or we could go with the more common chemicals: WB-ammonia, WA-vinegar, SB-sodium hydroxide, SA-hydrochloric acid.

3. I have some concerns about the Strength Control section on the second tab. I am most concerned with the wording and the fact that there is not a continuum for the acids. I thought we agreed to try to do an entire spectrum for acids and then use radio buttons for bases. Since the idea that K<1 defines a "weak acid" is really arguable, the idea of a spectrum is much more realistic. More importantly, students will unlikely know what K means; this is introduced in College Prep chem late in the year, if at all in HS. I think MS and biology teachers will see applications for this sim and K is totally unknown to them. If the wording under the acid slider were weakest, stronger, strong (or just weak and strong), then they could maybe make some sense out of bases. I would like it better than the radio button for acids and I would leave off the K altogether. Then when

the student looks at bases and sees that there are radio buttons, they can think about why the model had to change.

4. I know Chris is still working on fonts. I included a screen capture so he could tell how small the greater than and less than symbols are, just in case we keep the K. They are really indistinguishable.

5. Why were the reactivity tests dropped? There is no explanation in the google doc. Chris answered and that info is in the Reactivity section -pat loeblein 6/16/10 11:41 AM

CM: I don't know the status/usefulness of the other features that you proposed. All I can provide is time estimates:

15 minutes: Add pH paper and conductivity tester to "Custom" tab
2-4 hours: universal pH indicator (depending on design)
30 minutes: real solution labels on "Test" tab
12-15 hours: continuous strength control for weak-to-strong acids

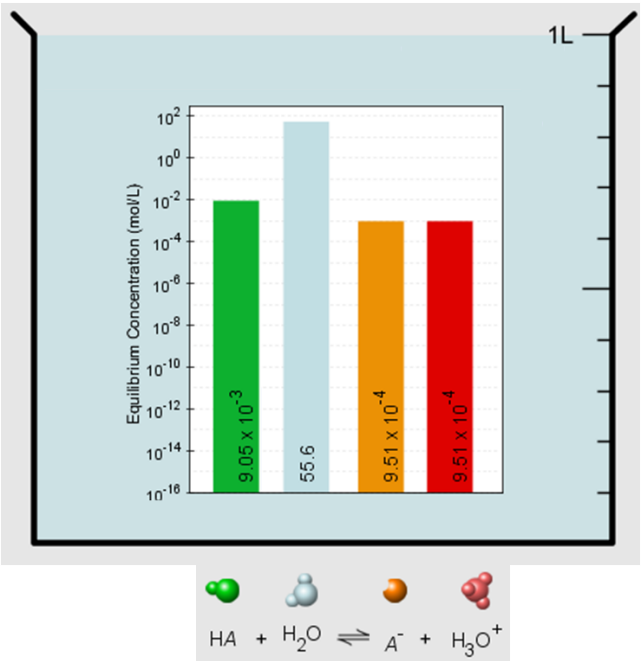
<u>06/15/10</u> - *Chris, Kelly, Trish, Kathy, Robert*

Bar graph

CM: About the bar graph... It's currently identical to the graph in Advanced Acid-Base, with the addition of the "Show water" feature.

Design questions:
(1) Do you want the order of bars to match the reaction equation? YES - as a result, will use new reaction equation for water. New equation: 2H2O <-> H3O+ + OH-, with 2 water molecule images above the symbol '2H2O'. We also need to shift the bar graph down in the beaker. -Kelly Lancaster 6/15/10 12:07 PM
(2) If order of bars matches reaction equation, where do we put H2O bar for strong bases? We will not show an H2O bar for strong bases. -Kelly Lancaster 6/15/10 12:07 PM
(3) Do you want to hide OH- for acids, and H3O+ for bases? YES - as a result, we can reduce the range of the bar graph. New range: 1e-8 to 1e2 mol/L. -Kelly Lancaster 6/15/10 12:08 PM
(4) Should the "Show water" check box control visibility of the H2O bar? NO - the H2O bar is always visible. -Kelly Lancaster 6/15/10 12:10 PM Will this look OK above reaction equation when H2O is hidden?

Also decided:
- need weaker 'weak acid' and 'weak base' on 1st tab - try K = 1e-7 for both
- remove all references to Ka and Kb in 2nd tab (i.e., no 'Ka < 1')
- do we need real-world examples of acids and bases on 1st tab? ask advisory board
- remove molecule symbols and icons below the bars in the graph



<u>06/16/10</u> - *Trish, Chris*

TL: In the dev list of "what's new". "6/15/10 disconnect concentration graph from "Show Water" control, always show H2O bar in graph (except for strong base)" The check box is still checkable. Should it be grayed out or something? I wasn't sure if you left that decision until the board has a say about whether it should be available or not?

CM: The "Show Water" check box is indeed only applicable to the magnifying glass, so should only be accessible when the magnifying glass is selected. I left it is for now because I think there are bigger problems with this check box -- it's not at all obvious that it applies to the magnifying glass. This check box needs to be clearly associated with the magnifying glass, either via a "Magnifying Glass controls" panel, or by placing the control on the magnifying glass.

<u>07/20/10</u> - *Chris, Kelly*

Students are confused by generic symbols:
- do we need a legend, or an intro tab?
- should we use actual chemicals? (this is what the advisory board wants)

Mutually exclusive "tests":
- pH paper (color depends on pH - need a ROYGBV color key - see below)
- conductivity test (luminance depends on # of ions - should we use bulb or row of LEDs? bulb for now)
- pH meter (on by default)

Mutually exclusive "views":
- magnifying glass (on by default, H2O off by default)
- bar graph

<u>08/10/10</u> - *Chris, Kelly, Kathy, Trish, Robert*

Which tools should be mutually exclusive?
- are students confused by "grayed-out" controls?
- do we need a "neither" button for the views?

What to do about generic symbols?
- put the symbol and icon next to the word on the control panel
- can students transfer from generic to specific?

Are the pH paper and conductivity tests necessary?
- do they distract students from the learning goals?
- do students connect conductivity with extent of dissociation?