Acid-Base Solutions

PhET Sim design document

version 0.8

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public (read-only) URL: http://docs.google.com/View?docID=dfnd4k2x_83gx2cgsd7

Contents

Recent Changes

- June 18 (Trish and Laurie)
  - revised learning goals
- May 8 (Archie)
  - changed to version 0.8
  - removed tab 4 ("Find The Unknown")
- April 29 (Archie)
  - do not show Lewis structures on 'view reaction equations' window for real chemicals (only custom)
- April 24 (Trish)
  - removed some chemicals from the chemical list

    - strong base K set to 10^7
    - some changes to learning goals
- April 17 (Archie)
    - changed to version 0.7
    - lactic acid removed from chemical list (other acids will be dropped soon)
    - new model for strength slider at intermediate strength
    - molecule count display change (change order and display symbols)
    - using "NEGLIGIBLE" rather than 0.0 for strong acids (see mockup)
    - "BH^+/B ratio" label changed in custom base mockup
    - outstanding issues list updated
    - new appearance for strength slider (see mockup)
- April 14 (Archie)
    - some clarifications in the design
    - new discussion about the 3-regime slider (see end of discussion)
- April 10 (Archie)
    - miscellaneous document updates to reflect decisions made at Feb 11 meeting (no design changes)
    - model for text resizing
- Feb 16 (Archie)
    - revised first mockup based on recent suggestions
- Feb 11 (Archie)
    - changed to version 0.6
    - new strength slider for consideration
    - new View checkboxes
    - removed HCN from list
    - new matching game design (tab 3)
    - new mockups for all changes
    - notes from design meeting
    - changed order so the discussion section is last
    - included section for Related Online Resources
    - see revision 1280
- Jan 23 (Chris)
    - changes to model section based on meeting with Trish
    - added model for Pure Water
    - added a couple of high priority issues related to the model
    - see revision 1043
- Jan 21 (Archie)
    - clarification of Matching Game (tab 3) behavior
    - comment replies
    - Chris's comments on usage scenarios included
    - if "pure water" is selected, K_a box should read K_w = 1E-14
- Jan 16 (Archie)
    - new mockup for tab 4
- Jan 15 (Archie)
    - new design and mockup for reaction equation resizing
    - new design and mockups for tab 3 (Matching Game)
- Jan 13 (Archie)
    - new mockup for tab 2 with bar graphs
    - Ka → K_a (and Kb → K_b)
- Jan 12, 2009 (Archie)
    - new mockup for custom weak base
    - new mockup for "view symbol legend"
    - included email discussion in Comments&Discussion for posterity

    - added section for the model
- Jan 7, 2009 (Archie)
    - changed to version 0.5
    - new "Comparing Solutions" tab
    - new "Symbol Legend" button and window
    - Laurie's general learning objectives added to learning goals
    - bar charts: changed order of bars and graph label
    - logarithmic concentration slider
    - Lewis structures shown in "View Reaction Equations"
- Dec 19 (Archie, following meeting with Kathy and Trish)
    - changed to version 0.4
    - intro and advanced tabs merged
    - new "Matching Game" tab (incomplete)
    - long list of chemicals (here)
    - see revision 365
- Dec 15 (Archie, following design meeting of Dec 12)
    - changed version to 0.3
    - new name for sim
    - now has three tabs
    - some layout changes
- Dec 9 (Archie)
    - changed version to 0.2
    - included K_a on pH meter
    - included Molecule Count view
    - included custom option for acids and bases
    - added molecule icons
    - added reaction equations
- Dec 4, 2008 (Archie)
    - document started, version 0.1
    - split from second tab of "Modelling Water, Acids & Bases" sim design document

Note: previous versions may be viewed from the Google Docs "File" menu, under "Revision History" (when this document is in edit mode).

Outstanding Issues

The following issues require action by the design team.

Higher priority:

1. Learning goals should be edited by Laurie and Trish. TL:4/23 Laurie will finalize TL: June 18
2. Laurie and Trish: We should write some usage scenarios for the sim - can you sketch some out. TL: 4/23 Trish will start writing a lesson after Laurie finishes the learning goals .
3. TL: Tips for TEachers needs to be completed 7/5 started waitinf for Jack's intereveiws on 7/16

Lower priority:

1. What should the View-ratio checkbox say for tab 2? The label must accommodate having an acid in one beaker and a base in the other (see mockup). It currently says "chemical ion ratio".

Learning Goals Final:

TL: I added these from our final document on July 5, 2009. The doc will be added to the activitiy database once the sim is on the website

Students will be able to use *Acid-Base Solutions* to do the following.

1. Given acids or bases at the same concentration, demonstrate understanding of acid and base *strength* by:

- Identifying certain common acids (or bases) as strong or weak.
- Relating the percent dissociation to the strength of acid (or base).
- 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).
- Identifying all of the molecules and ions that are present in a given acid or base solution. Without carrying out detailed calculations, decide which molecules or ions are present in relatively high concentrations and which are present in low concentrations.
- 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.
- Relating the strength of an acid or base to its dissociation constant, K_a or K_b
- 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 all molecules and ions in concentrated versus dilute solutions of a particular acid or base.
- Describing how the percent dissociation changes with dilution for a particular weak acid or weak base in water.
- Describing how the pH of a particular acid or base solution changes upon dilution.
- Interpreting what “acid concentration” means in terms of [HA] and [A-], and how that relates to strength.

3. Use both the strength of the acid or base and the concentration of its solution in order to:

- Predict percent ionization of the acid or base.
- Calculate pH of the solution.

· Calculate the concentrations of all of the molecules and ions in solution when a *strong* acid or base is dissolved in water.
· Calculate the concentrations of all of the molecules and ions when a *weak* acid or base is dissolved in water.
· 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.

4. Use and produce multiple representations that describe what's happening within a particular acid or base solution.

· 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 beaker view / dot view / molecule count to describe what is meant by acid strength.
· Interpret chemical equations and Lewis structures in terms of how acids react with water and how bases react with water.
· Interpret single or double reaction arrows in terms of the extent to which and acid or base dissociates in water.
· Describe the relationship between chemical equations and equilibrium expressions (Ka, Kb, and Kw equations).
· Relate the concentrations of all molecules and ions in solution to Ka values.
· Relate the strength of an acid to its Ka value.
· Interpret commonly used symbols: Ka, Kb, Kw, HA, A-, B, BH+

Advanced Learning Goals

- Predict the relative strengths of a series of acids having similar molecular structure.
- Predict the relative strength of a series of bases having similar molecular structures.
- Articulate the "5% rule" and describe when it is appropriate to use.
- Draw Lewis structures for molecules and ions in acid and base solutions, highlighting acidic hydrogens and lone pairs.

(older goals...)

Students will be able to...

1. Given acids or bases at the same concentration, demonstrate understanding of acid and base *strength* by:

- Identifying certain common acids (or bases) as strong or weak.
- Relating the percent dissociation to the strength of acid (or base).
- 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).
- Identifying all of the molecules and ions that are present in a given acid or base solution. Without carrying out detailed calculations, decide which molecules or ions

are present in relatively high concentrations and which are present in low concentrations.
- 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.
- Relating the strength of an acid or base to its dissociation constant, K_a or K_b
- Describing the similarities and differences between
    - strong acids and weak acids
    - strong bases and weak bases

more older goals:

1. describe the similarities and differences between
    - strong acids and weak acids.
    - strong bases and weak bases.
    - strong acids and strong bases.
    - weak acids and weak bases.
2. describe the similarities and differences between concentrated and dilute solutions.
3. describe 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).
4. calculate percent dissociation of an acid (or base) from their component concentrations.
5. relate the percent dissociation to the strength of acid (or base).
6. determine or predict the concentrations of water and acid (or base) components in solution
    - knowing percent dissociation
    - knowing ...?
7. identify whether certain common chemicals are strong or weak (chemicals given in drop-down).
8. identify the generalized symbols for acids (HA) and bases (B or MOH).

Objectives for student learning from sim:

Laurie composed the following general objectives that the sim should meet, not necessarily in the form of learning goals.

1. Students should develop a sense of what "strength" means in terms of acids and bases.
2. Students should develop a sense of what "concentration" means in terms of acid and base solutions.
3. Students should understand how strength and concentration together affect pH, percent dissociation, and concentrations of ions in solution.
4. Students should be able to predict all chemical species that will be in a particular acid or base solution, and identify what the major and minor species are.
5. Students should be able to use and produce multiple representations that describe what's happening and what's present in a particular acid or base solution. These representations include: bar graphs showing all solution components, beaker view /

dot view, chemical equations (using chemical symbols, equilibrium or non-equilibrium arrows), K_a/K_b values, K_a/K_b expressions, specialized symbols (K_a, K_b, HA, A-, B, BH+,MOH,M+), and Lewis structures.

6. Students should be able to describe what makes something an acid or a base (using pH values, chemical equations showing whether H3O+ or OH- are produced, etc.)

Laurie says: Embedded within many of these learning goals is being able to qualitatively describe effects of strength and/or concentration on pH, percent dissociation, and concentrations of species in solution, as well as to calculate pH, percent dissociation, and concentrations of species in solution.

Basic Sim Operation

Briefly, overall:

- first tab ("Solutions")
  - select a solution of weak or strong acid or base
  - change the concentration of the solution with a slider
  - observe (with 'dot view' or by bar graph) the concentrations of the various components
- second tab ("Comparing Solutions")
  - two controllable solutions are shown, so user can compare them
  - essentially two instances of the contents of the first tab
- third tab ("Matching Game")
  - game with points given for matching a solution with an unknown solution
  - the user first decides if it's an acid or base, then tries to match to unknown with normal solution controls
- fourth tab ("Find the Unknown")
  - like the first tab, except that the user chooses the chemical in two drop-downs (one to pick which unknown, the second to choose from a variety of unknown solutions)
  - also, one of the display elements is replaced by a "?" which is derivable from the other data shown

First Tab ("Solutions")

- see mockup
- Bar graphs
  - not controllable, but can be hidden (using checkbox below graphs)
  - always shows bars for H_3O^+, OH^- and H_20
  - shows HA/A- bars if a custom acid is in the beaker
  - shows B/BH+ bars if a custom weak base is in the beaker (see mockup)
  - shows MOH/M+ bars if a custom strong base is in the beaker
  - note that the number on the HA bar should change to the word "NEGLIGIBLE" (instead of 0.0) when there is a strong acid present (see mockup)
  - shows true chemical symbols if a real (not custom) chemical is in the beaker
    - some chemical symbols are long; these labels may have to be angled to fit (see mockup)
- Beaker
  - in default (start up) state, there is a weak custom acid in the beaker
  - contains 1 liter volume (not changeable)
  - can show dots, as in pH

        - controlled by beaker "View box" (see below)
- "View" box (by beaker)
    - ratio check boxes (see mockup)
        - can select to see either or both
            - dots for hydronium / hydroxide ratio
            - dots for ratio of dissociated acid (or base) components
        - the labels (for the first ratio only) will change according to what's in the beaker:
            - for acids, A^-/HA ratio
            - for weak bases, BH^+/B ratio
            - for strong bases M^+/MOH ratio
            - true chemical symbols if a real (not custom) chemical is in the beaker (eg, HCl, Cl-/HCl ratio, etc)
        - note that for strong acids and bases, there should be no minority species represented by dots
    - "Molecule Count" check box (see mockup)
        - when checked, show a display of total numbers of molecules of each type in the bar chart (similar to pH Scale feature)
    - "Label" check box
        - when checked, text appears on the beaker (like a label on a beaker on a shelf)
        - text gives name of chemical and its concentration
        - eg: "Hydrochloric Acid, 0.02 molar"
- pH readout
    - shows pH of solution
    - not controllable
- View box (below chart)
    - "Reaction Equations"
        - pops up a separate window that shows reaction equations; see mockup
        - window shows two equations
            - one of the following
                - $HA + H_20 \leftrightarrow H_3O^+ + A^-$ (weak acid) with Lewis structures
                - $HA + H_20 \rightarrow H_3O^+ + A^-$ (strong acid) with Lewis structures
                - $B + H_20 \leftrightarrow OH^- + BH^+$ (weak base) with Lewis structures
                - $MOH \rightarrow M^+ + OH^-$ (strong base) with Lewis structures
                - for a real chemical (from list) show a similar equation with correct chemical symbols, but no Lewis structures
            - $H_20 + H_20 \leftrightarrow H_3O^+ + OH^-$ (along with Lewis structures)
        - notes on equations:
            - the "A", "B" and "M" are replaced by the correct chemical symbols if a real (not custom) chemical is in the beaker
            - if the acid or base is strong, the second equation has a right arrow rather than the double arrow in the equation
        - resizing of symbols in equations
            - resizing is controlled by radio buttons
            - radio buttons defaults to 'off', in which case the symbols in the equations remain static (see mockup)

            - if the radio button is turned 'on', the sizes of all chemical symbols except for H_2O will vary with their concentration in solution (see mockup)
            - for the relation that governs the font size, see the model section (under "text resizing")
        - "Equilibrium Expressions"
            - pops up a separate window that shows equilibrium expressions (not controllable); see mockup
            - shows equations to calculate K_a (or K_b for bases) and K_w
            - symbols have the same properties as those in "reaction equations" (including resizing)
            - numerical readout for K_a/K_b and K_w
                - for weak K, shows value of the acid's K_a, or the base's K_b
                - for intermediate K, show no display of K
                - for strong K, it just says "Large"
                - K_w = 1E-14 (always)
                - in all cases, the symbols are still shown
        - "Concentration Graph"
            - when checked, the bar graphs are visible; otherwise bar graphs are gone
            - checked on by default
        - "Symbol Legend"
            - see mockup
            - pops up a separate window with text that shows what symbols mean (not controllable)
            - since the italics symbols are hard to read in the HTML rendering, it is recommended that we put an extra space after the italicized symbols
- "Solution" control box
    - choices in drop-down are (in this order):
        - no solute (pure water)
        - (all the real chemicals in alphabetical order)
        - custom acid (HA) -- default
        - custom base (B)
        - note: Chris, in designing the slider, please be aware of the possible need for a "custom weak acid" choice (in which the slider is restricted to the weak region), and a similar option for bases
    - strength slider
        - controls the strength of the acid/base only if a "custom acid" or "custom base" is selected (is greyed out otherwise)
        - if a weak acid/base is selected (but not "custom"), the pointer will show its strength but will not be adjustable (see mockup)
        - if a strong acid/base is selected, the slider will move to the value of that chemical's K within the strong regime (see mockup)
        - three regimes on slider:
            - weak ($10^{-10} < K < 1.0$)
            - undefined ($1.0 < K < 20$)
            - strong ($20 < K < K_{max}$) where K_{max} is the largest K value that appears in the tables below
        - note that all real chemicals fall in either the strong or weak regimes
    - concentration slider
        - will change the concentration of the acid/base in solution
        - goes logarithmically (see model for range)

        - bar graph and dots will change accordingly
          TL: The only thing that I have thought about as I play with version 0.01.18 is that the section of the strength slider that has no lable needs one. Right now, I feel like the way the slider behaves in conjunction with the bar graph will be helpful for students. see my email on June 11 for an image.
        KP: I am hesitant to put a label in the "Intermediate" strength section because that would draw more attention to it in terms of saying that this region has a name, etc. I see it as a bridge that connects the concept of strength across these areas that students learn about in class. I'd like to see how students interpret the slider in interviews and if there are any problems. TL: interviews seem like the best way to resolve this concern

-
    - concentration textbox
        - shows value of concentration slider (3 decimal places)
        - editable (ranges from 0.001-1.0)
    - when "no solute (pure water)" is selected:
        - both concentration and strength sliders disappear
        - concentration box reads 0.0

Second Tab ("Compare Solutions")

- two controllable solutions (as in tab 1), one in left and one in right panel
- variable view type (view is the same for both panels), selected with radio buttons:
    - beakers (see mockup)
        - sub-menu with check boxes for dots and/or molecule count
        - label for dots view will have to be something that can accommodate both acid and base (currently "chemical ion ratio")
    - bar graphs (see mockup)
        - bar graphs will have to be slightly reduced in size compared to tab 1, otherwise they are equivalent
    - equations
        - shows the same content as in the "View Reaction Equations" window in each panel
        - will have to be scaled down so that they fit

Third Tab ("Matching Game")

- a game to control a solution in the right panel, making it match the one presented in the left panel
- start-up state
    - see mockup
    - a solution is chosen at random and shown in the left panel
    - the "dots" for the H3O+/OH- ratio are shown, other view options are greyed out
    - a question appears at the right, and the user must chose if it's an acid or base
        - correct choice leads to next bullet ("matching state") and +1 point (see mockup)
        - incorrect choice leads to -1 point and "wrong" message
- matching state
    - see mockup
    - appears when previous question has been answered correctly
    - view options no longer greyed out
        - options have the same function as in tab 2

        - note there is no "equations" option, nor a "label" option
    - solution controls now available
        - uses the appropriate wording for "acid" or "base" (but not selectable)
        - user may control the concentration and strength with sliders
    - the user can change settings with no point changes until "check match" button is clicked, then
        - if the two solutions are sufficiently close (in concentration & strength)
            - +5 points
            - "Correct!" message
            - user must click "next solution" to continue
            - user can change sliders and "check match" again, but won't get any points until a new solution is started ('correct' and 'wrong' messages may still appear, though)
        - incorrect choice leads to -1 point and "wrong" message
- Correct, wrong, point messages
    - remain on the screen for N seconds; let's set N = 2
    - should use a standard font, despite the mockup
- user can at any time click "next solution" button, then
    - "number of solutions" readout will increment by one
    - a new solution is chosen and the display goes to start-up state
- "reset all"
    - changes "points" and "number of solutions" back to zero
    - display goes to start-up state
-

Model

The following describes the mathematical model governing all quantities in the sim.

- relations & notation (common to all calculations)
    - constants
        - A = 6.022e23 (Avogadro's number, 1/mol)
        - W = 55.56 (concentration of pure water, mol/L)
        - K_w = 1E-14 (equilibrium constant of water, $[H_3O^+]$ * $[OH^-]$, mol/L)
    - independent variables
        - c = concentration (mol/L)
            - set by user, ranges from 1e-3 to 1
        - K_a = strength of weak acid (mol/L)
            - set by user, ranges from 1e-12 to 1e2 or by chemical type (see table)
            - equal to
                - $[H_3O^+][A^-]/[HA]$ for weak acids
                - undefined (large value > 100) for strong acids
        - K_b = strength of weak base (mol/L)
            - set by user, ranges from 1e-12 to 1e2 or by chemical type (see table)

        - equal to
            - $[BH^+][OH^-]/[B]$ for weak bases
            - undefined (large value > 100) for strong bases
    - p = percent ionization (no units)
    - $[x]$ = concentration of molecule x (mol/L)
    - number of molecules of x = $[x]*A$
    - pH = $-\log_{10}([H_3O^+])$
- Weak Acid
    - $[HA] = c - [A^-]$
    - $[A^-] = (-K_a + \text{sqrt}(K_a^2 + 4*K_a*c))/2$
    - $[H_3O^+] = [A^-]$
    - $[OH^-] = K_w / [H_3O^+]$
    - $[H_2O] = W - [A^-]$
    - $p = 100 * [A-] / c$
- Intermediate-strength acid
    - Define intermediate part of slider as going from K=1 to K=20 (these are adjustable call K=1 $K_{weak\_intermediate}$ and K=20 $K_{intermediate\_strong}$)
    -
    - So $(K-K_{weak\_intermediate})/(K_{intermediate\_strong} - K_{weak\_intermediate})$ tells you fraction along intermediate part of slider
    - [HA] = [HA for K_weak_intermediate point using weak-acid model]$*10^{-4(K-K_{weak\_intermediate})/(K_{intermediate\_strong} - K_{weak\_intermediate})}$
    - Make the "-4" an adjustable variable.
    - This should show continuous [HA] in transition from weak to intermediate acid or base, and then a decline of 10^{-4} over intermediate region.
    - $[A-] = c - [HA]$
    - $[H_3O^+] = [A^-]$
    - $[OH^-] = K_w / [H_3O^+]$
    - $[H_2O] = W - [A^-]$
    - $p = 100 * [A-] / c$
- Strong Acid
    - [HA] = 0 (for model)
        - In bar graph, display NEGLIGIBLE where bar for HA was. (Replaces concentration number). There is no bar displayed (see mockup).
    - $[A^-] = c$
    - $[H_3O^+] = c$
    - $[OH^-] = K_w / [H_3O^+]$
    - $[H_2O] = W - c$
    - $p = 100$
- Weak Base
    - $[B] = c - [BH^+]$
    - $[BH^+] = (-K_b + \text{sqrt}(K_b^2 + 4*K_b*c))/2$
    - $[H_3O^+] = K_w / [OH^-]$
    - $[OH^-] = [BH^+]$
    - $[H_2O] = W - [BH^+]$
    - $p = 100 * [BH^+] / c$
- Intermediate-strength base
    - Define intermediate part of slider as being Y in length
    - Define current position of slider as being a distance y along that Y
    - So y/Y tells you fraction along intermediate part of slider
    - $[B] = [B \text{ for } K=1]*10^{-4y/Y}$.
    - This should show continuous [B] in transition from weak to intermediate base, and then a decline of 10^{-4} over intermediate region.
    - $[BH^+] = c - [B]$

    - $[H_3O^+] = K_W / [OH^-]$
    - $[OH^-] = [BH^+]$
    - $[H_2O] = W - [BH^+]$
    - $p = 100 * [BH^+] / c$
- Strong Base
    - $[MOH] = 0$
    - $[M^+] = c$
    - $[H_3O^+] = K_W / [OH^-]$
    - $[OH^-] = c$
    - $[H_2O] = W$
    - $p = 100$
- Acid-Base comparison: note that the base model is exactly the same as the acid model with the following exceptions:
    - $HA \rightarrow B$
    - $A^- \rightarrow BH^+$
    - $H_3O^+ \leftrightarrow OH^-$ (interchanged)
    - for strong case: $[H_2O] = W - c$ for acid and $[H_2O] = W$ for base
- Pure Water
    - $[H_3O^+] = 1e\text{-}7$
    - $[OH^-] = 1e\text{-}7$
    - $[H_2O] = 55.6$
    - $p = 100 * [H_3O^+]/[H_2O]$

Text Resizing

The following describes how to compute the font size for a chemical symbol in the "Reaction Equations" window, given the chemical's concentration.

- given a concentration c (mol/L),
    - $C = \log_{10}(c)$
- with the following constants
    - $C_0 = -16$, $C_1 = 4$
    - $T_0 = 1$, $T_1 = 72$
    - $dC = C_1 - C_0$
    - $dT = T_1 - T_0$
    - $m_0 = 2$, $m_1 = 4$
- compute the following coefficients
    - $D = (dT - dC) / (C_1^2 - C_0^2 - 2 \cdot dC \cdot C_0)$
    - $B = 1 - 2 \cdot D \cdot C_0$
    - $A = T_0 - B \cdot C_0 - D \cdot C_0^2$
- then the font size T is
    - $T = A + B \cdot C + D \cdot C^2$

Usage Scenarios

Justification for writing usage scenarios:

- The main purpose of usage scenarios is to force designers to think about *exactly* how what they've designed will be used, and to test that design before it moves to a more-expensive phase (development, manufacturing,...).

- There is a tendency to look at drawings, screenshots and bullet lists and say "yeah, that looks like it should work". Not until you attempt to describe *in detail* how tasks are accomplished will you uncover possible problems or limitations hidden in the design.
- Uncovering those problems before the design is implemented is a responsibility of good designers. The designer is in effect "testing" the design, and it's analogous to developers testing their code. Testers appreciate developers who test their code; developers appreciate designers who test their designs.
- Whether you do usage scenarios depends on how much testing you want to do before handing the design over to development. And it's a cost trade-off; the cost to fix things increases at later stages of a product. It's least expensive during design, and most expensive after it's been released.

Instructions for writing usage scenarios:

- Each learning goal should have at least 1 usage scenario (for 1 task), preferably more.
- A flowchart would be useful.
    - The flowchart shows how a task is accomplished.
    - Each node of the flowchart is a point at which the user can take 1 or more actions (>1 means they have choices).
    - The entry point to the flowchart is where the user starts the task, the exit point is where the task has been successfully accomplished.
    - There may also be "dead end" exit points, and these indicate where the user got confused and wasn't able to accomplish the task; whether these are acceptable depends on the situation.

Mockups

Notes:

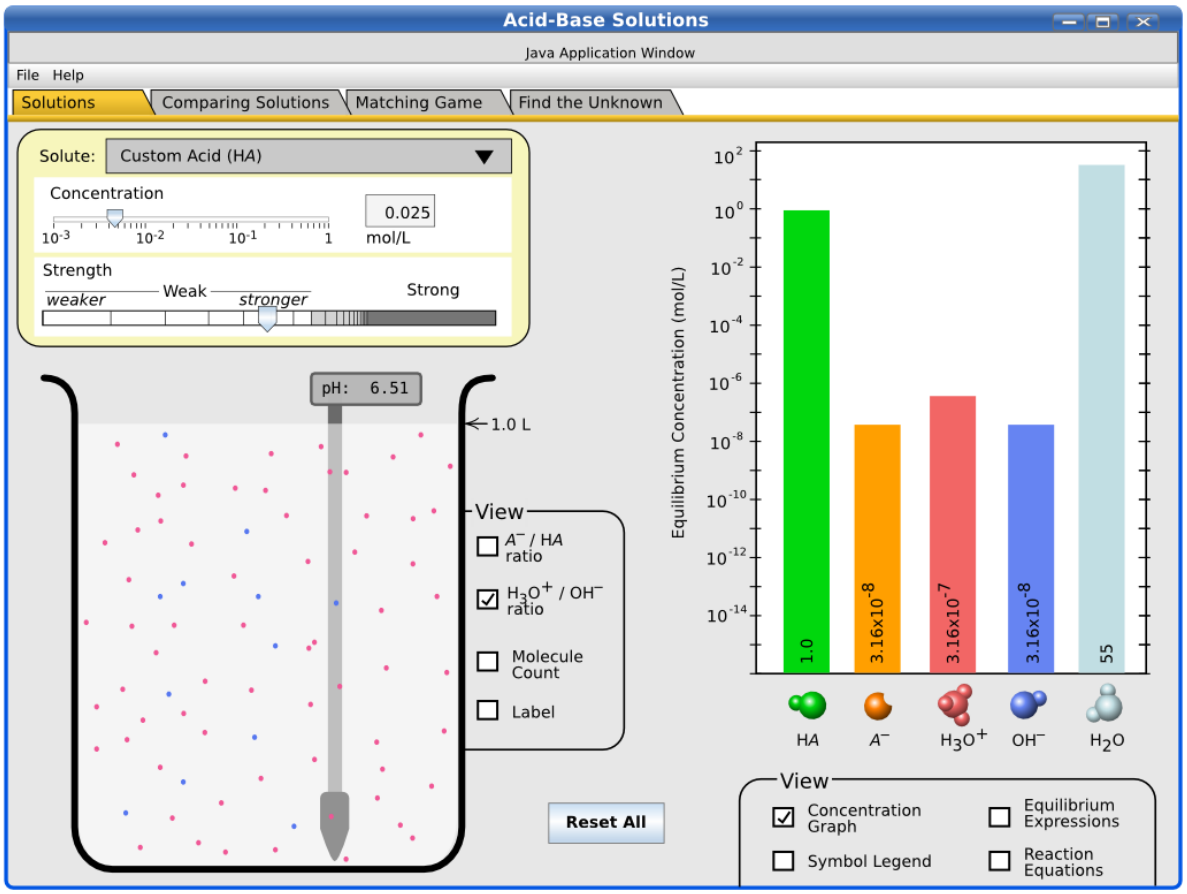
- mockups still show the fourth tab, which has been removed from the design
- all quantitative values in the mockups are bogus placeholders
- fonts in the mockups may not reflect what's used in the real sim

Mockup Index:

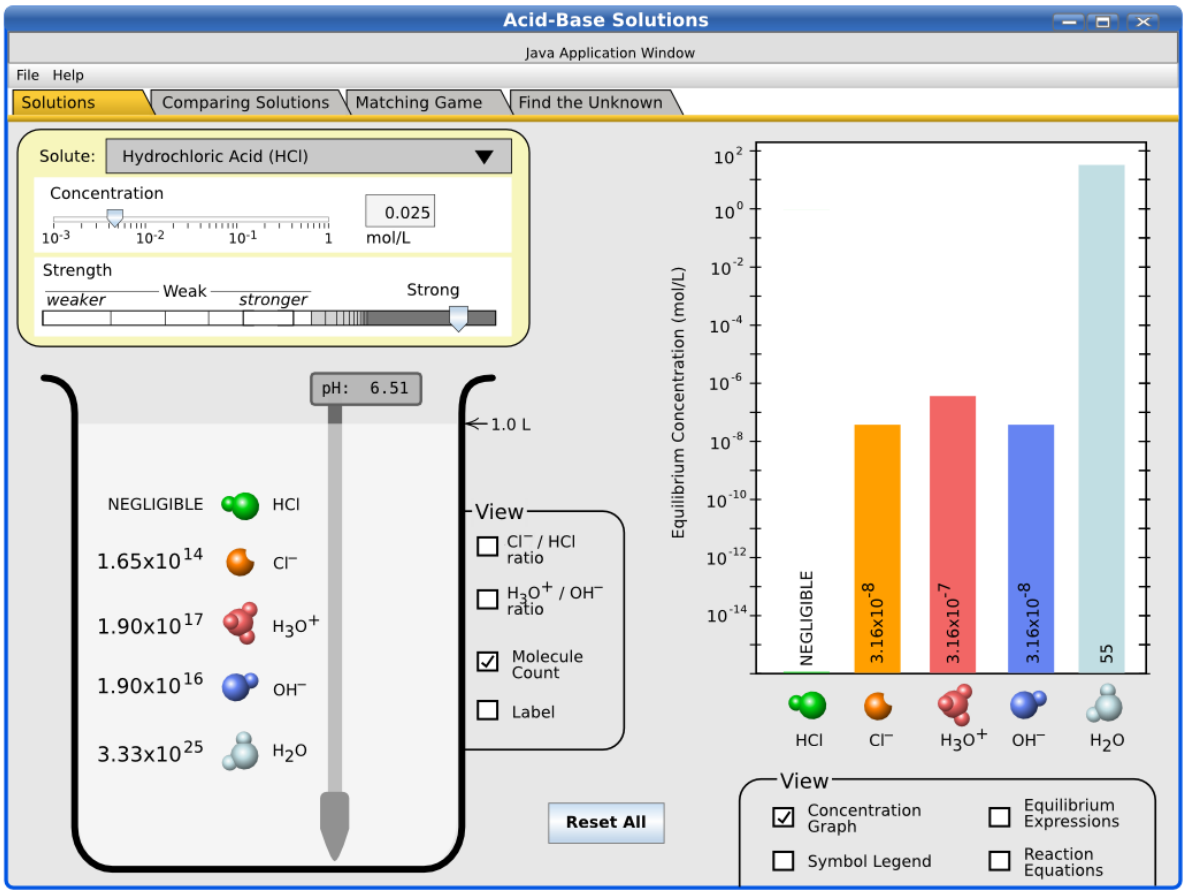
- after first two questions

Mockup Graphics:

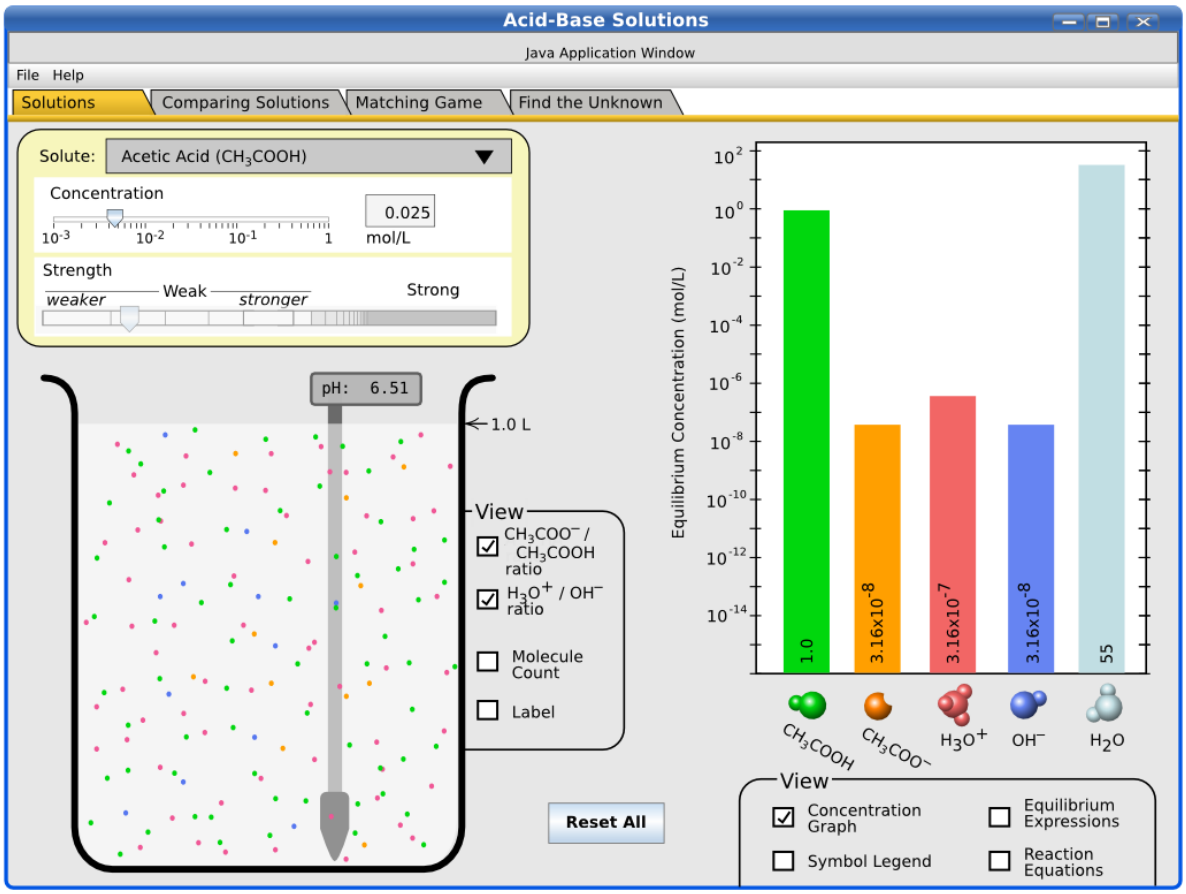
First Tab ("Solutions"):



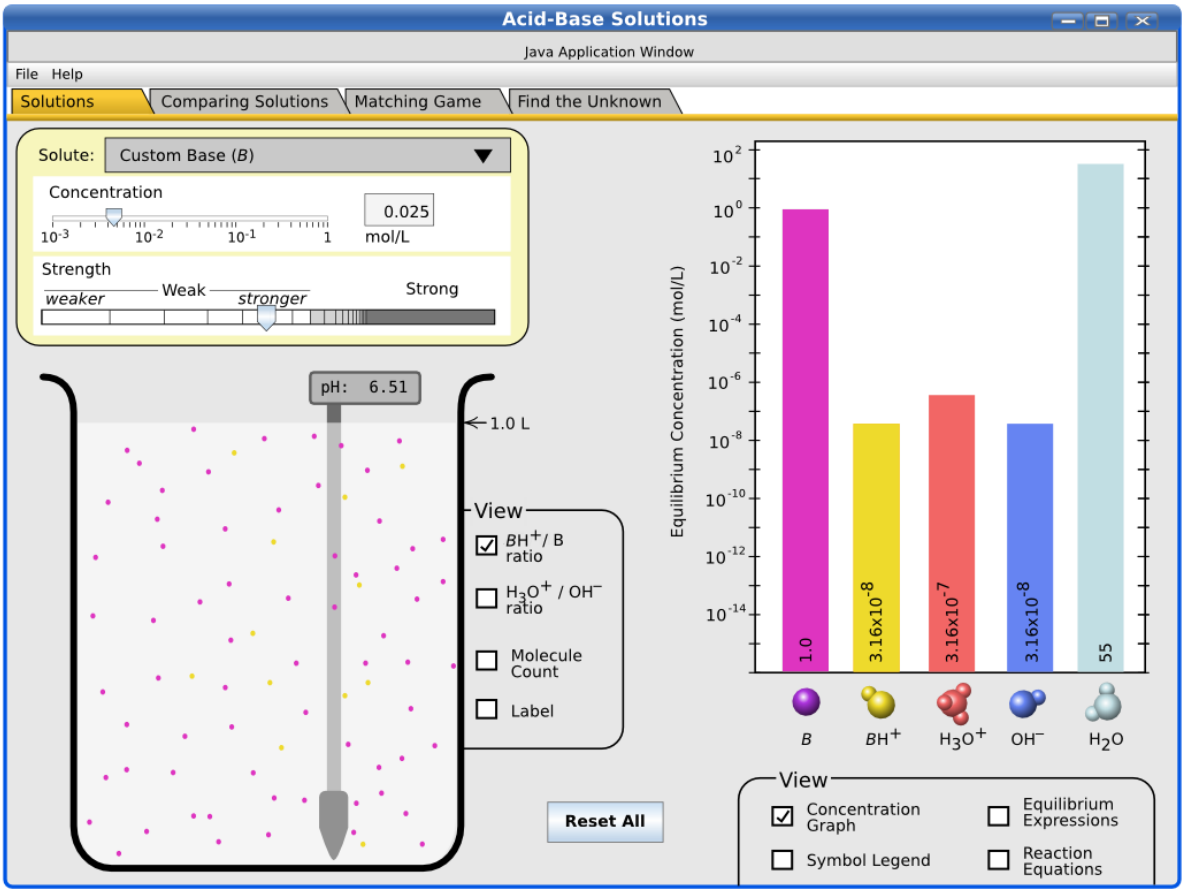
First Tab variant with "Hydrochloric Acid" and "Molecule Count" selected:



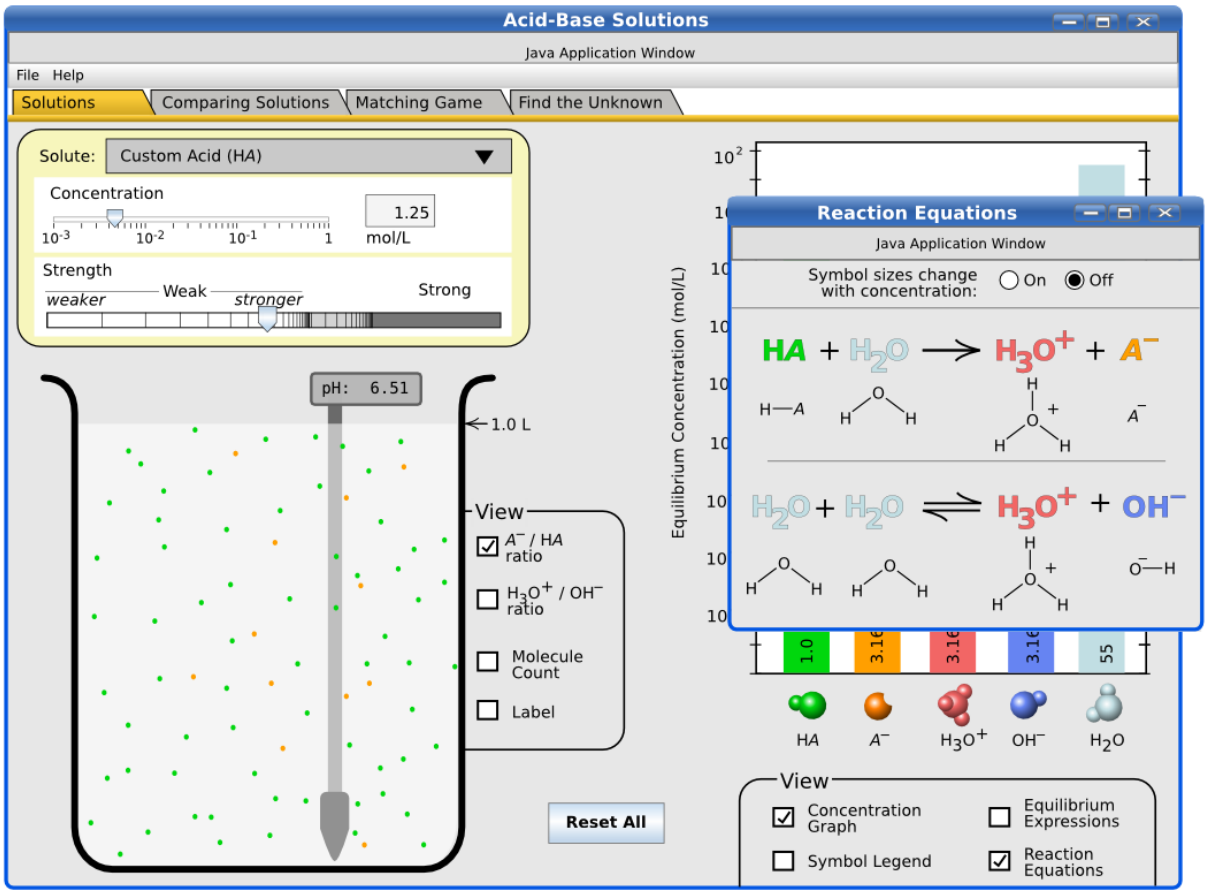
First Tab variant with "Acetic Acid" and all dots selected:



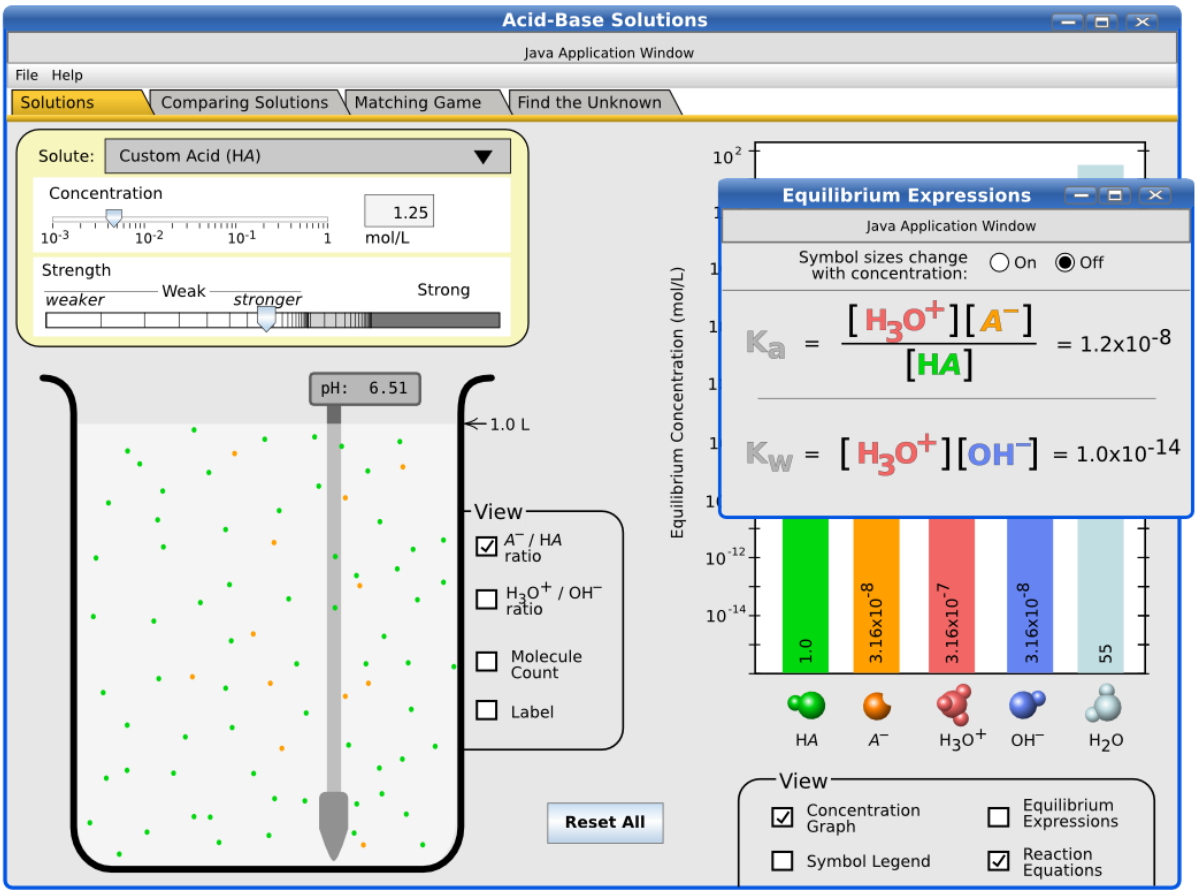
First Tab with custom base in solution:



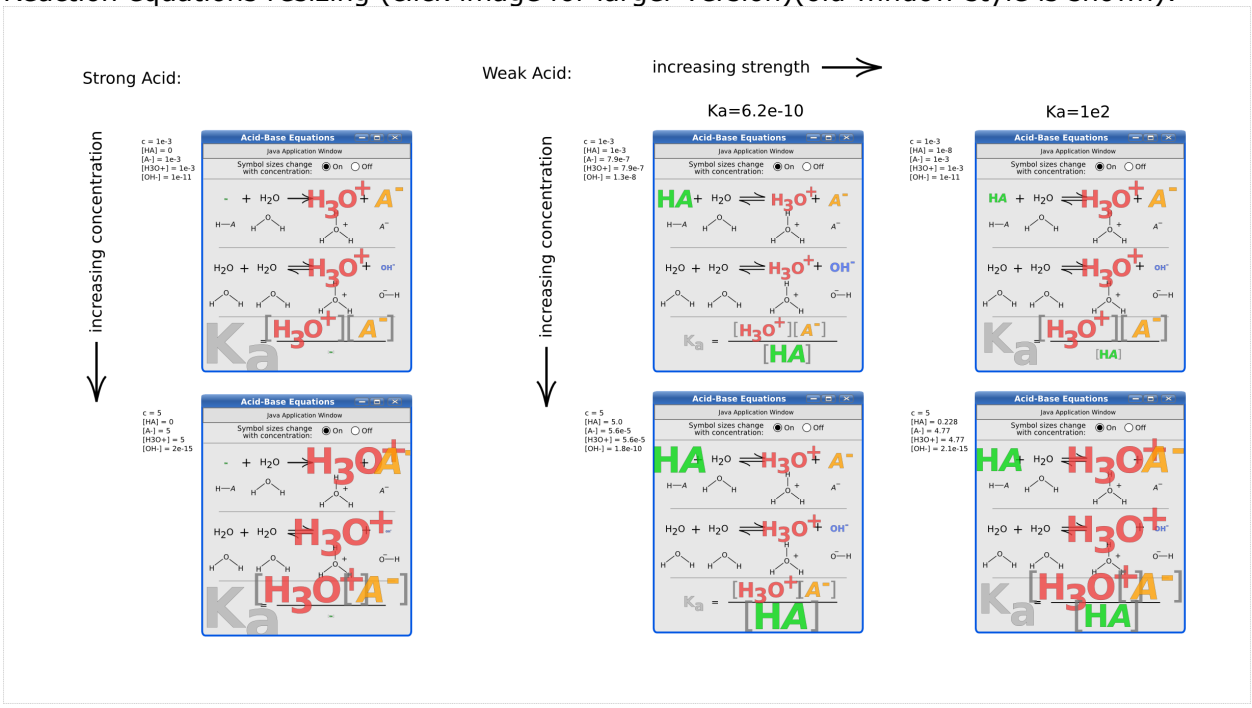
First Tab with View Reaction Equations Window:



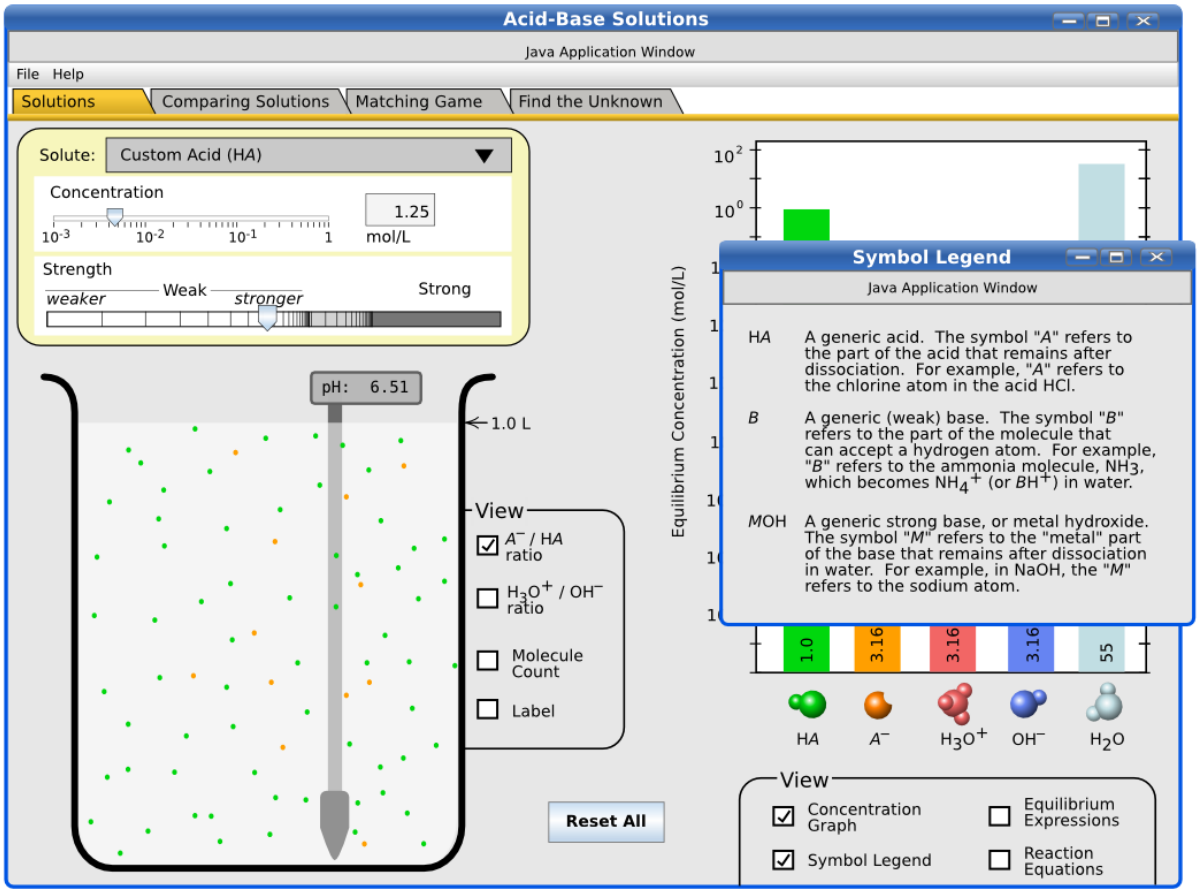
First tab with "Equilibrium Expressions" shown:



Reaction equations resizing (click image for larger version)(old window style is shown):



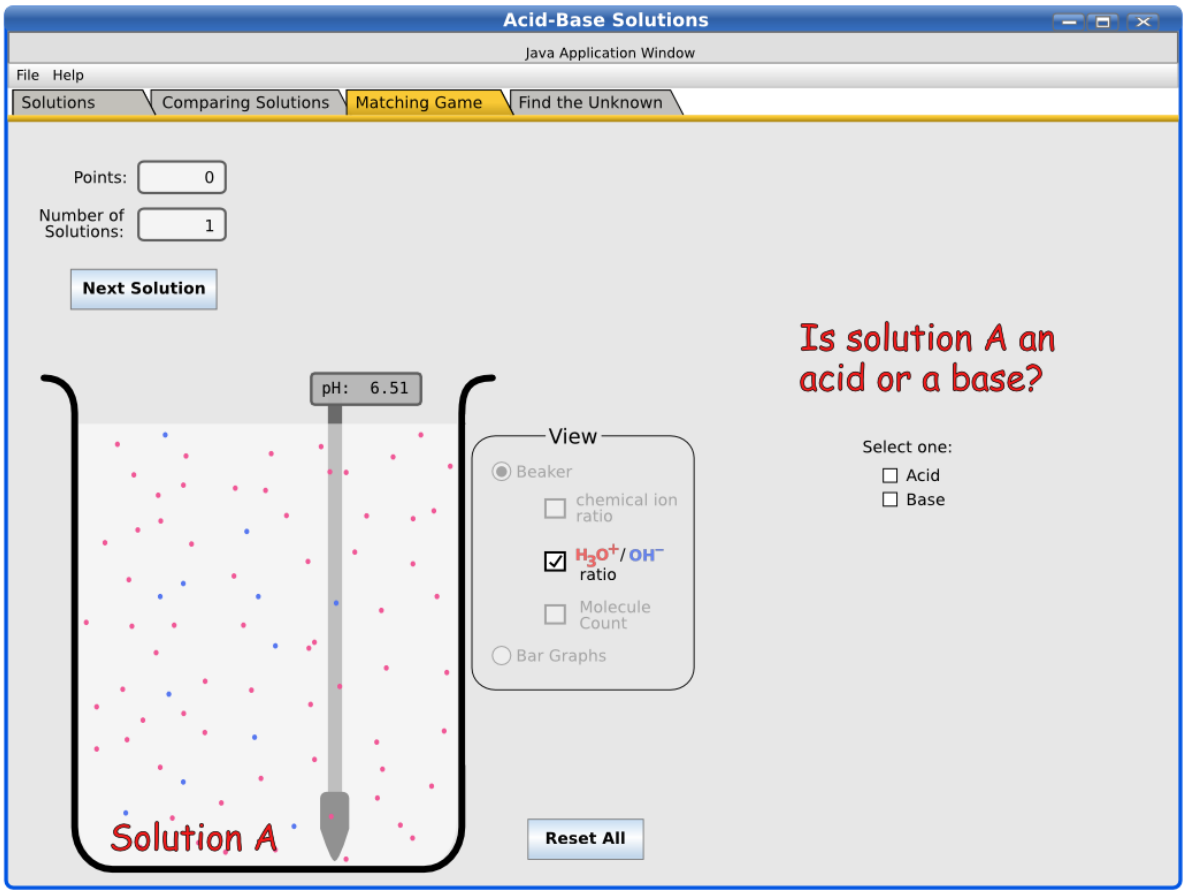
View Symbol Legend Window:



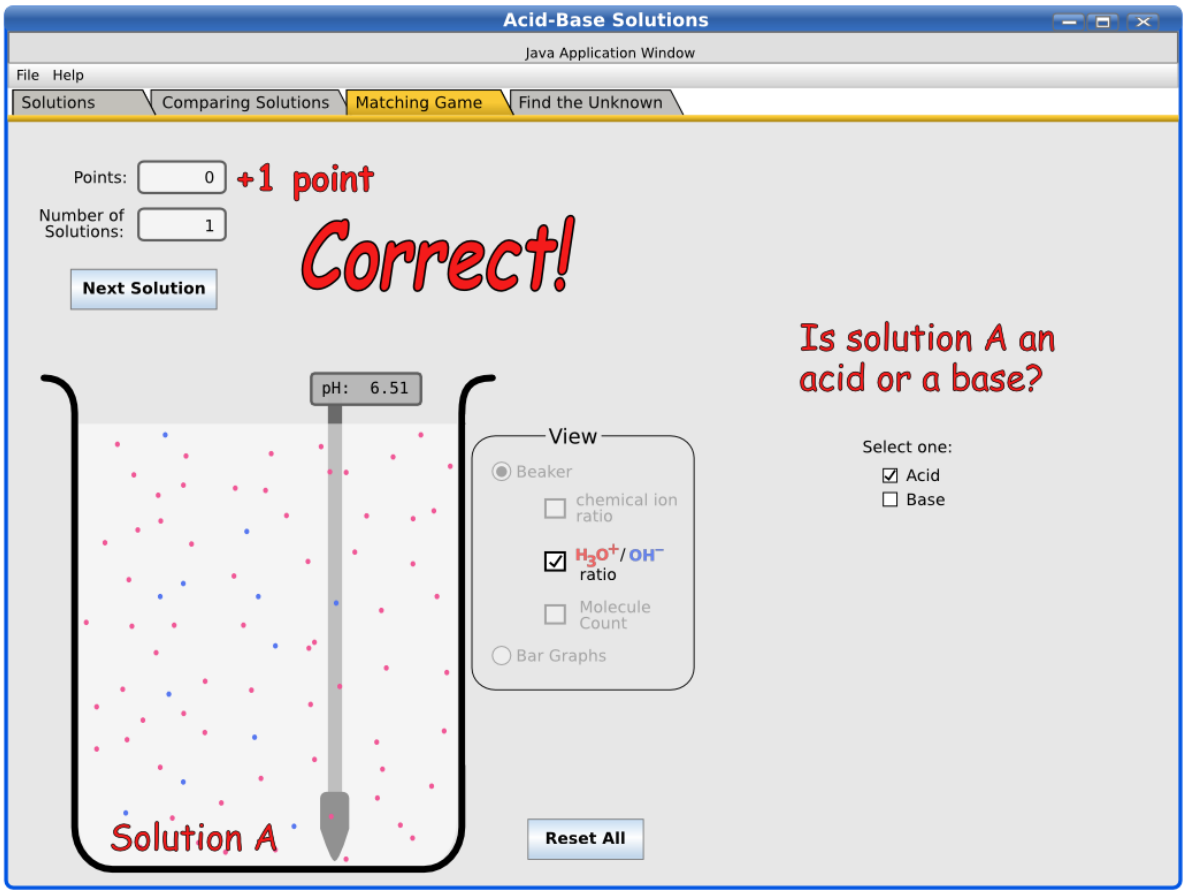
Second Tab ("Compare Solutions"):

Second Tab with "Bar Graphs" selected:

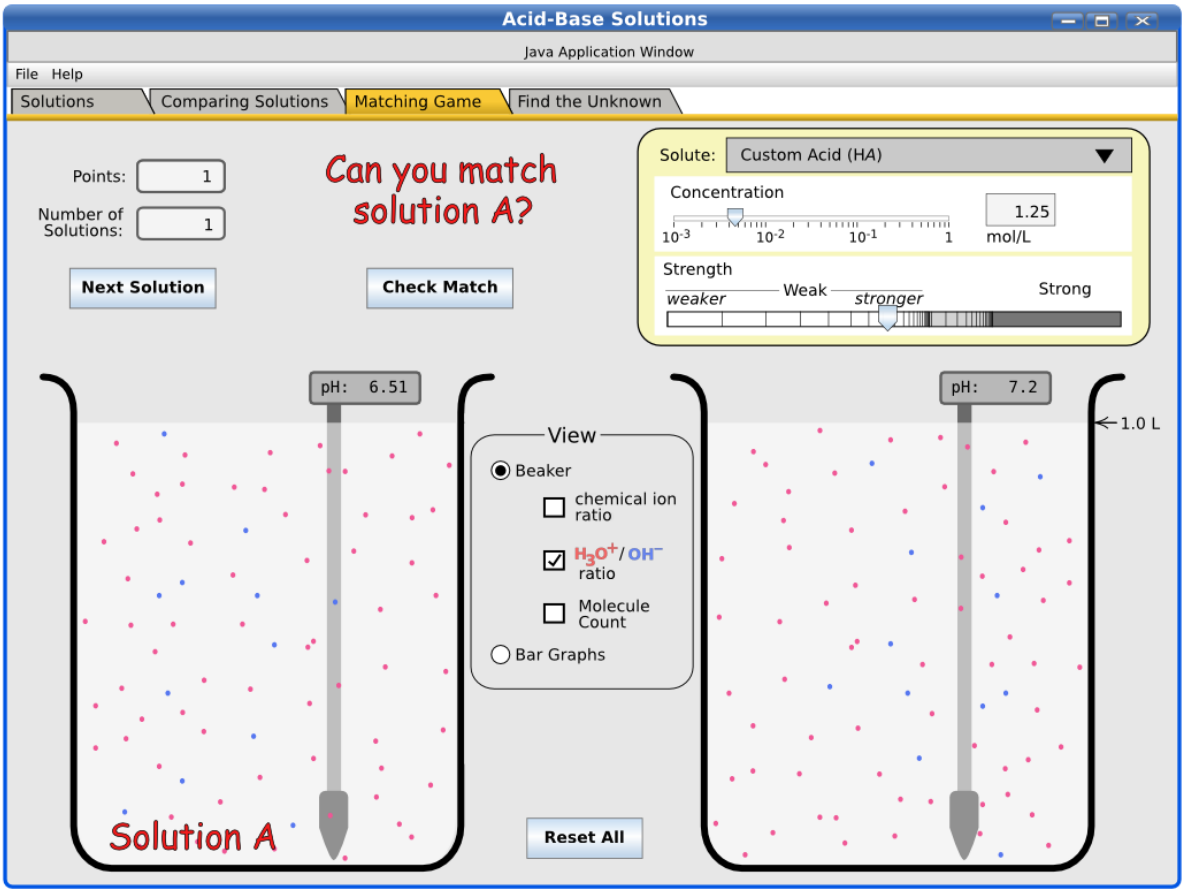
Third Tab ("Matching Game") initial state:



Third Tab after clicking "acid":



Third Tab after getting the first question correct:



List of common acids and bases

Acids:

HCl	Hydrochloric acid	Ka = 10^7 (Strong) HCl (aq) + H_2O (l) → H_3O^+ (aq) + Cl^- (aq)

$HClO_4$	Perchloric acid	Ka = 40 (Strong) $HClO_4\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + ClO_4^-\ (aq)$
$HClO_2$	Chlorous acid	$Ka = 1 \times 10^{-2}$ $HClO_2\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + ClO_2^-\ (aq)$
HClO	Hypochlorous acid	$Ka = 2.9 \times 10^{-8}$ $HClO\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + ClO^-\ (aq)$
HF	Hydrofluoric acid	$Ka = 6.8 \times 10^{-4}$ $HF\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + F^-\ (aq)$
CH_3COOH	Acetic acid (found in vinegar)	$Ka = 1.8 \times 10^{-5}$ $CH_3COOH\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + CH_3COO^-\ (aq$

Bases:

NaOH	Sodium hydroxide	$Kb = 10^7$ (Strong) $NaOH\ (aq) \rightarrow Na^+\ (aq) + OH^-\ (aq)$

NH_3	Ammonia (found in window cleaner)	$K_b = 1.8 \times 10^{-5}$ $NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$
C_5H_5N	Pyridine	$K_b = 1.7 \times 10^{-9}$ $C_5H_5N(aq) + H_2O(l) \leftrightarrow C_5H_5NH^+(aq) + OH^-(aq)$

Related Online Resources

- Animation showing differences between strong and weak bases: http://www.mhhe.com/physsci/chemistry/chang7/esp/folder_structure/ac/m2/s2/acm2s2_1.htm

Comments and Discussion

The following are comments and responses by the design team in chronological order (except for those organized within a thread). They have been archived here to document some of the reasoning and discussion behind the design decisions.

Kathy's comments (Dec 8, 2008)

1. I am thinking that it would be useful to import a few more things from pH scale ...
    - a readout for molecular counts (Archie says: done in design version 0.2.)
    - little icons representing the atoms / molecules. (Archie says: done in design version 0.2.)
    - ability to interact with HA (mol/L) on graph directly (Laurie says: I don't think this last point is necessarily important.)
2. Ability to vary the strength of the acid from weak to strong dynamically in addition to allowing selection of strong or weak acid or base (so having a slider that allows you to do this). (This dynamic interaction is usually pretty powerful for learning and relating the differences). - so for instance keeping the acid concentration the same, but varying its strength and seeing what that means in terms of the HA and A- concentrations.
    - (Archie) Now included in design version 0.2.
3. I think we might want to bring in the additional connection to the equilibruim equation that students use in class: HA(aq) + H_2O (arrows) $H_3O^+(aq) + A^-(aq)$ Ka=[H30+][A-]/[HA] So they can relate "strength" to these equations as well as to the visualization of what is in solution.
    - (Archie) An idea for this is shown in the mockup for design version 0.2.
    - Laurie says:
        - when dealing with strong acids, don't use equilibrium arrow. Just HA + H2O --> H3O+ + A-
        - It gets a little more complicated with strong bases as well. For the most part, the strong bases students will encounter in aqueous

solutions are metal hydroxides. So, NaOH, Mg(OH)2, KOH . . . The "generic" way of representing this would be either MOH --> M+ + OH- or M(OH)2 --> M2+ + 2OH-
        - If students select a particular acid or base solution from the drop-down menu, I think it would be useful to show the actual equation, so:
          HCl + H2O --> H3O+ + Cl-
          CH3COOH + H2O <--> H3O+ + CH3COO-
    - (Archie) included in version 0.3: "view reaction equations" window
4. Possible extension of this sim through the addition of a second panel which allows titrations/dilutions.
    - this would allow you to have a faucet of neutral water that you can add.
    - allow you to add small amounts of a acid or base
    - setting the mol/L of what you add, the qualitative strength of what you add, and to control pretty well the volume of what you add
    - this would add back in the ability to change the volume of the vessel [ie, the fluid]
    - (Trish) adding a titration panel seems like a big project and I wonder if it should be a separate sim.
    - (Laurie) Agree with Trish that titrations is a separate sim. Dilutions could be okay. I don't know if we'd want to do it "properly," that is, adding the concentrated acid to the water (instead of adding water to the acid--that's a real safety concern in lab. I know simulations aren't "real" but I'd hate to model unsafe lab practices anyway. There's a saying, "There she lies cold and placid, because she added water to the acid.") I think that for this sim, "diluting" using the existing slider is fine.
    - (Archie) These will not be implemented in this sim.
5. I could also envision a "find the unknown" game of sorts (different panel), where the teacher can make them do some calculations ...
    - e.g. find the pH if we plot up the concentrations.
    - or find the concentrations if they know the pH and the
    - (Laurie) I think this as a second panel would be good. One possibility is this: Pull-down menu has "Solution A," "Solution B," "Solution K" etc. Students can change concentration. But, essentially, they get a readout of pH, and bar graphs of concentrations of species (could also have the dot views). The first-level question is "Is it an acid or base?" Then, by using concentrations and dot views to see whether it's completely dissociated, they can answer the second-level question of "Is it weak or strong?" If it's strong, they could suggest an identify. If it's weak, they can then use the concentrations of species to calculate Ka or Kb and then identify the acid or base that way. Another possibility would be a "predict the pH" unknown game. Here, students would control the strength (Ka or Kb) and concentration, then predict the pH by performing calculations. They could then turn on the pH meter to check their answer.
    - (Archie) included in plans (version 0.3), but not completely designed yet
    - (Archie) design completed in version 0.5

Chris's comments (Dec 9, 2008)

1. Should the beaker have tick marks and labels, ala pH Scale?
    - (Archie) not necessary since solution volume cannot change
2. The "dot view radio buttons" should be placed near the beaker (as in pH Scale). Putting them below the graph gives the erroneous impression that these controls pertain to the graph.
    - (Archie) done in design version 0.2.

Laurie's comments (Dec 23, 2009)

1. Since many of the solutions we're dealing with are in an equilibrium state, would it be possible to have the dots moving in the beaker, and have a few change from HA to A- and vice versa? Since students can't change the volume of the liquid, the number of dots at a given concentration will remain constant, so I hope it's feasible to add motion.
    - Chris says:
        - implementation issues: requires adaptation of the ph-scale code, instead of direct reuse; requires a model for animating the movement of the dots, when to change from HA to A-, etc; may have an impact on performance (depending on number of dots, how much they're moving, efficiency of the animation algorithm, etc)
        - User-interface issues: possible confusion or incorrect conclusions when compared to the static presentation in ph Scale sim; controls may be less responsive depending on performance issues
        - None of these issues are particularly difficult, it's just more time (in the ballpark of 4-10 additional hours?). I'll be happy to try it, if that's what you want.
    - (Kathy) I understand why you want to show motion, but motion seems like it would significantly increase the complexity of the sim, and I am wondering if this is the right sim to try to address that learning goal? I think adding the motion in this panel may draw students attention away from the main connections that we are wanting them to make with this sim. We would NOT worry about collisions, just have the dots do a random walk sort of thing within the liquid as they do in salts and solubility.
    - (Laurie) I don't think we need to show motion. I'm thinking (like Kathy) that showing the dynamic, close-up process is another sim, and I'm thinking of ways that Salts and Solubility might be a useful template for that.
    - (Archie) we decided to not include any animation
2. I don't know how important it really is to constantly show the concentration of water.
    - (Trish) It seems to me that the water concentration doesn't need to appear, but I wasn't sure about higher level applications. I haven't been able to think of a reason for HS or lower grades to use it. In a recent ACS workshop, we were using the concentration of water in order to determine the entropy change for dissolving urea, but that has been the only time we have ever calculated it. The lab is one that I think few HS teachers would attempt, but I used it this year. I have not yet decided if it was worthwhile; I'll be interviewing a few students after break to see if they retained anything from the lab.
    - (Kathy) I am still thinking that it can be quite useful to have it there, because it reminds students that this is in water, and that water is still by far the dominant species. (So not a learning goal that asks them to calculate water concentration ... just much more basic than that.) Does it make the model problematic? I think we could definitely rearrange the *order* of the bars though. (No reason water should be first ... I'm thinking it should be to the far right, as it is in pH scale. And then HA and A- should be to the left - closer to the action.)
    - (Laurie) I do think we should include the H2O bar; it is the major component of all these solutions. Like Kathy's suggestion about putting it to the right of the graph. So maybe have HA; A-; H3O+; OH-; H2O
    - (Archie) done in version 0.5

3. The graph displays "equilibrium concentrations," not initial concentrations, so we may need to be more specific in our labeling. Or, we might think of how to show "initial concentrations" and/or "equilibrium concentrations."
    - (Kathy) I like the idea of changing the labeling to "equilibrium concentrations". The idea of adding "initial concentrations" is intriguing, but I'd worry about them leaving it set in that mode and then playing with other controls like concentration and strength and not seeing any change in pH, etc. and then just missing the fact that they have it set in initial concentrations?
    - (Archie) done in version 0.5
4. The pull-down menu should be organized so that "strong acids" is a subheader for all the strong acids, "weak acids" is a subheader for all the weak acids, etc. We don't actually say "strong acid" or "weak acid" anywhere, and this might trigger students to think about comparing various strong acids, various weak acids, and strong versus weak acids, or strong acids versus strong bases. But having the pull-down menu already organized like this gives them some language and makes them wonder, "what do they mean by strong acid or weak acid" and then to explore. ... We'll just use two specific strong bases (NaOH and KOH), so the generic symbol "MOH" won't appear to students.
    - (Archie) decided not to do this, after discussion with Laurie and Kathy. Instead the drop-down will list a generic strong acid and base, a custom weak acid and base, and alphabetically listed real chemicals.
5. It would be helpful to have a lower limit like 0.001 M, instead of zero. Otherwise, how close to zero are we getting? The scale (like all the other scales) will not be linear. Is it a problem to suggest it is by using equal interval tick marks? Perhaps we don't have tick marks? - (Laurie) I'm going to need to do a little research about a few particular acids. For instance, can we even have an 8 M solution of HCN?
    - (Kathy) We can certainly make the concentration slider logarithmic to accommodate the need for that - we need some indication of what the scale represents. Students will have the digital readout so can also see that. So a range of 0.001 to 8, with ticks at 0.001, 0.01, 0.1, and 1. But I think we do want them to be able to go to pure water as comparison, so maybe we just have a "Pure water" in the drop down menu?
    - (Archie) done in version 0.5
6. Make another tab basically what the current "Solutions" tab is now, with this major suggestion. Maybe we can call it "Comparing Solutions" and there are basically two identical panels that look like the current left-hand panel (with acid / base pull-down menu, concentration slider, and strength slider, and beaker view beneath). So where the bar graph is now, make that another panel with a pull-down menu, concentration slider, and strength slider, with the beaker view beneath. Make the default in both panels "water." Then students can select various acid and base combinations to compare in the two panels. So say a student wants to compare two strong acids. He chooses HNO3 on the left-hand side and HCl on the right-hand side. Maybe he then chooses to start with the same concentrations of each. He can now compare pH, percent dissociation, etc. of those two solutions. Or perhaps she wants to compare the same acid but at different concentrations. She can set each panel to the same acid and play with concentrations, being able to make direct comparisons in the two panels. Or compare a strong acid with a strong base at the same concentrations.
    - (Archie) "Comparing Solutions" added in version 0.5

Wendy's comments (Dec 30, 2008)

1. I would like to suggest a legend. I realize there is not room in the play area so maybe in a popup window? This might also be good for the pH sim. The only place we define OH- and H3O in that sim is via the abstract. I doubt most students even read that. This new sim has even more symbols with no words to attach to. When trying to write this up I found myself switching symbols around and using a where there should be a b. Words might be easier to hold onto until there's meaning for the symbols. Don't know for sure. But if no one is opposed to a legend in a separate window, I think that's a start.
    - (Chris) Probably best to add a button that displays the legend in it's own window. The alternative would be a menu item, but user's will likely never find it. Also keep in mind that this will result in more text for translators to deal with.
    - (Kathy) It sounds like you are suggesting that it is like the view reactions button, you can call it up if you need it. That sounds fine to me.
    - (Laurie) We could have a key, though, that says "HA" = generic weak acid and "A-" = what's left when HA dissociates in water. Maybe that would be okay.
    - (Archie) Legend included in version 0.5.
2. I think something should be different in this notation [HA and A-]. I'd suggest H? and ?- or some other symbol that you would not find in the periodic table.
    - (Kathy) My understanding of the design was that the "A" in HA and A- are going to read the actual compound in all places except for when you select custom acid, in which case it will switch to A to represent the generic acid. "HA" is pretty commonly used
    - (Wendy) I see now that it's common practice in chemistry to use HA or MOH basically mixing a chemical equation with abbreviations. I'm sure this leads to all sorts of misunderstandings with students. Is there a happy medium where we don't propagate the misconceptions but chemists are still comfortable? I certainly had no idea MOH meant metal hydroxide. I was convinced it was a typo. It's a struggle to get students to understand chemical formulas and I can't imagine how mixing in abbreviations can do anything but muddle this issue. Changing the Font on the abbreviations or something could certainly help with this or even putting in the word metal so you'd have metalOH. I know this makes it longer but it's sure more clear. How tied are chemists to using this sort of abbreviation? Is it part of the learning goals that students become familiar with these abbreviations or is this just something that chemistry books do but it's not an important outcome of the sim?
    - (Laurie) I'm keeping an eye on Wendy's concerns, and some of them, like using "MOH" shouldn't be an issue. I believe we'll just use two specific strong bases (NaOH and KOH), so the generic symbol "MOH" won't appear to students. In terms of using "HA," A-," "B" and "BH+" --these will only appear under custom weak acids or custom weak bases. It's the generic symbolism used by chemists, and the words that go with them would be more confusing than just using these symbols, I think. (We could say "weak acid" for "HA" and "conjugate weak base" for "A-" but you see how that will cause confusion since we're not doing conjugate weak acid/weak base pairs in this particular sim.) Wherever we have a specific chemical system, we will use those chemical symbols. We could have a key, though, that says "HA" = generic weak acid and "A-" = what's left when HA dissociates in water. Maybe that would be okay.
    - (Wendy) Is it acceptable to make the A italics or bold or even a different font from the H in HA? That would at least identify this as a different

creature from the rest of the symbols. Chris said a legend is possible and I think it'd be a great help in this sim.
    - (Archie) Learning goal concerning A & B symbols included in version 0.5. Symbols "A" "B" and "M" will be italicized.
3. Ka is not defined anywhere in the sim. It appears that the ratio of HCL/CL tells you something about the amount of Hydrogens that disassociated from the Chlorines. The Hydrogens make the Hydronium? But if that was completely true this ratio would just be 1 so some of the hydrogen in the hydroniums have to come from the water and leave some Hydroxide. I may have the science completely wrong (most likely I do) so someone, please straighten me out. I don't want ot make too many suggestions until I know the importance of these measurements.
    - (Kathy) Ka is [H30+][A-]/[HA] and represents the products/reactants of the reaction: HA --> H30+ + A- This tells you where the equilibrium of the reaction lies -- that is, do you have a lot of products or a lot of reactants. So if you have a lot of products compared to reactants, then the Ka is large and you can conclude that almost all of the HA you add will end up being dissociated (this is strong acid). So by looking at Ka, you can get a sense of how strong your acid is, how much will dissociate (so how much HA you can expect to still find in solution). Ka is not necessarily taught in middle school, so we didn't want it up as default, but for teachers who want to teach to it, this will give students a much better handle on the relationship between the *strength* of an acid and Ka.
    - (Archie) Ka is defined in the "View reaction equations" window (it's been there since Dec 18).
4. I have no theory at all as to why the label is "Custom Weak Acid" rather than "Custom Acid" and similarly there is "Custom Weak base" and not just Custom Base. I assume there's some limit with what the sim can demonstrate??
    - (Kathy) Laurie and Trish both felt it was quite problematic having a continuum between weak and strong, so this is what we came up with that they felt comfortable with. Perhaps they can elaborate more on the troubles with just one continuum.
5. I don't know why Strong Acid is (HA), Custom Weak Acid is also (HA), Strong Base is (MOH) and Custom Weak
   Base is (B). Really no guess at all.
    - (Kathy) Many strong acids have the same structure as weak acids (an HA). But most strong bases are a metal hydroxide (MOH) where as weak bases have a different structure (B) which then grabs a proton to make (BH). It is the OH in the MOH that comes off and makes it basic. I think if the sim was working and you saw that KOH and NaOH were all strong bases, you might have started to make sense of why MOH was used for a strong base with M representing K or Na.
6. I'm also confused by showing Hydrochloric Acid versus Chorine. How is this related or different from showing Hydronium and Hydroxide ratio? I vaguely remember this being a misconception? Students think pH tells you the strength of the acid but actually is a measure of how acidic or basic something is and the strength of the acid is more like concentration. But that can't be quite right since you have both an acid strength and acid concentration slider. From reading the learning goals I'm thinking the Acid or Base causes the water to dissociate into Hydronium and Hydroxide? That is the pH?? Many of these questions would be answered if I could play with the sim and see what happens to all these ratios. I'd like to be able to add Acid to water and watch what happens but that's titration right?
    - (Kathy) Looking at the A-/HA ratio tells you the strength of the acid (how much of it has dissociated). If you have a very small amount of acid, then the pH can still be close to neutral even if you have a strong acid. So as you

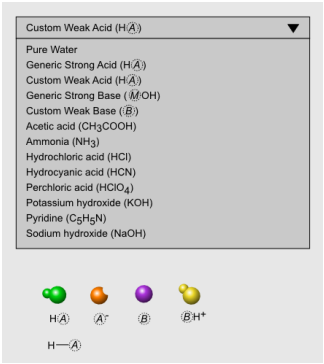
increase the concentration, you will then see the H3O+/OH- ration change and the pH change, even though you have the same acid (strong) and the A-/HA ratio isn't really changing (almost all A-). You are adding acid to water here, that is the concentration. The higher the concentration the higher the acid to water ratio. But this concentration is the amount of acid before it was added to the water (so that is the HA + A-). This is a subtle issue that is often not addressed in chemistry courses, but which you can teach to using the sim. Titration is when you have water, add some acid to make it acidic, and then titrate with some base to bring it back to neutral.

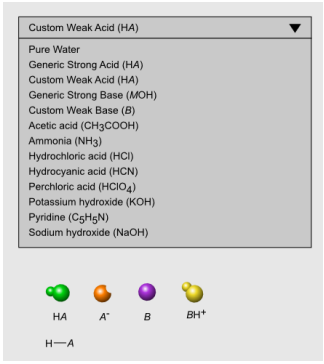
Will the symbols need to be translatable? (Jan 2009) (Answer: No)

- (Marj) Looks like we're fine. I've heard from Vietnamese, Russian, and Arabic. I think I may need to look for chinese contacts that aren't translators to get a specific answer for that language.
- (Marj to Jia Shi of the CU-SEI) Could you let me know how chemical formulas are written in Chinese? Are they written as we write them in English, for instance water as H2O? We're developing a new PhET sim and are trying to figure out if the chemical formulas will need to be translatable.
    - (Jia) I think this is not a concern. Chemical formulas are written in China as we write them, i.e. CO2 and H2O etc. Of course Chinese characters will be written under each formula as well.
- (Wendy) I just heard from the Hewlett Chinese translator and they use HCL so don't need to translate it!
    - (Chris) Not sure how to interpret this piece of news... Is this one more data point, or is it a decision that we don't need to translate chemical formulae?
    - (Wendy) It's a decision to not translate chemical formulas.
- (Archie) It appears that the symbol "Ka" should actually have a subscripted "a". Will this make for problems if people need to translate "K_a" into something else in another language?
    - (Chris) Subscripts and superscripts are implemented using HTML. In this case, the string would be "<html>K_a</html>". This makes translation more difficult for the translator, because he/she must know HTML syntax. But we require this in many other places, so it's nothing new.

Generic acid-base symbols "A", "B" and "M" (Jan 13 2009)

- (Archie) Kathy, Wendy, Noah and I talked today about a new way to help students with the "generic" acid and base symbols that we use in the sim. We now use "HA" for a generic acid and "B" for a generic base. We would like to try to distinguish these symbols from standard atomic symbols. The Olmsted and Williams Chemistry textbook appears to do this by italicizing the A or B. We also talked about using an additional mark such as a circle around the letter. I mocked up these two approaches, as they would appear in the drop-down menu, the bar chart labels, and a simple Lewis structure. (Chris says that graphics in the drop-down are not a problem.) Please take a look at the two images at the right (click them for larger images). I'd like to hear what you think of them, or if you have some other ideas





for making these symbols less confusing to those who are not fluent in the chemistry lingo.
- (Wendy) I really like the dotted line version. It is hard to notice a difference with the italics version.
- (Laurie) I'm okay with italicizing the "A" and the "B." I'm concerned that putting a circle around them conveys that they are single atoms, when they really just represent "the rest of the molecule."
- (Chris) The version that shows text with some italics is pretty easy, just use HTML to do the italics. Having to deal with HTML will some complication for the translators. The version with the dotted-circle-around-letters... no idea how I could do that. I guess the circled letters could be images, but there's no way I could make them flow so seamlessly with the text. Font sizes vary by platform, so plan on the text and image fonts not matching. And Java labels only provide the ability to put an icon next to text (not on top of text, or in the middle of text). If this is what Archie was asking me about, then I must retract my "not a problem" prognosis.
    - (Archie) I think the entire chemical symbol, circle and letters and all, would be a graphic (if we went that way). We've already determined that they do not need to be translatable.
- (Kathy) How about we try italics and then see what interviews show?
- (Archie) Ok, we're going with italics only for now (version 0.5).

Range of K_a for custom weak acids (Jan 14 2009)
- (Kathy & Archie) Wikipedia says that K_a values below 100 signify "weak acids". So to see the greatest amount of change in the various quantities for our custom weak acid, we should use a range of K_a that goes all the way up to 100.

Trish's comments (Jan 16)
- I think things are really shaping out nicely.
- I think questions about strength and concentration ranges will have to be answered after we seen the dot views.
- Laurie and I are going to get the revised goals into the design doc soon.

Chris's comments on design version 0.5 (Jan 19)
- Concentration slider. Java provides no support for placing tick marks at log intervals. So this will be a custom Piccolo slider.
- Symbol legend. Any reason why we're not using color here, to match with colors used elsewhere?
- (Archie) We should use colors here, once we settle on what the text should be.
- Unless I'm given specifics, I'll assume that anything with a color needs to be configurable via a developer control panel. Or should that control panel be visible to the user?
- (Archie) Yes, I think the colors should be configurable via a developer control panel.

Acid-base equations (Jan 19)
- (Chris) Changing the symbols sizes with concentration creates layout issues. Overlapping stuff as shown in the screenshots is (imho) a total mess -- it looks more like a programming error than an intentional user-interface design, I would be embarrassed to show this to someone. I don't think this solution is readable or usable. The alternative is to dynamically adjust the layout so that things don't overlap, but that will require the window size to shrink and grow (quite large, by the way). We have a design problem here. I'm willing to give it a try, but I hope someone has a "plan B".
- (Archie) After some discussion (though not everyone has weighed in), design folks seem more or less satisfied with the appearance in the mockup. It resembles the

behavior of the popular Ohm's Law flash sim. The equations will not be resizing by default -- you have to click the radio button, so they won't be ugly unless you've chosen it.

- (Chris) What do we do when the concentration of something goes to zero? Does the symbol disappear? That seems really odd, and again makes reading the equation awkward and confusing.
- (Archie) The present design just has them very small; this can be seen with the "HA" symbol for the strong acid in the mockup.
- (Chris) Outlines are shown around the symbol fonts (eg, for H2O, the font is light blue, with a dark blue border). These outlines are obviously important, so that the fonts show up on the background. But there is no support for this feature in Java. We can do drop shadows, but that's different (and much less readable) than outlined fonts. If you want this feature, it will be developed as a common code project.
- (Archie) The symbols do not need to be fonts. They can be images since they will not be translatable.
- (Chris) Rendering the equation on the right-hand side of "Ka =" is going to be time-consuming. Because of the font outlines and colors, I can't simply ask HTML to render this equation for me. I'll need to write custom code to create separate pieces, and then combine them. Not hard, just several hours of grunt work. I'm only bringing it up because it's probably not obvious that this is more expensive than other equations.
- (Archie) Again, these will be images, not fonts.

"Matching Game" (Jan 19)

- (Chris) I suggest putting the question/controls on the left, and the score on the right -- opposite what you have now.
    - (Archie) I would be concerned that the controls would no longer be near the adjustable beaker. Comparing with tab 2, each control box is above the beaker it controls. Or do you recommend swapping the two beakers, too?
- (Chris) I think the questions/controls box should have a consistent label, since the contents of the box changes (which in itself concerns me, but I'll roll with it.)
    - (Archie) What do you suggest for a box label?
- (Chris) The initial wiggle-me for instructions has issues. I probably won't be able to reuse our "help item" infrastructure, due to the arrow placements, arrow style, and i18n issues. Can this look more like a typical help item? I can certainly make the arrows look as show, but it will be custom code (or images).
    - (Archie) I think the wiggle-me instructions can be of the standard type (like a typical help item). (Edit, Jan 23) I have changed them to the standard type, I think.
    - (Wendy) The first rule of Wiggle-me's is that they should not be used until the sim fails in an interview. All other methods of interface design should be tried first.
        - (Archie) Ok. Can you suggest what we could do instead? Somehow the user needs to know the object of the game.
        - (Chris) Imho... The matching game is incomprehensible without instructions. It's a little confusing even with the instructions.
- (Chris) You show a fun-looking font for the instructions and "Correct"/"Wrong" indicators. We'd have to distribute a font with the sim, and believe me, we don't want to go there. Fonts are large, fonts have licenses, fonts are often locale-specific, they require common code support, build process support, translation-utility support, etc, etc, etc. Unless you want to tackle the font issue in general, please plan to use the standard PhET font used everywhere in this sim. And if

that's OK, please change the mockups quickly before someone changes their mind ;-)
    - (Archie) We should keep it simple, with standard fonts.
- (Chris) When do the "Correct" and "Wrong" indicators disappear? As soon as the user interacts with the sim again? Or after N seconds? Or...?
    - (Archie) After N seconds. Let's try N=2.

color of solution in beaker (Jan 20)

- (Chris) The design document doesn't say anything about changing the color of the solution in the beaker to match the selected acid/base. So I'm moving forward as if the solution is always the color of water, and using the same color for water that was used in the "pH scale" sim. If this is not correct, please let me know ASAP.
    - (Trish) I think that these solutions are generally the color of water. Laurie, would you agree?

Chris's additional questions (Jan 21-23)

- I see no H2O involved in the reactions for strong bases. But the reset of the document describes W (H2O concentration) as being constant throughout. Please explain.
    - (Trish) My understanding is that the H20 concentration will never change whether there is acid or base. Laurie, is that right?
    - (Laurie) When placed in water, acid molecules react with water molecules to form hydronium and the conjugate base (or ion). With weak acids, this doesn't occur to an extent to affect concentration of water. However, at high enough concentrations, strong acids, which completely ionize in water, actually do affect the total water concentration. If we're talking 5 M HCl in one liter, that's 5 moles of water molecules involved in HCl + H2O --> H3O+ + Cl-. The actual concentration of water will be more like 50.6 M, instead of 55.6 M for pure water. I have this worked out in the Excel model I sent out a few weeks ago. With strong bases, the salt that is the strong base (NaOH, or KOH) simply dissolves in the water; there isn't a reaction with water like with acids. So it's really just NaOH (s) --> Na+(aq) + OH-(aq). So concentration of water doesn't change in this case.
- When the solution is "Generic Strong Base": When this choice is selected, should the "B/BH+ ratio" check box change to "MOH/M+ ratio"?
    - (Laurie) Sure; MOH will be zero (no dots) and M+ will be whatever the concentration is.
    - (Chris) If MOH is always zero, that's going to make it problematic to calculate the number of M dots, because the MOH/M ratio will always be zero.
    - (Laurie) Perhaps it's not a calculation. Whenever a strong base is selected, MOH = 0, and [M[= [OH-] = concentration of MOH. It will be the same for strong acids. For a general strong acid HA, [HA] = 0, and [H3O+] = [A-] = original concentration of HA. We're not depicting the actual ratios anyway--can't for these differences in orders of magnitude. I guess I assumed we'd used the algorithm from pH scale to determine the number of dots that are displayed. So say a concentration of 1E-7 is 50 dots, etc. Knowing the concentrations, can we use the model from pH scale to specify numbers of dots for each species?
    - (Chris) Yes, should be able to reuse what was done in ph-scale. I'll have the same developer controls available so you can tweak.
    - (Kathy) Just to confirm ... as Laurie said we are not showing ratios ... each chemical [MOH] and [M+] will be represented by a different dot color, and

the number of dots for that color will be represented by the concentration of that chemical.

- Should the equation window show show MOH -> M + OH ?
  - (Trish) yes
- Do the H2O & H3O concentrations (bars and molecule counts) go to zero? I don't see this specified...
  - (Trish) H20 concentration will never change; the H30 should change according to Kw= H30*OH= 1E-14
  - (Laurie) For strong bases, the H2O shouldn't change. Then what Trish said: [H3O+] = 1E-14 / [OH-] This relationship will ALWAYS be true at 25 degrees Celsius. If you know [H3O+] you can know [OH-] and vice versa. (This was the model in the pH sim as well.)
- What is the purpose of *p* (percent ionization) in the model? Is it ever used or displayed to the user?
  - (Archie) No, it's not displayed. It has no use for us, as far as I can see.
- Are these equations correct? weak base, Kb = [BH+][OH-]/[B]; strong base, Kb = [M+][OH-]/[MOH]
  - (Trish) Weak is correct: weak base, Kb = [BH+][OH-]/[B] Kb or Ka for strong acids or bases don't really have any meaning because the reactant (denominator) would be zero. I see the format used for the strong acid in the equation pop-up uses Ka = [H][H3O+]/[HA] with a near zero dot for the magnitude of the acid HA, so I guess following that strong base, Kb = [M+][OH-]/[MOH] with a tiny dot for [MOH].

Pure Water (Jan 23-27)

- (Chris) When the solution is "Pure Water": What does the equation window show? What happens to the concentration & strength sliders? (grayed out? invisible?)
- (Trish) It seems to me that only the water should be shown, Laurie do you agree?
  - (Laurie) Yes; simply 2H2O(l) <--> H3O+(aq) + OH-(aq) I'd say we gray out the concentration slider, but show "Kw = 1E-14" where the strength slider is. It may be useful to see that water is a weaker acid than any of the other acids, and a weaker base than any of the other bases by listing its equilibrium constant value
- (Trish) The view controls should display H30/OH and the check box for molecule count.
  - (Kathy) I agree.
- (Trish) Molecule count should show only for water, hydronium and hydroxide.
  - (Kathy) I agree.
- (Trish) I think *p* stands for percent ionization, so *p*= [H3O+]/55.6*100 (the numerator could be [OH-] because the ions are equal in water or 1e-7). I don't know how many decimals we are planning to display.
- (Trish) The bar graphs should show only H2O, H3O and OH, but should continue to have space for 5 bars. This would help emphasize that other ions are not present in my opinion.
  - (Kathy) I agree ... size stays the same ... Others are just "zero".
  - (Archie) I think the other columns should disappear completely, not just read zero.
- (Trish) Reaction equations window: Maybe just display the water equation and Kw= [H30+][OH-]. I am wondering if the Ka should be directly under the acid or base reaction and if we should be also displaying Kw. Or should the K equations be in another window? Seems like another thing that might be best discussed with all the team present.
  - (Kathy) Do we want to bring up Kw? The reason I suggested having pure water was to allow students to see what it is like without an acid.

Monday's impromptu design meeting (Jan 26)

- Chris, Wendy, Trish and Archie present
- what to do when "Pure Water" is selected
    - concentration/strength sliders disappear
    - concentration/strength readouts
        - 55.56 appears in concentration readout
        - Kw=1e-14 appears in K readout
    - two bars gone (but box is the same size)
    - reaction equations lose one equation
    - view controls
        - H3O/OH ratio available
        - other dot-ratio not visible
        - molecule count has only H3O and OH and H2O
- new design for solution control box
    - should box have 'solution' title?
        - no: seems redunant with neighboring tab label
        - no: 'pure water' is not a solution, but is available from that control box
    - 'Acid Concentration' -> 'Solution Concentration'
    - strong/weak radio buttons
        - when 'strong' is selected
            - strength slider greys out
            - K = 'Large'
    - what happens with pure water
        - 'Solution Concentration' -> 'Concentration'
- buttons at lower-right should be check boxes
    - Chris says that's better for this function
    - bar charts move down and check boxes go above
- reaction equations
    - should be in two windows
    - 'reaction equations' (chemical <-> equations) should be one window and 'equilibrium expressions' (Ka and Kw) should be another
    - should show water Kw with Ka/Kb
- matching game tab
    - Wendy expressed concerns about the existence and design of the matching game
    - Trish said she liked it

Summary of suggestions from design meeting of Jan 29

- Kathy, Trish and Archie present (Chris's written concerns also addressed)
- new slider suggested with weak and strong on the same slider,
    - weak varies from $K=10^{-12}$ to $K=10^{2}$
    - weak continuum is separated by a "black out" region from the single "strong" value (which is undefined, but greater than the weak values)
- K display is removed from solution control box; moved to "view equilibrium expressions" window (see next item)
- "view reaction equations" split into two buttons (and their associated windows):
    - "view reaction equations" pops up a window the two equations with arrows
    - "view equilibrium expressions" pops up a window showing the K equation and value, and a K_W expression
- concentration slider goes from 10^{-3} to 1.0
- a new checkbox in the "view" control attached to the beaker called "label"

        - displays text on the beaker that looks like the label on a beaker in a chemistry lab
        - gives name of chemical and its concentration
        - for example, "Hydrochloric Acid (HCl), 0.1 molar" (if custom acid is selected, it will read "Custom Acid, 0.1 molar")
- order and names of options in solution drop down:
    - no solute (pure water)
    - custom acid
    - custom base
    - (all real chemicals, sorted alphabetically)
- remove HCN from chemical list
- "matching game"
    - initial state
        - no wiggle-me
        - right beaker invisible, replaced with the question "Is the solution an acid or base?", along with check boxes for an answer
        - -1 point if wrong, +1 point if correct
    - after first question is answered correctly, go to the "matching" state
        - remove middle step with "is it weak or strong" question
            - strong/weak option can be selected in the "matching" state
        - text reads "Can you match solution A?" near the "check match" button (left beaker is labelled "Solution A")
        - -1 point if it's incorrect when the "check match" is clicked, +5 if correct
        - if correct, go to a new chemical (in initial state) and increment "number of solutions" count

Strength Slider (Feb 8-11)

- (Archie) After our meeting last week, we considered a new strength slider design. It would involve a custom slider, but it would have the bonus of keeping the weak and strong values all on the same slider. This would offer (1) less control changing and (2) a visualization of the relationship of "strong" to "weak" values. See the mockup . I had to put some background color there (yellow) to separate the two slider controls. The idea is that if the slider is dragged into the (grey) "dead zone" and released there, then it will snap to the nearest white region. The setting for "Strong" has only one value (no sliding in that region).
- (Chris) I'm afraid that I really don't like this control. It's tempting to like it because it puts everything on one control. But I think there are a lot of semantic problems with it, and it's going to cause confusion and misinterpretations.
    - Putting all of these values on a slider implies that there is a continuous range. This is what sliders do, vary a value over a continuous range. That is not the case here; there is a range of values for weak, and strong is not part any range.
        - (Archie) There really is a continuous range (of K values). It's just that the strong values are much bigger and not precisely defined (it is infinite in some respects).
    - Students may try to assign some meaning to the grayed out region between weak and strong (I sure did when I first saw it). We keep trying to make an analogy between this problem and the "clock speed" slider in Optical Tweezers. But they are different problems. In Optical Tweezers, there really is a continuous range, our model just doesn't work for values in the "gray" part of the range, so we force the user to skip over those values. In Acid-Base, there is no range of values in the gray zone, you're using it as a *separator*, not an unsupported part of a range.

        - (Archie) I think there is meaning to those values: they are K values for which there exists no real chemical.
    - Imagine the student asking "What type of acid/base is in the grayed out region?" or "Why does the slider always snap to one value in the strong range?" How will you answer these questions?
        - (Archie) You could say "there is no chemical with those K values, so you can't select them."

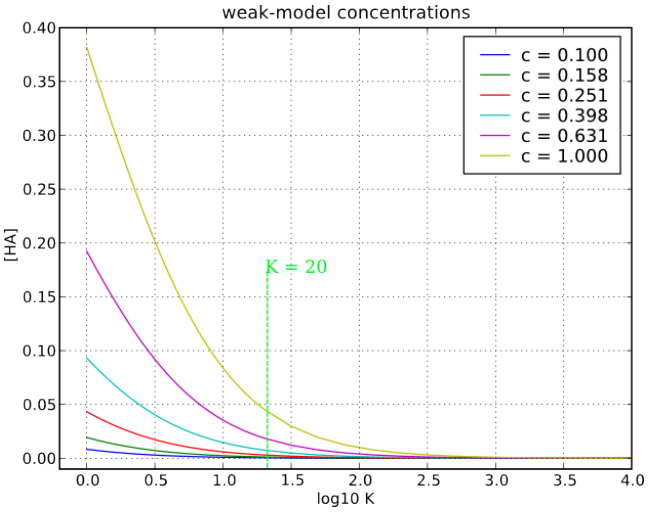
Design meeting (Feb 11)

- Kathy, Trish, Laurie, Chris and Archie present
- Values on pH meter and concentration bars should have two significant figures
- K_a values for the strong acids were provided by Laurie (from "Chemistry: The Practical Science" by Kelter, Mosher and Scott)
- Came up with a new slider design (similar to design of Feb 11, revision 1222)
    - allows the user to continuously change K from weak to strong for "custom" acids and bases
    - three regimes on slider:
        - weak ($10^{-10} < K < 1.0$)
        - undefined ($1.0 < K < 20$)
        - strong ($20 < K < 10^6$)
    - ratio of slider lengths in the three regimes are approximately 4:1:2
    - all real chemicals fall in either the strong or weak regimes
- Remove X on bar graphs (the button that minimizes them)
- (Laurie) Options in drop down could be be
    - no solute (pure water)
    - custom weak acid
        - stength slider is restricted to the weak region
    - custom strong acid
        - stength slider is restricted to the strong region
    - fully adjustable acid
        - no restrictions on the strength slider
    - (same three for bases)
    - (all real chemicals in alphabetical order)
- when pure water is selected, both concentration and strength sliders disappear, and concentration box reads 0.0
- Trish is working on improved learning goals

New concerns about the design (April 14 2009)

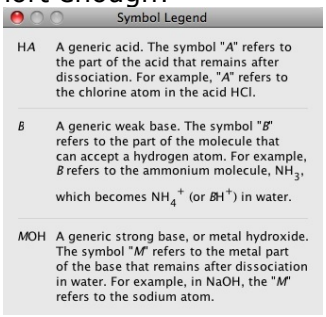
- (Chris) how do handle chemicals in the 'undefined' region of the strength slider?
    - We cannot interpolate since weak and strong chemicals have different models, different symbols (eg, MOH), and other non-continuous changes (such as the double-headed arrow becomnig a one-way arrow).
    - We should use the weak model in the intermediate range, and jump to the strong model above that.
    - (Chris) As I understand it the reason that we need this undefined region is due to a lack of consensus on the quantitative boundary between weak and strong. But if we're not showing the value of K, then isn't it OK to simply have weak and strong regions on the strength slider?
        - (Archie) K is being displayed in the 'equilibrium expressions' window
        - (Kathy) We want to represent continuum of conditions so that they see [A] decrease continuously as they change the strength.

- (Archie) Changing from the weak model (in the intermediate regime) to the strong model (in the strong regime) will yield discontinuities in some of the concentrations calculated, such as [HA], [A-], etc (see model equations). The plot at the right (click it for larger version) shows this effect. The plot shows what the weak-acid model predicts for the HA concentration ([HA]) as strength (K) is increased, for various solution concentrations (c, in the figure legend). The strong-acid model predicts that [HA] should be zero, which is the limit of all the [HA] curves shown; that's good. But the behavior will change abruptly when K moves from the intermediate to the strong regime at K=20 -- note that $\log_{10}(20)=1.3$, marked with the green line. So the worst discontinuity will happen for the highest solution concentration, c=1.0, in which case [HA] will abruptly jump from about 0.05 down to zero as the slider moves from the intermediate to the strong regime. Note that the other concentrations shown on the bar chart are simply related to [HA] -- see the model . Also note that the bar chart is logarithmic, so a sudden change from 0.05 to 0.0 will mean the sudden disappearance of a very large bar (see the first mockup). We may have to make a new model for the intermediate region to avoid this discontinuity.



    - (Kathy) We discussed interpolating the concentrations between the strong and weak regions, but using the same symbols and chemical equations used in the weak (since these still apply). I will edit the model above.
    - (Chris) I'm opposed to the suggestion of creating a new model for the "undefined" region. I am by no means an expert in this subject. But it seems to me that we're trying to demonstrate a continuity where none exists. In reality there is a discontinuity between weak and strong, and seeing that discontinuity is important to understanding the difference between weak and strong. For bases especially, the discontinuity is so large that we're talking about a different type of reaction. I realize that the power of sims is to show "magic" situations, but in this case I don't think applying such magic is relevant or beneficial.
- (Chris) How do you want the play area to behave when the acid-base main window is resized? Do you want everything to uniformly scale, similar to ph-scale?
    - (Archie) I think that plan is best (ie, everything to uniformly scale).
- long chemical symbols
    - Including long chemical symbols will be difficult. At the moment, you can see what the bar-chart labels and beaker-view box labels look like when Acetic Acid is selected. You can see that they have been made to angle to fit, and the view box is kind of ugly. But what should be done with lactic acid, whose symbol is about twice as long? (Acetic: CH3COOH, Lactic: CH3CH(OH)COOH). Our options are to (a) leave some large empty space to accommodate those few long names, (b) drop lactic acid (or find some abbreviation for it), and keep the current layout, (c) only use the generic symbols (HA, A-, etc) in places outside of the drop-down menu, (d) do some

sort of (difficult) dynamic sizing of all elements when a long chemical name needs to be shown.
    - (Laurie) I'm okay to drop lactic acid. I think it's important to use actual symbols for specific acids and their conjugate bases. Uses yet another short-hand symbol (like HLac or something like that will likely be even more confusing).
    - (Trish) One way to shorten the organic acid names is to use this notation: Acetic = HC2H3O2 and Lactic = HC3H5O3 . Is that short enough?
- Symbol Legend
    - The "Symbol Legend" shows only the meaning of HA, B, and MOH (ie, only the left-hand sides of the generic reaction equations). Are we happy with that, or do people want symbols like A- (and the like) there?
    - (Laurie) Perhaps we should include A- in the legend. Have to think more about whether to include BH+.
    - (Chris) Be aware that there will be some formatting issues with the HTML text. See the figure at the right for an example.



Kathy's review of the design (April 16-17)

- Kathy made a new model for the intermediate range of the strength slider. This has been included in the model design for version 0.7. She says that the intermediate region should be 30-50 pixels in length at the default window size.
- (Kathy) In comparing solutions tab, I think it is necessary to display species names regardless because you don't have the graph to match to.
    - (Archie) For consistency (and since we thought we might want it anyway), I put the species names in the default molecular count view for version 0.7.
- (Kathy, Trish & Archie) In the Feb 11 design meeting (see discussion above), Laurie suggested having the 'custom acid' in the drop-down menu be replaced by three options (custom strong, custom weak, and fully adjustable). We decided to stick with the single 'custom' option.
- (Kathy) There should be a space after the italics *B* and *M* in the symbol legend, considering the formatting issues that Chris described for that text (see "Symbol Legend" bullet above).
- (Kathy) Comparing Solutions tab
    - I think here we do need to include species names with molecular count for sure since don't have graph displayed at same time to refer to. (Archie: done.)
    - It would be nice to have some indication of which dots represented what ... for H3O+/OH- ratio could we use colored text for H3O+ and OH- to make that connection? I don't have any great ideas for connect dot color for the chemical ions, but perhaps you have ideas or think it is unncessary.
- (Kathy) Matching Game tab
    - Should these solutions be generated randomly for each user, or a set of pre-defined solutions? (Which would be better for teachers ... I can think of pros for each myself).
- (Kathy) Find the unknown tab
    - Trish - can you and Laurie critically review this tab and think about its value ... we have never done this quite at this level, so I'm wondering how much you'd use this as a teacher? Would students be able to just go "look up" the answer in the other tabs? I see value in making them decide what they need

to use to find the unknown, but I'm just wondering how you think this would playout in the classroom with real students (who are lazy)?

Trish and Laurie's meeting (April 24 2009)

- random chemicals in matching game (tab 3)?
  - (Kathy) In the Matching Game tab, should the solutions be generated randomly for each user, or a set of pre-defined solutions? Which would be better for teachers ... I can think of pros for each myself.
  - (Trish) I agree that there are advantages either way. Is there any research or could we propose a research?
  - (Archie) Since we don't know, we might as well stick with the original design (random).
- Lewis structures
  - (Archie) What should be done about the "simplified Lewis structures" that are shown in the reaction equations window when larger molecules are shown? For example, showing acetic acid there will probably not fit. And furthermore, some structures should probably not be represented this way (such as $N0_3$) due to their difficult interpretation.
  - (Trish) Laurie and Trish suggested that the Lewis structure would only be shown for the "custom" acid and base. There is still a problem about if the student choses "custom base" and then moves the slider to strong. What would be shown? The learning goal about Lewis structures is an advanced one and we may want to consider using Lewis structures in a future sim.
- Tab 4 (find the unknown)
  - (Kathy) Review Panel 4 and think about how teachers and students will use it .... I'm wondering if students will just seek out the answer by going back to 1st panel and matching to get answer? I like students having to decide what they need to know in order to calculate the unknowns, but can you elaborate on whether you see teachers using this panel a lot and benefits of it?
  - (Trish and Laurie) Laurie and Trish discussed producing clicker questions that could be used instead. We could put a link in the Teaching Tips doc.
- Learning goals
  - Concerning this goal: "calculate percent dissociation of an acid (or base) from their component concentrations."
  - (Trish) After the meeting on 4/10, we decided this could be left in, but that we would not display % dissociation on any of the panels. We could put something in the unknowns to help teachers.

New questions by Chris (April 27-29 2009)

- (Chris) The beaker view controls have a "Label" check box, described in the design doc like this:
  - "Label" check box; when checked, text appears on the beaker (like a label on a beaker on a shelf); text gives name of chemical and its concentration; eg: "Hydrochloric Acid, 0.02 molar"
  - Questions:
    - Can you provide an example of what you mean by "like a label on a beaker on a shelf" ?
      - (Archie) The example is just like the one given: "Hydrochloric Acid, 0.02 molar." Just use the name and concentration.
    - Where on the beaker should the label appear? Do you want to prevent overlap with Molecule Counts?

        - (Archie) It should not overlap the molecule counts. Anywhere on the beaker that doesn't overlap is fine.

Jack's Comments (June 11th 2009)

Kathy and Wendy asked me to look over the current version of the sim and comment on it, here are my findings.

The "Strong Acid" region of the strength slider.

- I am OK with when you are in Custom Acid that there is no change as you move across the "Strong Acid" range, I think that this nicely shows students that nothing happens and that the HA amount is negligible.
- However, I am not comfortable with the fact that when you select HCl and TL:HClO4 that the slider ends up in different positions within the Strong Acid area. I realize that in the design there were Strong Acid Ka values obtained from the Kelter text and that the slider position is based on these values. I could NOT find these values in any other General Chemistry text nor in the CRC manual. I reviewed 10 different texts (Kelter, Ebbing, Zumdahl, Brown/Lemay, McMurry/Fay, Kotz, Glibert/Kriss, Olmsted, Chang, and Tro) and the Kelter text was the ONLY one that had these values. In that text they dedicate exactly two sentences in the entire chapter to state that there is a strength difference between Strong Acids but that this difference is NOT observable in water.
    - Question 1: Because the sim only involves aqueous solutions, should we be showing a difference in acid strength for HCl and HClO4?
        - TL: I think Jack is right that it doesn't seem correct to show different values for the strong acids. It is also my understanding that the difference is only seen in situations that we are not using.
        - LL: I agree. If we worked with nonaqueous solvents, then we would be able to show a difference.
        - KP: I lean the other way on this issue since there IS a difference in strength between these acids and the sim is correctly showing that this IS NOT observable in water. But since you all agree on this point, I relent.
    - Question 2: If the answer to Q1 is NO, can we just default that Ka values for these two acids to the same arbitrary value?
        - TL: seems reasonable to me to pick the same value that we are using for " custom strong acid". KP: We don't have a "custom strong acid" .... choice would be based on if we change the range of Ka in the slider - then just choose something in the middle I think.
        - LL: Also, I then think we make that part of the slider much narrower than it is now.
        - KP: If we are going to show the same strength values for the two acids, then I agree the range could be narrower ... maybe 40% of what it is now. That will still allow a student to see that nothing changes in this region. (Chris, how much work is this?)

The Ka value for Hydrofluoric Acid (HF).

- This Ka appears with a variety of leading numbers (same exponent) in many different text books and resources.
- Current value in sim = 6.80 x 10-4
- CRC value = 3.52 x 10-4
- Range of text book values: 3.5-7.2 x 10-4
- Most common text values: 6.8 x 10-4 and 7.2 x 10-4
- **JB (6-11-09, 2pm): UPDATED VALUE From 2008-2009 CRC (Ka = 6.31 x 10-4)**
    - This value discrepancy will only be an issue if students are asked to do calculations and the sim number differs from the text value they are using.

    - May be easily cleared up with a note in the "Teaching Tips" document
        - TL: I think it will be important that we acknowledge that there are discrepencies in the references for chemical equilibrium values. I am not sure that all chem teachers are aware.
        - LL: I agree that a note in the "Teaching Tips" document would be a good place for this. Perhaps use HF as an example that a range of values can be found, depending on the source. Then provide the values that we used for the sim. This would allow students to use them in calculations.
    - Question 1: Should we report this to two decimal places if there is no solid number?
        - TL: I think 2 sig digits could be used, but it seems like we should be consistant thoughout the sim, not just for some things.
        - KP: Trish - are you talking about consistency between the concentration numbers and Kas? I think it is useful when you are in custom acid to be able to see small changes in the conc of HA - e.g. the diff in concentration of HA between 9.99e-1 and 9.98e-1 (Ka diff of about 4.6e-7 to 6.4e-7 at 1 mol/L) - so I would like to keep 2 decimal places on concentrations, but I am fine if Ka's are all just one decimal place - they all have 0 as their last value at the moment.

Symbol Legend Descriptions

- I am not comfortable with some of the wording in the legend, some of the terminology does not match what we teach students. My suggested changes are presented in RED below.
    - HA second sentence: "The symbol A refers to the conjugate base present in solution after dissociation"
        - TL: I agree that the description is not consistant with normal chemistry explanations, but we were hoping to provide an explanantion that described the process and to avoid "techno speak". This sim is designed to be an inquiry introduction to help students understand what is happening in the solution. Perhaps we could include the conventional terminology in the Tips?
        - KP: What do folks think of this: "HA is a generic acid. When an acid dissociates, a hydrogen ion separates from the rest of the molecule (*A*). For example ... "
    - HA third sentence: "For example, in HCl, A refers to the chlorine portion of the acid"
        - TL:I prefer "ion" (or "atom") over "portion" because I don't think "portion" provides a visual model for students.
        - KP: I like atom.
    - B second sentence: "The symbol B refers to the part of the molecule that can accept a hydrogen ion."
        - TL:I agree that "atom" is incorrect and we should use "ion"
    - MOH second sentence: "The symbol M refers to the metal part of the base present in solution after dissociation in water"
        - TL:Instead of "present in solution" would "remains in solution" be reasonable? KP: tL suggestion needs a "that" - e.g. "that remains in solution"
        - "The symbol M refers to the metal part of the base that remains in solution after dissociation in water"
    - MOH third sentence: "For example, in NaOH, the M refers to the sodium portion of the base"

        - TL:I prefer "ion" (or "atom") over "portion" bececause I don't think "portion" provides a visual model for students.

Problems with "comparing solutions" tab (Chris, June 15 2009):

- What does "Equations" refer to? Reaction Equations? Equilibrium Expressions? Both?
- Radio buttons imply that the Equations will replace the Beaker or Bar Graph. That's not going to work. The equations will not fit in play area, they are much larger than the allotted space. Shrinking them to fit will make them unreadable (see the equation for CH3COOH).
- If the equations are shown in the play area, do we still have the scaling feature and (if so) where do the on/off radio buttons appear?
- Is the "chemical ion ratio" check box intentionally labeled differently than what what we did in the the first tab?
    - (Chris) Never mind. Each beaker has different disassociated components.