

## **TITLE**

Saturated Solutions

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## **COURSE**

General Chemistry

## **TYPE**

Interactive Lecture Demonstration Guide

## **TEACHING MODE**

Lecture Demonstration

## **LEARNING GOALS**

Students will be able to:

- Compare and describe saturated and unsaturated solutions at the particle-level, and in terms of macroscopic observations.
- Explain how and whether changes in solute amount and changes in volume affect the concentration of unsaturated and saturated solutions.
- Relate the maximum concentration of saturated solutions (at a particular temperature) to the identity of the solute.

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## SATURATED SOLUTIONS

### PLACEMENT IN COURSE

Start of the 2<sup>nd</sup> semester of General Chemistry.

Solutions and solution stoichiometry have been introduced. Students may have some understanding of the energetics of solution formation and the dynamic equilibrium that exists for a saturated solution. States of matter and phase changes have been introduced.

### PRIOR KNOWLEDGE

- Solute & solvent
- Concentration calculations involving molarity
- Dilutions
- Phase changes, evaporation

### LEARNING OBJECTIVES:

Simulation	Format	Objectives, concepts
Salts & Solubility	Instructor-led	<ul style="list-style-type: none"><li>• Compare and describe saturated and unsaturated solutions at the particle-level, and in terms of macroscopic observations.</li></ul>
Concentration	Instructor-led	<ul style="list-style-type: none"><li>• Explain how and whether changes in solute amount and changes in volume affect the concentration of unsaturated and saturated solutions.</li></ul>
Molarity	Instructor-led	<ul style="list-style-type: none"><li>• Relate the maximum concentration of saturated solutions (at a particular temperature) to the identity of the solute.</li></ul>

### RESOURCES

Salts & Solubility: <http://phet.colorado.edu/en/simulation/soluble-salts>

Concentration: <http://phet.colorado.edu/en/simulation/concentration>

Molarity: <http://phet.colorado.edu/en/simulation/molarity>

### KEYWORDS

Solute, solvent, solution, saturated, unsaturated, supersaturated, concentration, molarity.

- **Solubility** is the amount of solute required to form a saturated solution.
- A solution with a concentration of dissolved solute that is less than the solubility is said to be **unsaturated**.
- A solution with a concentration of dissolved solute that has reached its “maximum” value is **saturated**.
- A solution is said to be **supersaturated** if more solute is dissolved than in a saturated solution. This is an unstable condition.

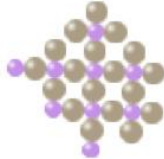





*Copyrighted textbook  
image omitted*

*Description:*

A supersaturated solution undergoing crystallization  
after addition of a seed crystal.

Slide 1: The terms unsaturated, saturated, and supersaturated are introduced.

A demonstration can support the initial discussion, e.g. have three different sodium acetate solutions to which sodium acetate solid is added. Based on initial observations, which solution is saturated? Add a seed crystal to each to distinguish between the unsaturated and supersaturated solutions.

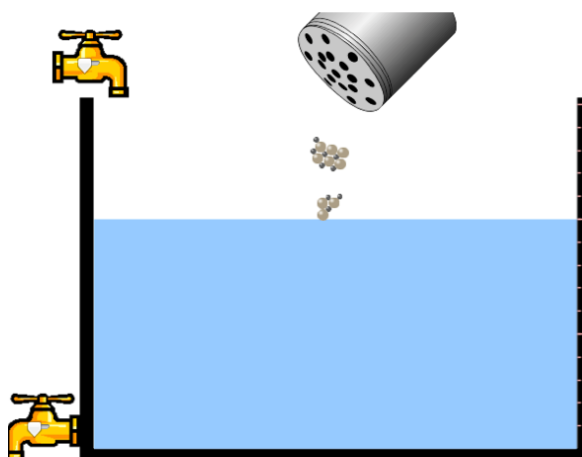
<p>Salt</p> <p>Mercury(II) Bromide</p> <p>Ions <span style="color: purple;">●</span> Mercury(II) <span style="color: brown;">●</span> Bromide</p> <p>Dissolved <input type="text" value="0"/> <input type="text" value="0"/></p> <p>Bound <input type="text" value="9"/> <input type="text" value="18"/></p> 	<p>Salt</p> <p>Silver Bromide</p> <p>Ions <span style="color: grey;">●</span> Silver <span style="color: brown;">●</span> Bromide</p> <p>Dissolved <input type="text" value="0"/> <input type="text" value="0"/></p> <p>Bound <input type="text" value="9"/> <input type="text" value="9"/></p> 	<p>Salt</p> <p>Copper(I) Iodide</p> <p>Ions <span style="color: green;">●</span> Copper(I) <span style="color: red;">●</span> Iodide</p> <p>Dissolved <input type="text" value="0"/> <input type="text" value="0"/></p> <p>Bound <input type="text" value="12"/> <input type="text" value="12"/></p> 
<p>Salt</p> <p>Strontium Phosphate</p> <p>Ions <span style="color: pink;">●</span> Strontium <span style="color: green;">●</span> Phosphate</p> <p>Dissolved <input type="text" value="0"/> <input type="text" value="0"/></p> <p>Bound <input type="text" value="18"/> <input type="text" value="12"/></p> 	<p>Salt</p> <p>Thallium(I) Sulfide</p> <p>Ions <span style="color: purple;">●</span> Thallium <span style="color: yellow;">●</span> Sulfide</p> <p>Dissolved <input type="text" value="0"/> <input type="text" value="0"/></p> <p>Bound <input type="text" value="14"/> <input type="text" value="7"/></p> 	<p>Salt</p> <p>Silver Arsenate</p> <p>Ions <span style="color: grey;">●</span> Silver <span style="color: orange;">●</span> Arsenate</p> <p>Dissolved <input type="text" value="0"/> <input type="text" value="0"/></p> <p>Bound <input type="text" value="12"/> <input type="text" value="4"/></p> 

Slide 2:

The Slightly Soluble Salts tab of the sim Salts and Solubility is used.

Describe for the class that, in this sim, you control a “microscopic salt shaker” that will add salt to water and that different salts may be selected (these are shown in slide 2).

- Based on the name of a particular salt, students can be asked to write the formula.
- With the sim paused it is possible to shake the shaker and examine representations of each ionic solid.



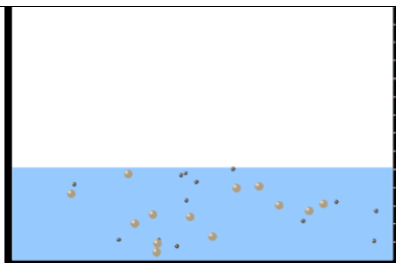
Sketch what happens when  $\text{AgBr}(s)$  is added to water.

Describe the salt

- Before it is added to water.
- When it is first added.
- When a lot is added.

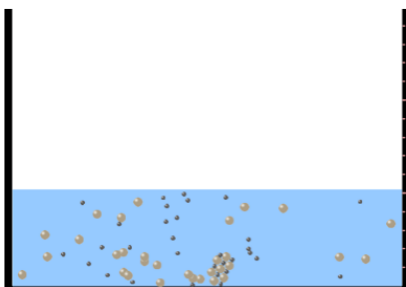
Use the terms unsaturated, saturated, and supersaturated (as applicable) to in your description.

Slide 3: Allow students to make initial predictions and then investigate with the sim. Notice that, within the sim, it is possible to select salts with cation:anion ratios other than 1:1.



Ions	Silver	Bromide
Dissolved	15	15
Bound	0	0
Total	15	15

Unsaturated or saturated?



Ions	Silver	Bromide
Dissolved	23	23
Bound	8	8
Total	31	31

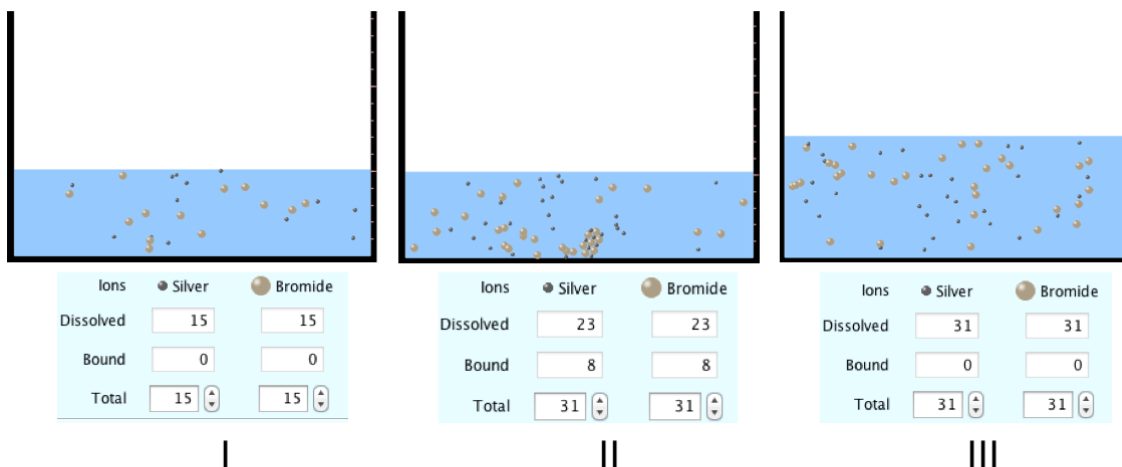
Unsaturated or saturated?

Will  $\text{Ag}^+$  ions combine with  $\text{Br}^-$  ions in this saturated solution?

- A. Yes, some  $\text{AgBr}(s)$  will form.
- B. Yes, more and more  $\text{AgBr}(s)$  will form until all the ions are used up.
- C. No,  $\text{AgBr}(s)$  will not form since the solution is saturated.

Slide 4: After having used the sim to investigate, check for understanding with questions, polling, etc. The concept of dynamic equilibrium may be introduced; even though solid remains in the saturated solution, dissolution and crystallization continue. The  $\text{Ag}^+(aq)$  and  $\text{Br}^-(aq)$  ions are forming  $\text{AgBr}(s)$ , but  $\text{AgBr}(s)$  is also dissolving at the same rate.

Macroscopically, the presence of  $\text{AgBr}(s)$  in the water (bound ions) indicates a saturated solution.



Use the terms unsaturated, saturated, and supersaturated (as applicable) to describe solutions I, II, and III.

Which solution has the highest concentration?

Slide 5: Several topics may be discussed here:

- Solution II is saturated since it still includes bound ions.
- Both I and III are unsaturated solutions.
- Even though II and III have the same total number of ions, with the addition of more water all of the salt in solution III has dissolved.
- Solution II has the highest concentration. Students often think that all of the ions in the container (bound and dissolved) contribute to the concentration. Would a solution with 23 dissolved  $\text{Ag}^+$  &  $\text{Br}^-$  ions and 18 bound ones have the same concentration as solution II? Yes.

Change volume

Change volume

Add solute

Change volume

Add solute

Observations

Slide 6: Although particle-level descriptions are important, in the lab chemists are not observing individual ions or atoms. They are making macroscopic observations, like seeing the color of a solution, and using instruments to make measurements.

In the **Concentration** sim there are different ways to change the volume, add solute, and make observations.

We will use the sim to conduct a few experiments involving unsaturated and saturated solutions.



## The Concentration of Unsaturated vs. Saturated Solutions

		Type of solution	
		Unsaturated	Saturated
Exp. 1	} Will the concentration change?		
Volume = constant			
Solute increased			
Exp. 2	}		
Solute = constant			
Volume change			

Slide 7: Begin by making a prediction for experiment 1 (constant volume, more solute added). Then, with the sim, begin adding solute. The probe will show an increase in concentration, and the solution will become darker. Eventually, when it becomes saturated, adding more solute no longer increases the concentration.

## The Concentration of Unsaturated vs. Saturated Solutions

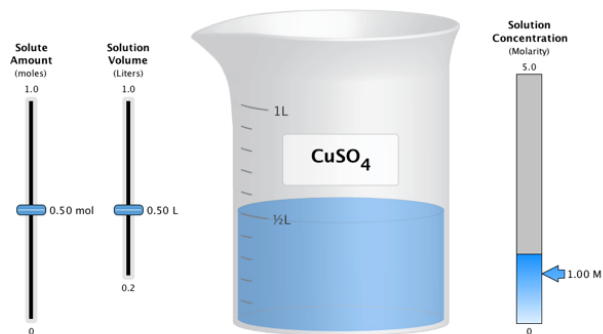
	Type of solution	
	Unsaturated	Saturated
Exp. 1		
Volume = constant		
Solute increased	<b>Increases</b>	<b>Constant</b>
Exp. 2		
Solute = constant		
Open bottom faucet	<b>constant</b>	
Open top faucet	<b>decreases</b>	
Wait & let it evaporate	<b>increases</b>	

Slide 8: There are several ways to conduct experiment 2 (amount of solute constant, but volume changed). Have the class identify different ways, make predictions, then test with the sim. In each case it is helpful to have students identify what is happening at the particle-level. Post the results for the unsaturated solution, then make predictions and test the saturated solution.

A prevalent misconception here is that as the volume decreases due evaporation the concentration will increase since the ratio of moles of solute/L of solution is increasing. This is paired with the misconception that all of the solute (both dissolved and solid) contribute to the concentration.

The **molarity** sim may also be used to address this point.

Initially a 1.00 M solution  
0.50 mol solute  
0.50 L solution



Slide 9: With the **molarity** sim “prepare” a 1.00 M solution of CuSO<sub>4</sub> by adding 0.50 mol solute to 0.50 L.

Predict what will happen to the concentration if the amount of solute increases, or if the solution’s volume is reduced (evaporation occurs without heating).

Initially a 1.00 M solution  
0.50 mol solute  
0.50 L solution

Add more solute

Volume decrease (evaporation)

Slide 10: More solute can be added, but the solution will become saturated and the concentration will then no longer increase. Similarly, the volume can be decreased but once again the concentration will reach a maximum.

- The sliding concentration scale (right side of the sim) is very effective at showing the maximum solution concentration for a particular solute.
- It is possible to illustrate that different solutes have different maximum concentrations with this sim.