Salts and Solubility Activities

I use this sim throughout the year in several units see the "Plans for Using PhET in Chemistry" page. Activities 4 and 5 are not listed in the plans, the activities are ones that I have used in Chemical Kinetics and Equilibrium Unit with advanced students.

Table of Contents

The activities can also be found in the PhET Teaching Ideas in Microsoft office format if you would like to edit them, go to:

Activity 1: http://phet.colorado.edu/en/contributions/view/2860

Activity 2: http://phet.colorado.edu/en/contributions/view/2859

Activity 3: http://phet.colorado.edu/en/contributions/view/2861

Activity 4: http://phet.colorado.edu/en/contributions/view/3132

Activity 5: http://phet.colorado.edu/en/contributions/view/2866

Clicker Questions: http://phet.colorado.edu/en/contributions/view/3111

The Salt and Solubility sim is also used in two Reactions and Rates Activities:

http://phet.colorado.edu/en/contributions/view/2984

http://phet.colorado.edu/en/contributions/view/3210

Plans for using PhET simulation activities in Loeblein's High School Chemistry

This is a list of lessons that can be found in the Teaching Ideas section of the PhET website

IC In Class Activity; **CQ** clicker questions; **HW** homework ; **Demo**: teacher centered group discussion

Introduction to Atoms, Molecules and Ions:

Build an Atom: IC/CQ
Salts & Solubility 1: IC/CQ
Isotopes: IC/CQ
States of Matter: demo/IC/CQ
Models of Hydrogen Atom: IC/Demo includes Neon lights and Discharge Lamps

Formulas, Composition, Measuring chemicals, Chemical Reactions, Stoichiometry

Reactions and Rates 1: Demo/IC/CQ
Balancing Chemical Reactions: IC/CQ
Reactants, Products, and Leftovers: 2 activities HW/CQ

Solutions

Salts & Solubility 2: IC/HW
Sugar and Salts: IC/HW/CQ
Molarity: IC/CQ
Concentration (activity still in draft)
Beer's Law (activity still in draft)

Gases

Gas Properties & Balloons and Buoyancy: Demo/IC/HW/CQ
Gas Properties – Gas Laws IC/HW/CQ

Thermochemistry Introduction

Reactions and Rates 2**:** IC/CQ

Atomic structure, Periodicity and General Bonding

Build an Atom: IC/CQ
Build a Molecule: IC or HW/CQ
Molecule Polarity: IC or HW /CQ
Molecular Shapes: IC or HW /CQ
Molecules and Light: IC
Greenhouse Gases: IC

Liquids and Solids

Density:IC/CQ
States of Matter and States of Matter Basics: IC/CQ
Atomic Interactions: Demo or HW (activity still in draft)

Chemical Kinetics and Equilibrium

Reaction and Rates 3: IC/CQ
Reaction and Rates 4 (also uses Salts & Solubility, States of Matter): IC/CQ

Acids, Bases and Electrolytes

pH Scale: IC/CQ
Acid Base Solutions: IC/CQ
Salts &Solubility 3: IC/CQ
Sugar and Salt Solutions Demo

Nuclear sims:

Beta Decay IC
Alpha Decay IC/CQ
Radioactive Dating Game IC/HW
Nuclear Fission IC (authored with Chasteen)
Rutherford: (activity still in draft)

Non-obvious controls:

- Be sure to try all the different tabs at the top of the simulation. The model increases in difficulty as you go from **Table Salt** to the right.
- You can **Pause** the sim and then use **Step** to incrementally analyze.
- If you are doing a lecture demonstration, set your screen resolution to 1024x768 so the simulation will fill the screen and be seen easily.

Important modeling notes / simplifications:

- Water is not shown to help the students focus on the ion dissociation and crystal formation.
- The models are all qualitative interpretations of the three dimensional world. The crystal structures vary and the ion sizes vary to help the students build the concept that there are variations in the natural world, but to keep the simulation easy for students to develop their ideas, the models are oversimplified. The ion sizes are not to scale because the particle model wouldn't be visible in a reasonable size container. It might be good to show students tables with the correct sizes.
- Notice that the volume is much smaller in the **Table Salt** tab because it is so much more soluble.
- To use the sim for problems where students are testing their predictions about what will happen relating Q&K, they will need to enter amounts in the ion **Total** space on the right.
- In the activity lesson plan by Trish Loeblein available from the **Teaching Ideas and Activities** link, there is a data table of results from multiple tests using the sim.

Insights into student use / thinking:

- Tl_2S has such a small solubility (8/4) that the number of dissolved particles varies significantly, so it would not be a good one to use for calculating K_{sp} (Solubility Product Constant). It is a good situation to talk about sample size.
- My students were asked to explain how they know that a solution is saturated. A common misconception was that if there are no changes occurring that the solution is saturated. This misconception meant that several students were doing calculations for solubility and K_{sp} when the solution was actually unsaturated
- My students did sometimes guess that the container size was being adjusted because the particles sizes were different; so I had to help them understand the simplifications mentioned in the modeling notes.

Suggestions for sim use:

- The simulations have been used successfully with homework, lectures, in-class activities, or lab activities. Use them for introduction to concepts, learning new concepts, reinforcement of concepts, as visual aids for interactive demonstrations, or with in-class clicker questions. To read more, see **Teaching Physics using PhET Simulations**
- Inquiry strategies take advantage of the simulation design. Invite the students to ***play*** with the simulation without any instruction. Use a ***guided inquiry*** approach to learning or ask ***concept questions***. For help with creating effective guided inquiry activities or questions, see: **Guidelines for Contributions** or **Concept Questions**
- For activities and lesson plans written by the PhET team and other teachers, see: **Teacher Ideas & Activities**

Lesson plan for *Soluble Salts* 1: Introduction to Salts-Understanding ionic formulas

http://phet.colorado.edu

Background: I teach a dual credit chemistry course using Chemistry 6th Edition Zumdahl Houghton Mifflin, NY, 2003 at Evergreen High School. The students in my class are taking their first high school chemistry course and receive credit for the first semester of college chemistry and the corresponding lab. I have written a series of five activities using the *Soluble Salts* simulation to be used throughout the year. This is the first in the series. I used this in first unit before Naming Compounds. *(Section 2.8 Zumdahl).* I found this activity helped students visualize compounds; many of them referred to the "colored balls" as they made sense of formula writing.

***Soluble Salts* Introduction:** I didn't need to show how to use the simulation, except to mention that when there are an abundance of particles that the processing can make equilibrium a long time to achieve or freeze our computers. Later, I'll discuss the role of water and why it is not seen in the simulation.

Helpful simulation notes:

- Tl_2S has such a small solubility (8/4) that the number of dissolved particles varies significantly so some students have trouble with it. I found it a good time to talk about why larger samples are helpful in science experiments.
- Notice that the volume is much smaller for NaCl.

Learning Goals: Students will be able to:

- Determine the chemical formula by observation of ionic ratios in solutions
- Relate the simulation scale to real lab equipment through illustration and calculations
- Predict the chemical formula of compounds with a variety of ion charge combinations

Before the activity:

1. Do the clicker questions 1-3. (I plan to use them again during mid-term test review days)
2. Have a 5 ml test tube and some salts. Open the sim and show what the "test tube" looks like in the sim. I had some baking soda and showed how what adding some in increments looks like.
3. Write KI on the board. Review how atoms become ions and how ionic charge enables the salt to bind together. Review the terms cation and anion. (Section 2.6) Review that metals form ions by losing electrons and nonmetals gain electrons (section 2.7). In this case K loses one and I gains one. The two combine to make a neutral substance. Go though the process for $MgCl_2$ too.

During the activity: Check the answers that students have for question 1 to make sure they are on the right track. When you research strontium phosphate, you get many different types of compounds because the common ones have hydrogen or $P_2O_7^{-2}$. It may be best to give the students $Sr_3(PO_4)_2$ at the appropriate time in the lesson. The students were not able to find Tl_2S either; the research points to minerals like $TlAsS_2$.

The compounds are: NaCl AgBr Tl_2S Ag_3AsO_4 CuI $HgBr_2$ $Sr_3(PO_4)_2$

Post activity:

Lesson plan for *Soluble Salts* 1: Introduction to Salts-Understanding ionic formulas
http://phet.colorado.edu

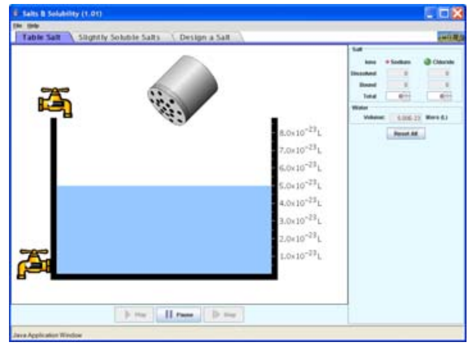
1. Use the Reflection handout to gather information about using the sim or the clicker question version (questions 4-8). I wanted to see what the kids drew the first two years, so I used the handout version. The clicker questions include misconceptions that I saw in my students' answers.
2. After the lecture using 2.8, have them draw microscopic models for lead (II) hydroxide versus lead (IV) hydroxide. Then, launch the sim to show the use of the roman numerals and discuss.

Visualizing ionic formulas using *Salts and Solubility* simulation from the PhET
Activity 1

Learning Goals Students will be able to:

- Determine the chemical formula by observation of ionic ratios in solutions
- Relate the simulation scale to real lab equipment through illustration and calculations
- Predict the chemical formula of compounds with a variety of ion charge combinations

Directions Open the *Salts and Solubility* simulation at http://phet.colorado.edu



1. Shake some salt out and note the ratio of the sodium to chloride.
   a. Write a formula for sodium chloride using the periodic table to find the elements' symbols.
   b. Check with the instructor to see if your answer makes sense.

2. Go to the *Slightly Soluble Salts* tab.
   a. Determine the formulas of the other six salts. Makeup a symbols for Arsenate and Phosphate, they aren't elements, so you won't find their symbols on the periodic table.
   b. Check a common ions table or use other resources to see what the charge of each ion is and explain why your formulas make sense.
   c. Use resources to find the formulas for the six compounds. Cite the sources. Correct any of your formula and explain the changes you had to make.

4. Look at the volume scale on the Table Salt tab and talk about what the container would look like.
   a. Draw a picture that shows how big the container is compared to a 5 ml test tube.
   b. Show a calculation to support your reasoning.
   c. How would your drawing change for the salts on the *Slightly Soluble Salts* tab?
   d. Why do you think the volume had to change? Explain why the volume change makes sense.

5. Use the *Design a Salt* tab to make models of a variety of ionic combinations. Make a table like the one below. Determine the formula for all possible compounds for ions with charge of -3 to +3; give evidence by drawing a picture of the salt as it is represented in the simulation; explain why the formula makes sense.

Cation charge	Anion charge	Formula C_xA_y	Drawing	Reasoning

Lesson Plans for *Salts and Solubility* 2*:* Introduction to solubility
http://phet.colorado.edu

Background: I teach a dual credit chemistry course using Chemistry 6^{th} Edition Zumdahl Houghton Mifflin, NY, 2003. The students in my class are taking their first high school chemistry course and receive credit for the first semester of college chemistry and credit for the corresponding lab. I have written a series of five activities using the *Soluble Salts* simulation to be used throughout the year. This is the second activity in the series. I plan to use this in the second unit as part of the Composition of Solution (section 4.3).

Soluble Salts **Introduction:** I didn't need to show how to use the simulation, except to mention that when there are an abundance of particles that the processing can make equilibrium a long time to achieve or freeze our computers. As part of this acitivity, I'll discuss the role of water and why it is not seen in the simulation.

Helpful simulation notes:

- Tl_2S has such a small solubility (8/4) that the number of dissolved particles varies significantly so it would not be a good one to use for calculating K_{sp}.
- Notice that the volume is much smaller for NaCl

Learning Goals: Students will be able to:

- Write the dissolving reaction for salts
- Describe a saturated solution microscopically and macroscopically with supporting illustrations
- Calculate solubility in grams/100ml
- Distinguish between soluble salts and slightly soluble salts macroscopically.

Before the activity:

1. Explain the hydration process. On page 135, there is a good picture. Project *Soluble Salts* and have a class discussion about why the water molecules are not included in the simulation.
2. On the board, demonstrate how the dissolving process is written as a balanced reaction. $HCl_{(s)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$ and $MgCl_2$. Emphasize that the ionic charge must be given for the aqueous ions.
3. Review how to change atoms to grams and L to ml.

During the activity:

In step 2: The students are asked to explain how they know that a solution is saturated to me. The first time I used the sim, a common misconception was that if there are no changes occurring that the solution is saturated. This misconception meant that several students were doing calculations for solubility and K_{sp} when the solution was actually unsaturated.

For step 3: To calculate the solubility, use the number of molecules of the dissolved ions in a saturated solution, then think about the stoichiometry to determine the number of molecules of the salt that dissociated. Then convert to molecules to moles, then moles to grams and divide by liters, then make a ratio to change the volume to 100ml. The order that students do the conversions doesn't matter. For example the calculation for NaCl (180 Na ions dissociate in

5E-23L) might look like: (180molecules/6.02E23molecules/mole)*(58.5grams/mole)/(5E-23L)*.1=35g/100ml

Post-lesson: use the clicker questions

Post activity class discussion questions:

1. Have the students read the final paragraph on p151 where the solubility rules are introduced. Talk about what is meant by soluble, slightly soluble and insoluble.

   The solubility rules in our text: Alkali metals salts, ammonium salts and nitrates are soluble. Halides are soluble except silver, mercury and lead. Sulfates are soluble except silver, mercury and lead and large alkali earth metals. All other salts are insoluble. (There are many versions of the rules; this is what we use).

2. Write the seven compounds in words used in the sim on the board and have the students use the solubility rules to predict which of the salts would be soluble based on the rules. (The compounds are: NaCl, AgBr, Tl_2S, Ag_3AsO_4, CuI, $HgBr_2$, $Sr_3(PO_4)_2$)

3. As a class, have a discussion that provides a "rule" to explain what "soluble" means in terms of g/ 100ml. *(Our book does not give a general rule for "soluble" in quantitative terms. The high school book that we use in regular chemistry class (Chemistry published by Merrill in 1994) has 3 g in 100ml.)* I expect them to be able to see that the magnitude of g/ml of the slightly soluble is quite small compared to that for NaCl.

Useful information:

Compound	K_{sp} expression (x is moles/l dissociated)	Molar mass	Common information			From sim	
			Solubility in moles/L	K_{sp}	Solubility in g/100ml	# Cations at saturation	# Anions at saturation
NaCl	x^2	58.5	6.0	36	35	180	180
AgBr	x^2	188	7.3E-7	5.3 E-13	1.4E-5	45	45
Tl_2S	$(2x)^2x$	441	5.3E-8	6 E-22	2.3E-6	8	4
Ag_3AsO_4	$(3x)^3x$	463	1.4E-6	1.0 E-22	6.4E-5	255	80
CuI	x^2	190	1.0E-6	1.1E-12	1.9E-6	64	64
$HgBr_2$	$x(2x)^2$	361	2.5E-7	6.2E-20	9E-6	16	32
$Sr_3(PO_4)_2$	$(3x)^3(2x)^2$	452.8	2.5E-7	1E-31	1.1E-5	45	30

Student Directions for *Slightly Soluble Salts* 2*:* Introduction to solubility
http://phet.colorado.edu

Learning Goals: Students will be able to:

- Write the dissolving reaction for salts
- Describe a saturated solution microscopically and macroscopically with supporting illustrations
- Calculate solubility in grams/100ml
- Distinguish between soluble salts and slightly soluble salts macroscopically.

1. Write the dissolving reaction for sodium chloride and predict what you should see when you add the salt to the water in the simulation.
   - Use *Slightly Soluble Salts* to test your ideas about the dissolving process.
   - Write a summary of how dissolving can be modeled and include illustrations.
   - Test your ideas with the other 6 salts in the simulations, and then write the dissolving reactions.

2. A general definition of a saturated solution is: A solution in which the maximum amount of substance has been dissolved in another substance.
   - If you were dissolving table salt in a beaker of water, what would a saturated solution look like?
   - Use the simulation to see what a saturated solution looks like on a microscopic level. Talk about how you know the solution is saturated and check with Ms. Loeblein to see if your reasoning is correct.
   - Write a description of a saturated **salt** solution microscopically and macroscopically, and support your ideas with drawings.

3. The ratio of the maximum amount of the substance per volume of solvent at saturation is the solubility. For example, the solubility of sugar is 203g/100ml of water at 20°C.
   - Design an experiment using *Slightly Soluble Salts* to determine the solubility in g/100ml that includes varying the water volume.
   - Use your design to find the solubility of the seven salts. Make a data table with results and show samples for the necessary calculations.
   - Which salt gave you the best data? Explain why you think the data is "best" and why you think that salt gave good results.
   - Which salt gave you the poorest data? What makes the results poor and explain why the results may be poor

4. Sodium chloride is considered soluble and the other salts are slightly soluble.
   - Draw a beaker with 100 ml of water. Then draw how much a **soluble salt** like sodium chloride would dissolve. Explain the reasoning you used to decide how much salt to draw.
   - Draw another beaker with 100 ml of water and draw how much a **slightly soluble salt** like silver bromide would dissolve. Explain the reasoning you used to decide how much salt to draw.

Lesson Plans for *Soluble Salts* 3*:* **Solution Equilibrium and K_{sp}**

http://phet.colorado.edu

Learning Goals: Students will be able to:

- Describe the equilibrium of a saturated solution macroscopically and microscopically with supporting illustrations.
- Write equilibrium expressions for salts dissolving
- Calculate K_{sp} from molecular modeling

Background: I teach a dual credit chemistry course using Chemistry 6th Edition Zumdahl Houghton Mifflin, NY, 2003. The students in my class are taking their first high school chemistry course and receive credit for the first semester of college chemistry and credit for the corresponding lab. I have written a series of five activities using the *Soluble Salts* simulation to be used throughout the year. This is the third in the series. I plan to use this during second semester as part of Equilibrium (section13.1-2). *Reversible Reactions* is used as part of the pre-activity lesson. *(06-07, I didn't use Reversible reactions)*

***Soluble Salts* Introduction:** This is the third time we will have used it, so I'll just mention that an abundance of salt may freeze the program.

Helpful simulation notes:

- Tl_2S has such a small solubility (8/4) that the number of dissolved particles varies significantly so it would not be a good one to use for calculating K_{sp}.
- Notice that the volume is much smaller for NaCl.

Pre-Activity:

1. Draw a beaker of water with a lid on it and discuss the liquid/vapor equilibrium. Give the definition of chemical equilibrium; the state where the concentrations of all reactants and products remain constant. Relate that to the liquid/gas equilibrium. (My students were introduced to equilibrium in physics and we often referred to a closed container of water.) Review microscopic vs macroscopic. Have the students draw the beaker of water and then add a magnifying lens to show the water molecules
2. Project *Reversible Reactions*, talk about how this could be the reaction and how the rate of the forward reaction was calculated in the prior unit. Then discuss the reversibility of reactions and what the reverse reaction rate would mean. Then explain that at equilibrium the rates are the same, but the amounts of reactants and products are not necessarily the same.
3. Introduce the equilibrium expression (p613)
   $aA + bB \leftrightarrow cC + dD \quad K=[A]^a[B]^b/[C]^c[D]^d$
   Explain that solids and pure liquids are not included in equilibrium expressions. Give a few examples of reactions with a variety of coefficients and number of products or reactants. Have the students practice as the reactions are presented.
4. Show a test tube of water and add some salt. Continue to add salt until there is some solid on the bottom. Shake to demonstrate that the solution is saturated. Review what saturated means and how to write the dissolving reactions for salts. Have the students practice with some salts that are not in the sim. (The compounds are: NaCl, AgBr, Tl_2S, Ag_3AsO_4, CuI, $HgBr_2$, $Sr_3(PO_4)_2$)
5. Review changing molecules/liter to moles/liter and practice a few.

Post Activity: There are some clicker questions.
05-06 We did a K_{sp} lab with $Ca(OH)_2$ using a serial dilution of Ca^{+2} and OH^- ions on our 90 minute block the same week. (Flinn AP Chem lab book, #13, p81). Then, we did activity 4.

Teaching note 06-07: We had done the sim activities 1 &2 very early in the year. When we got to activity 3, I did not have the students try to find their old data. The activity took 2 50 minute periods. We did a K_a lab in Flinn 14 instead of the K_{sp} one to try to help the students move from solubility to reaction equilibrium. I felt like we had K_{sp} ideas well developed.

Useful information:

Compound	K_{sp} expression (x is moles/l dissociated)	Molar mass	Common information			From sim	
			Solubility in moles/L	K_{sp}	Solubility in g/100ml	# Cations at saturation	# Anions at saturation
NaCl	x^2	58.5	6.0	36	35	180	180
AgBr	x^2	188	7.3E-7	5.3 E-13	1.4E-5	45	45
Tl_2S	$(2x)^2x$	441	5.3E-8	6 E-22	2.3E-6	8	4
Ag_3AsO_4	$(3x)^3x$	463	1.4E-6	1.0 E-22	6.4E-5	255	80
CuI	x^2	190	1.0E-6	1.1E-12	1.9E-5	135	135
$HgBr_2$	$x(2x)^2$	361	2.5E-7	6.2E-20	9E-6	16	32
$Sr_3(PO_4)_2$	$(3x)^3(2x)^2$	452.8	2.5E-7	1E-31	1.1E-5	45	30

Student Directions for *Soluble Salts* 3*:* **Solution Equilibrium and K_{sp}**
http://phet.colorado.edu

Launch *Soluble Salts* and start a Word document to write a lab report.

Learning Goals: Students will be able to:

- Describe the equilibrium of a saturated solution macroscopically and microscopically with supporting illustrations.
- Write equilibrium expressions for salts dissolving
- Calculate K_{sp} from molecular modeling.

1. Observe what happens as you add one shaker of salt to the water. Talk about your observations and then investigate salts dissolving in water further. When you feel like you understand what equilibrium means for a salt dissolving in water, write an introduction for your lab report that explains your understanding of equilibrium. Illustrate your introduction with "test tube" size drawings and "close-up" views to show the ions and crystals. Some things to think about are:
   a. In general terms, what the reactant is and what the products are when you put a salt in water.
   b. What would a test tube of the salt/water equilibrium look like?
   c. What is happening on a molecular scale when equilibrium is established?
   d. How does the speed at which you add the salt effect the equilibrium?
   e. How does the volume of water or amount of salt added affect the equilibrium?

2. Design experiments to determine the value of the constant for each salt include the effect of varying volume.
   a. Write your procedure
   b. Show sample calculations.
   c. Make a data table for each salt that demonstrates good experimental design.
   d. Write the equilibrium expressions for each salt with the determined constant.

3. Write a conclusion for your experiment that includes addressing these questions.
   a. Which salt gave you the best data? Explain your reasoning.
   b. Which salt gave you the poorest data? Explain your reasoning.
   c. How do your values compare to the published ones? Cite your references.
   d. How do the solubility rules relate to the Ksp values that you determined?
   e. How could you use K_{sp} values to predict solubility?

Lesson Plans for *Slightly Soluble Salts* 4*:* **Using Q and LeChatelier's Principle**

phet.colorado.edu

Learning Goals: Students will be able to:

- Calculate Q.
- Predict what would be observed on a macroscopic level to a solution by comparing Q to K_{sp}.
- Use microscopic illustrations, to help explain the predictions.
- Use LeChatelier's Principle to predict how changing the amount of water will affect the solution.

Background: I teach a dual credit chemistry course using Chemistry 6th Edition Zumdahl Houghton Mifflin, NY, 2003. The students in my class are taking their first high school chemistry course and receive credit for the first semester of college chemistry and credit for the corresponding lab. I have written a series of five activities using the *Soluble Salts* simulation to be used throughout the year. This is the fourth in the series. I plan to use this during second semester as part of Equilibrium and predicting system changes by calculating Q and using LeChatlier's principle (section13.5-6,& 15.6). This will immediately follow activity 3.

Pre-activity:

We will have just finished activity three, so I should be able to go into this one with little introduction.

Have a test tube with water and some baking soda. Put a little in and shake. Start over and put a large amount in. Relate Q and K using $NaHCO_3$ (mm=84) equation. Solubility is 10.3 g/100ml or K_{sp} = 1.5 (ignoring the acid/base equilibrium).

Demonstrate temperature effects on the $NO_2 \leftrightarrow N_2O_4$ equilibrium (I have a closed container of it that I can put in hot or cold water for this purpose). Talk about how temperature would affect a solution of baking soda.

Post-activity: There are some clicker questions.

Discuss how temperature affects the equilibrium and make sure that students realize that K_{sp} is temperature dependant.

Helpful simulation notes:

- Tl_2S has such a small solubility (8/4) that the number of dissolved particles varies significantly so it would not be a good one to use for calculating K_{sp}.
- Notice that the volume is much smaller for NaCl.
- Need to enter amounts in the ion total spot to use the sim for Q=K, Q > K and Q < K

Useful information:

Compound	K_{sp} expression (x is moles/l dissociated)	Molar mass	Common information			From sim	
			Solubility in moles/L	K_{sp}	Solubility in g/100ml	# Cations at saturation	# Anions at saturation
NaCl	x^2	58.5	6.0	36	35	180	180
AgBr	x^2	188	7.3E-7	5.3 E-13	1.4E-5	45	45
Tl_2S	$(2x)^2x$	441	5.3E-8	6 E-22	2.3E-6	8	4
Ag_3AsO_4	$(3x)^3x$	463	1.4E-6	1.0 E-22	6.4E-5	255	80
CuI	x^2	190	1.0E-6	1.1E-12	1.9E-5	64	64
$HgBr_2$	$x(2x)^2$	361	2.5E-7	6.2E-20	9E-6	16	32
$Sr_3(PO_4)_2$	$(3x)^3(2x)^2$	452.8	2.5E-7	1E-31	1.1E-5	45	30

Student Directions for *Slightly Soluble Salts* 4: **Using Q and LeChatelier's Principle**

Learning Goals: Students will be able to:

- Calculate Q.
- Predict what would be observed on a macroscopic level to a solution by comparing Q to K_{sp}.
- Use microscopic illustrations, to help explain the predictions.
- Use LeChatelier's Principle to predict how changing the amount of water will affect the solution.

1. Start by getting out your lab report from **Solution Equilibrium (Soluble Salts activity 3)**. Look at your data table to find out how many Strontium and Phosphate ions can be dissolved in $1x10^{-16}$liters of water. Predict what would happen if you started with $1x10^{-16}$liters of water and shook in 150 Strontium and 100 Phosphate.

   a. Test your idea and explain your results.

   b. Calculate the value of Q for 150 Strontium and 100 Phosphate; show your work.

   c. Summarize how comparing the values for Q and Ksp can help predict what will happen when you put salts in water. Illustrate your summary with "test tube" size drawings and "close-up" views to show the ions and crystals.

2. Look at your data table in the **Solution Equilibrium lab** to find out how many Sodium and Chloride ions can be dissolved in $5x10^{-23}$liters of water.

   a. Predict how many sodium and chloride ions would give a solution that looks similar to the one you made in #1. Explain how you chose your numbers.

   b. Test your prediction and describe your results. Try different combinations to test your understanding.

   c. Calculate Q for two trials; show your work. How do the values compare to the K_{sp} for sodium chloride?

   d. Would you describe this solution as saturated or unsaturated? What ion numbers would give you a solution that would give you a different answer? Explain your reasoning and support your answer with at least one calculation of Q.

   e. Reread the summary you wrote to 1c. Check your reasoning, then make changes or add to your summary as necessary.

3. Write LeChatelier's Principle in your own words.

   a. If you had a saturated solution, what should happen if you add water? Explain your reasoning using LeChatelier's Principle and then test your ideas using the simulation.

   b. Predict how your answer would change for an unsaturated solution and then test your ideas.

   c. Test to see how letting out water affect saturated and unsaturated solutions.

   d. Explain using LeChatelier's Principle what happens to saturated and unsaturated solutions when the amount of water is varied. Illustrate your explanations with "test tube" size drawings and "close-up" views to show the ions and crystals.

Lesson Plans for *Soluble Salts* 5*:* **Designer salts**
phet.colorado.edu

Learning Goal: Students will be able to predict what would be observed on a macroscopic and microscopic level for salts with varying ionic charge given the K_{sp}.

Background: I teach a dual credit chemistry course using Chemistry 6th Edition Zumdahl Houghton Mifflin, NY, 2003. The students in my class are taking their first high school chemistry course and receive credit for the first semester of college chemistry and credit for the corresponding lab. I have written a series of five activities using the *Soluble Salts* simulation to be used throughout the year. This is the fifth in the series. I plan to use this as a follow up soon after Activity 4. There is not a section that addresses this directly in our text. *I think some of the value of this activity is for the students to think about power relationships in an application.*

Helpful simulation notes: The ions can vary in charge from -3 to +3. The K_{sp} varies from 1 to 10^{-40}. The simulation assumes that the particles have the same mass.

Post-activity: There are some clicker questions
Do practice problems given Ksp and ionic charge. Solve for molarity of ions and have the students make drawings to illustrate the dissolving. I'll make up specific problems and include solutions later.

Student Directions for *Soluble Salts* 5*:* **Designer salts**
phet.colorado.edu

Learning Goal: Students will be able to predict what would be observed on a macroscopic and microscopic level for salts with varying ionic charge given the K_{sp}.

1. If KCl and $MgCl_2$ had the same K_{sp}, how do you think the dissolved ions would compare? Address the following questions and explain your reasoning:
   a. Which do you think will have more ions in solution?
   b. How do you think the number of chloride ions would compare?
   c. How would the number of dissolved K^+ ions compare to the number Mg^{+2} ions?

2. Use the *Designer Salts* tab in ***Soluble Salts*** to investigate how KCl and $MgCl_2$ would compare.
   a. Describe how you used the simulation to test your ideas.
   b. Record your data and show that the K_{sp} values are the same.
   c. Read your predictions and reasoning for question 1 and make notes about things that you would change.

3. Predict how the dissolved ions of KCl and K_2O would compare if the salts had the same K_{sp}. Include your reasoning for all ions, positive and negative ions.

4. Use the *Designer Salts* tab in ***Soluble Salts*** to investigate how KCl and K_2O would compare.
   a. Describe how you used the simulation to test your ideas.
   b. Record your data and show that the K_{sp} values are the same.
   c. Read your predictions and reasoning for question 3 and make notes about things that you would change.

5. Predict how the dissolved ions of KCl and MgO would compare if they had the same K_{sp}. Include your reasoning for all ions, positive and negative ions.

6. Use the *Designer Salts* tab in ***Soluble Salts*** to investigate how KCl and MgO would compare.
   a. Describe how you used the simulation to test your ideas.
   b. Record your data and show that the K_{sp} values are the same.
   c. Read your predictions and reasoning for question 5 and make notes about things that you would change.

7. Look at the three sets of salts that I asked you to compare. What do you think I was designing the lab to investigate? Propose other questions that would help continue the study. Show me your questions.

8. After your questions have been approved, organize a procedure to continue the study. Then run tests, make a data table to summarize your study, and write a discussion that demonstrates that you can meet the learning goal.

Salts and Solubility

Clicker questions for 5 actvitites

Each set of clicker questions and the activity can be downloaded from the Teaching Ideas database at PhET

by Trish Loeblein updated July 2008

Salts and Solubility Activity1

Learning Goals Students will be able to:

- •Determine the chemical formula by observation of ionic ratios in solutions
- •Relate the simulation scale to real lab equipment through illustration and calculations
- •Predict the chemical formula of compounds with a variety of ion charge combinations

Trish Loeblein July 2008 Questions 1-3 are a pretest. 4-8 are reflective

1. Which is the formula for the compound made from M^{+1} and N^{-2}

   A. MN_2

   B. $M_2 N$

   C. MN

   D. $M_2 N_2$

2. Which is the formula for the compound made from M^{+3} and N^{-1}

   A. MN_3

   B. $M_3 N$

   C. MN

   D. $M_3 N_3$

3. Which is the formula for the compound made from M^{+3} and N^{-2}

   A. MN

   B. $M_3 N_2$

   C. $M_2 N_3$

   D. $M_6 N_6$

4. I thought this lab was _________ USEFUL for learning about ionic formulas.

   A. very

   B. mostly

   C. barely

   D. not

5. I thought this lab was __________ ENJOYABLE for learning about ionic formulas.

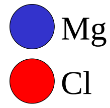
A. very

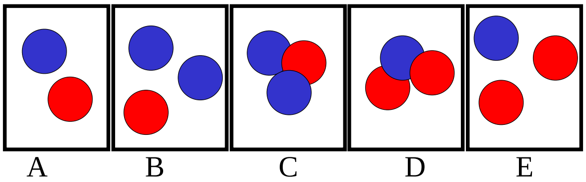
B. mostly

C. barely

D. not

6. Which is the best drawing for Magnesium chloride in a water solution?

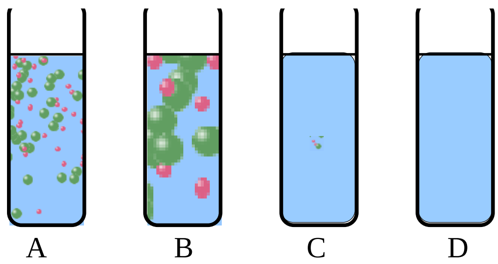




7. How would the drawing change if Magnesium chloride were changed to Magnesium oxide?

A. The ratio of the ions would be the same
B. The ratio would change to 1 magnesium for every oxide
C. The ratio would change to 2 magnesium for every oxide
D. You would have to use different colors

8. Which drawing best represents how large ions should be drawn in a 5 ml test tube of water?



Salts and Solubility Activity 2

Learning Goals: Students will be able to:

- Write the dissolving reaction for salts
- Describe a saturated solution microscopically and macroscopically with supporting illustrations
- Calculate solubility in grams/100ml
- Distinguish between soluble salts and slightly soluble salts macroscopically.

Trish Loeblein July 2008

1. Which is correct for dissolving barium iodide in water ?

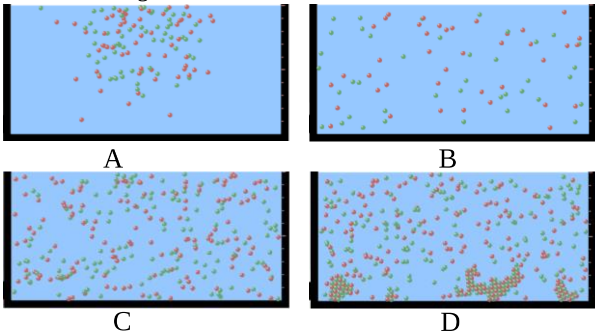
A. $BaI_{2(s)} \rightarrow Ba_{(aq)} + 2I_{(aq)}$

B. $BaI_{(s)} \rightarrow Ba_{(aq)} + I_{(aq)}$

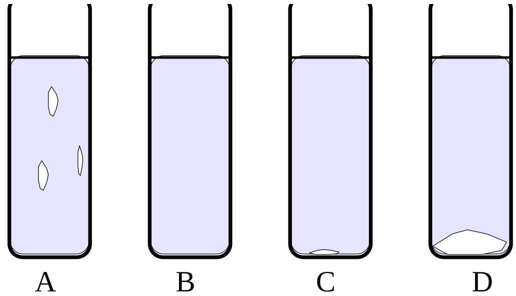
C. $BaI_{2(s)} \rightarrow Ba^{+2}_{(aq)} + 2I^{-}_{(aq)}$

D. $BaI_2 \rightarrow Ba^{+2} + 2I^{-}$

2. Sue used *Salts* to learn about “saturated solution”. Which image best shows a saturated solution?



3. Waldo added salt to a test tube of water to learn about “saturated solution”. Which image best shows a saturated solution?



4. If you used the sim to test silver chloride, you would see 80 Ag^{+} ions dissolved in 1E-17 liters. What is the solubility in 100 ml of water?

A. .0019 grams/100 ml water

B. .00019 grams/100 ml water

C. .0024 grams/100 ml water

D. .00024 grams/100 ml water

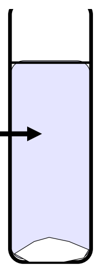
The calculation for AgCl example:

80 AgCl /6.02E23 AgCl/mole) *(178.8grams/mole)
= 2.4E –20 grams

2.4E –20 grams/(1E-17L) = .0024 grams/L

.0024 grams/L* .1L/100ml=.00024 g/100ml

5. You knew a salt was either sodium chloride or silver chloride.
If you put **1** gram in 10 ml of water in a test tube, and it looked like this →



Which is it?

A. Sodium chloride

B. Silver Chloride

C. This is not an identifying test

6. How a drawing for Magnesium oxide be different from Magnesium chloride?

A. The ratio would be the same, <u>but</u> the balls would be connected
B. The ratio would change to 1 magnesium for every oxide <u>and</u> balls would be separate
C. The ratio would change to 1 magnesium for every oxide <u>and</u> balls connected
D. The ratio would change to 2 magnesium for every oxide <u>and</u> balls connected

Salts and Solubility Activity 3

Solution Equilibrium and K_{sp}

Learning Goals: Students will be able to:

- Describe the equilibrium of a saturated solution macroscopically and microscopically with supporting illustrations. (not covered in these questions)
- Write equilibrium expressions for salts dissolving
- Calculate K_{sp} from molecular modeling.

Trish Loeblein updated July 2008

I simplified the reactions by omitting (aq), my students have found this helpful and they know that they must put it on tests.

---

1. Table salt dissolves in water: $NaCl(s) \rightleftharpoons Na^+ + Cl^-$

What is the correct K_{sp} expression if s is the molar solubility Sodium chloride?

a. $K_{sp} = s^2$
b. $K_{sp} = 2s^2$
c. $K_{sp} = s^5$
d. $K_{sp} = 4s^4$

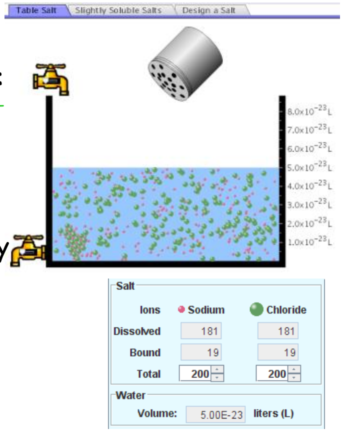


Table salt dissolves in water: $NaCl(s) \rightleftharpoons Na^+ + Cl^-$

$K_{sp} = [Na^+] [Cl^-]$

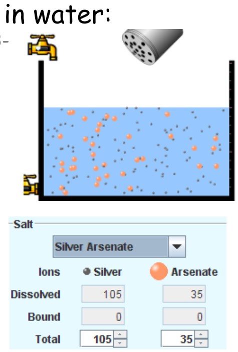
For every NaCl molecule that dissolves there was one Na^+ and one Cl^- put into solution, so if we let s equal the amount of NaCl that dissolved then the expression substitutes to be $K_{sp} = s^2$

---

2. Silver arsenate dissolves in water: $Ag_3AsO_4(s) \rightleftharpoons 3\ Ag^+ + AsO_4^{3-}$

What is the correct K_{sp} expression if s is the molar solubility Silver arsenate?

a. $K_{sp} = s^2$
b. $K_{sp} = 3s^2$
c. $K_{sp} = s^4$
d. $K_{sp} = 3s^4$
e. $K_{sp} = 27s^4$



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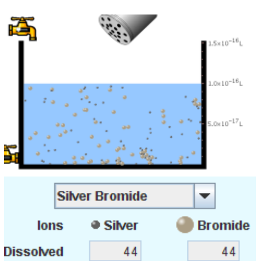
3. What is the proper expression for the molar solubility s of **AgCl** in terms of K_{sp}?

a. $s = K_{sp}$
b. $s = (K_{sp})^2$
c. $s = (K_{sp})^{1/2}$
d. $s = K_{sp}/2$



$K_{sp} = [Ag^+][Br^-]$

$[Ag^+]=[Br^-]$ (44 of each are dissolved)

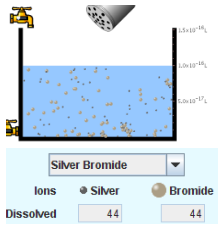
$K_{sp} = s^2$

$s = (K_{sp})^{1/2}$

Answer to previous slide

AgBr ↔ Ag^+ + Br^- $K_{sp} = 5.0 \times 10^{-13}$

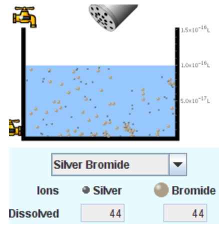
4. A saturated solution of AgBr in 1×10^{-16} liters of water contains about 44 Ag^+ and 44 Br^- ions as shown.
Suppose that K_{sp} were reduced to 2.5×10^{-13}. How many Ag^+ ions would you expect to see at equilibrium ?



a. 11 b. 22 c. 31 d. 44 e. 88

AgBr ↔ Ag^+ + Br^- $K_{sp} = 5.0 \times 10^{-13}$

Suppose that K_{sp} were reduced to 2.5×10^{-13}. How many Ag^+ ions would you expect to see at equilibrium ?



$$s = \sqrt{Ksp}$$

$$= \sqrt{2.5x10^{-13}}$$

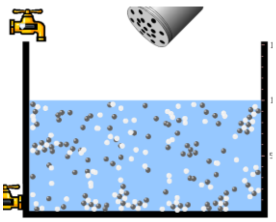
$$\approx 31$$

Answer to previous slide

5. Two salts have similar formulas XY and AB, but they have different solubility product constants.

XY: $K_{sp} = 1 \times 10^{-12}$

AB: $K_{sp} = 1 \times 10^{-8}$



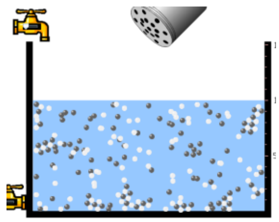
Which one would be more soluble?

A. AB
B. XY
C. The amount that dissolves would be the same.
D. Not enough information

6. Two salts have similar formulas XY and AB, but they have different solubility product constants.

XY: $K_{sp} = 1 \times 10^{-12}$

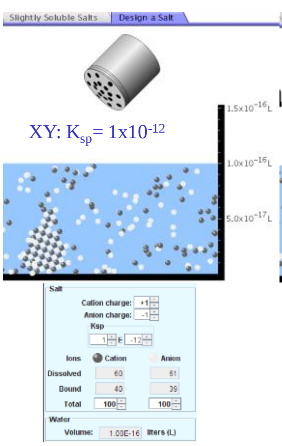
AB: $K_{sp} = 1 \times 10^{-8}$



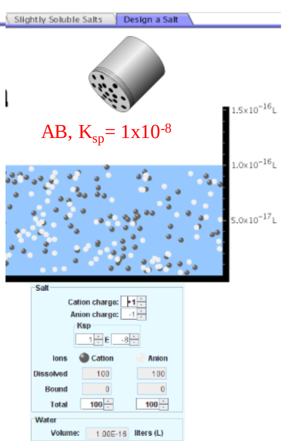
Which one would be more likely to precipitate?

A. AB
B. XY
C. They behave the same
D. Not enough information

XY: $K_{sp} = 1 \times 10^{-12}$



AB, $K_{sp} = 1 \times 10^{-8}$



Salts and Solubility Activity 4

The clicker questions do not directly address the goals because the are quantitative or have been well discussed by the group during the activities.

Learning Goals for 4: Students will be able to:

•Calculate Q.

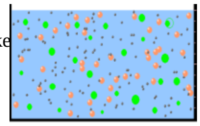
•Predict what would be observed on a macroscopic level to a solution by comparing Q to K_{sp}.

•Use microscopic illustrations, to help explain the predictions.

•Use LeChatelier's Principle to predict how changing the amount of water will affect the solution.

Trish Loeblein updated July 2008

Two salts, XB and AB, are dissolved in a beaker of water. There are equal number of moles. They have different solubility product constants.



XB: K_{sp}= 1x10^{-12} **AB: K_{sp}= 1x10^{-8}**

1. If you added B^- ions which would precipitate first?

A. AB

B. XB

C. They behave the same

D. Not enough information

2. 0.010 moles of $MgCl_2$ and 0.020 moles of $CuCl_2$ are dissolved in 0.10 liters of water. A solution of NaOH is slowly stirred in. Which precipitate forms first ?

$Cu(OH)_2$ K_{sp} = 2.2x10^{-20}
$Mg(OH)_2$ K_{sp} = 6.3x10^{-10}

a. $MgCl_2$ b. $CuCl_2$ c. $Mg(OH)_2$ d. $Cu(OH)_2$

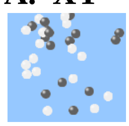
Salts and Solubility Activity 5

Learning Goal for 5: Students will be able to predict what would be observed on a macroscopic and microscopic level for salts with varying ionic charge given the K_{sp}.

Trish Loeblein July 2008

1. Which will have more dissolve particles in a saturated solution? K_{sp}=3 E –13 A compound made from

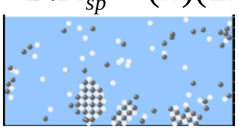
A. XY **B. XY_2** **C. no difference**



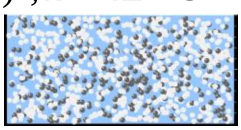
Answer to 1

$$A. K_{sp} = x^2; x = 5E-7$$

$$B. K_{sp} = (x)(2x)^2; x = 4E-5$$



XY

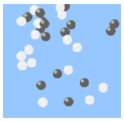
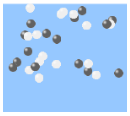


XY_2

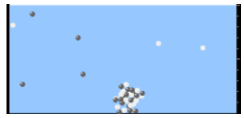
Why doesn't the mass of the particle matter?

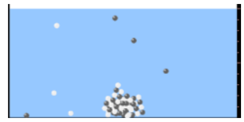
2. Which will have more dissolve particles in a saturated solution?
K_{sp}=2 E –15
A compound made from

A. X^{+1} and Y^{-1} B. X^{+2} and Y^{-2} C. no difference

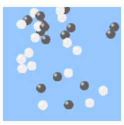
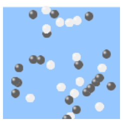
Answer to 2


XY


XY

3. Which will have more dissolve particles in a saturated solution?
K_{sp}=2 E –15
A compound made from

A. X^{+2} and Y^{-2} B. X^{+2} and Y^{-3} C. no difference

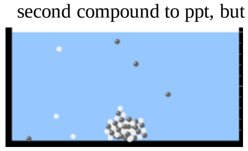



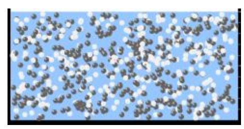
Answer to 3

$$A. K_{sp} = x^2; x = 4E - 8$$

$$B. K_{sp} = (3x)^3(2x)^2; x = 5E - 4$$

If you run the sim at the default volume, you cannot get the second compound to ppt, but only 4 dissolve of the first.


XY


X_3Y_2