Interpreting Solubility Curves

Why?

Solubility is a measure of the amount of solute that will dissolve in a given amount of solvent – usually water. A solubility curve shows how much solute dissolves in a given volume of a solvent at a given temperature. How much sugar dissolves in a cup of hot coffee? How much salt can dissolve in cold water? Chemists use this type of information when preparing solutions. Solutions are combinations of two or more substances that exist together in a homogeneous mixture.

Learning Objectives

• Determine solubilities based on information presented in table format.
• Distinguish solubility trends between solids and gases with changes in temperature.

Success Criteria

• Interpret a solubility table.
• Deduce the amount of solute in a given amount of solvent based on a solubility table.

Vocabulary

• solute
• solubility
• supersaturated
• solvent
• saturated
• solution
• unsaturated
• independent variable
• dependent variable

Use a vocabulary term to answer the first two questions below.

1. Which term applies to a sponge that is dry? Unsaturated

2. Which term applies to a sponge that is soaked? Saturated

3. Can you add more water to a sponge that is already soaked? No
Model

Table 1. Solubility Data

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Solute (g) per 100g of H₂O (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>33</td>
</tr>
<tr>
<td>30</td>
<td>42</td>
</tr>
<tr>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td>70</td>
<td>62</td>
</tr>
<tr>
<td>90</td>
<td>73</td>
</tr>
</tbody>
</table>

Task

Complete the model: Using the grid below make a graph of the solubility data in Table 1.

- Label x-axis, y-axis and create appropriate scales for each.
- Plot points using a pencil

Key Questions

1. What information is provided by the data in Table 1?
   - The amount of solute that can be dissolved in 100g of H₂O at various temps.

2. What is the relationship between temperature and solubility for this solute?
   - As the temp goes up, the solubility goes up

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Authored by E. Graham and R. McGrath, Modified by L. Tumminello, R. Quackenbush K. Levy and K. Levy
Edited by Linda Padwa and David Hanson, Stony Brook University
3. What will happen to this solute when 12 g is added to 100 g of water at 20°C?
   \textit{It will all dissolve}

4. What type of solution is obtained when 12 g of this solute is added to 100 g of water at 20°C (unsaturated, saturated, or supersaturated)?
   \textit{Unsaturated}

5. At 20°C, what is the maximum amount of this solute that can be dissolved in 100 g of water?
   \textit{37 g}

6. What type of solution is obtained when the maximum amount of a solute is dissolved in water (unsaturated, saturated, or supersaturated)?
   \textit{Saturated}

7. At 20°C, 50 g of this solute is added to 100 g of water. What will happen to the extra solute?
   \textit{It will fall to the bottom}

8. What type of solution is obtained under the conditions in Question #7 (unsaturated, saturated, or supersaturated)?
   \textit{Supersaturated}
1. **Exercise**  
Use Table G to answer the following questions.

![Table C Solubility Curves](http://nysedregents.org/testing/reftable/archiref/ChemRef1-7.pdf)

1. Compare the graph that you constructed from the data in Table 1 to graphs in Table G. Which of the solutes in Table G is the solute in your graph?

   \[ \text{NH}_4 \text{Cl} \]

2. Identify the substance in Table G that is most soluble at 60°C.

   \[ \text{KNO}_3 \]

3. Identify the substance in Table G that is least soluble at 60°C.

   \[ \text{SO}_2 \]

4. Identify and state the difference between the solubility curves for ammonia and sodium nitrate. Note that ammonia is a gas and sodium nitrate is a solid at room temperature.

   \[ (\text{NH}_3) \quad (\text{NaNO}_3) \]

   \[ \text{NH}_3 \rightarrow \text{the amount of solute that dissolves decreases as the temp increases} \]

   \[ \text{NaNO}_3 \rightarrow \text{the amount of solute that dissolves increases as the temp increases} \]
5. Use the temperature dependence of solubility to identify whether the substances in Table G are gases or solids. Make two lists below, one for gases and one for solids.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>KI</td>
</tr>
<tr>
<td>NH₃</td>
<td>NaNO₃</td>
</tr>
<tr>
<td>HCl</td>
<td>KNO₃</td>
</tr>
<tr>
<td></td>
<td>NH₄Cl</td>
</tr>
<tr>
<td></td>
<td>KCl</td>
</tr>
</tbody>
</table>

6. Suggest a reason why solubility decreases with increasing temperature for gaseous solutes but increases for solid solutes.

**Problems**

1. Everyday Jen walks in to Dunkin' Donuts and orders a medium iced coffee with four sugars or hot coffee with four sugars. She notices that the iced coffee is never as sweet as the hot coffee. Why?

*Not all the sugar dissolves in the iced coffee so it doesn’t taste as sweet.*

2. Ryan would like to make rock candy. The recipe calls for 200 g of sugar dissolved in 100 g of water. Ryan makes the observation that there is still sugar left on the bottom of the pan. Based on your knowledge about solubility, what could Ryan do to ensure that all of the sugar dissolves?

*Heat up the water*

3. A standard driveway is 550 cm by 305 cm (18' by 10'). If there is 5 cm of snow (about 2 inches) on the driveway – what is the maximum amount of rock salt that can be dissolved by the water from the snow? Rock salt is NaCl. *(Hint: density of water is approx 1 g/cm³ because 1 mL = 1 cm³. Is this exact? No, but it is close enough for our purposes here.)*

\[
\text{Volume of snow} = 838750 \text{ cm}^3 \\
38 \text{ g NaCl in 100 g H}_2\text{O} \\
\frac{38 \text{ g NaCl}}{100 \text{ g H}_2\text{O}} = \frac{x \text{ g NaCl}}{83750 \text{ cm}^3} \\
318725 \text{ g NaCl}
\]

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SOLUBILITY CURVE WORKSHEET

Use your solubility curve graph provided to answer the following questions.

1. What are the customary units of solubility on solubility curves? _grams of solute per 100g H2O per temp_ changes.

2. Define solubility. _the amount of solute that can be dissolved in a substance at a specific temp_ changes.

3. According to the graph, the solubility of any substance changes as _temp_ changes.

4. List the substances whose solubility decreases as temperature increases. NH₃ + Ce₂(SO₄)₃

5. Which substance is least affected by temperature changes? _NaCl_

6. How many grams of ammonium chloride (NH₄Cl) at 50°C? _50 g_

7. _NaCl_ and _KCIO₃_ have the same solubility at approximately 780°C.

8. Which compound is least soluble in water at 10°C? _KCIO₃_

9. How many grams of KNO₃ can be dissolved at 50°C? _80g_ or _80g_

10. Are the following solutions unsaturated, saturated, or supersaturated?
    a. 45g of NaNO₃ in 100 g of water at 30°C. _unsaturated_
    b. 60g of KClO₃ in 100 g of water at 60°C. _supersaturated_

11. How many grams of sodium chloride, NaCl, are required to saturate 100 grams of water at 100°C? _40g_

12. How many grams of NaNO₃ are required to saturate 100 grams of water at 90°C? _more than 150g_

13. How many grams of KI will saturate water at 20°C? _145g_

14. At what temperature would 25g of potassium chlorate (KClO₃) dissolve? _60°C_

15. At what temperature would 55g of NH₄Cl dissolve? _60°C_

16. 89 g NaNO₃ is prepared at 30°C.
   a) Will all of the salt dissolve? _Yes_
   b) What mass of NaNO₃ will dissolve at this temperature? _95g_

17. If 25 grams of NH₄Cl is dissolved at 50°C, how many additional grams NH₄Cl would be needed to make the solution saturated at 80°C? _39g_ or _45g_

18. At 50°C, how many grams of KNO₃ will dissolve? _80g_

19. At 70°C, how many grams of cerium (III) sulfate (Ce₂(SO₄)₃) dissolve? _5g_

20. Determine if each of the following is unsaturated, saturated, or supersaturated.
    a. 55g of NH₃ at 20°C. _supersaturated_
    b. 10g of Ce₂(SO₄)₃ at 10°C. _unsaturated_
    c. 125g of KNO₃ at 60°C. _supersaturated_
    d. 65g of NH₄Cl at 80°C. _saturated_
    e. 12g of NH₃ at 90°C. _supersaturated_

   f. 80g of NaNO₃ at 10°C. _saturated_
   g. 145g of NaNO₃ at 80°C. _saturated_
   h. 35g of NaCl at 100°C. _unsaturated_

CPSH Chemistry

Mr. G Edelman
Worksheet #1: Molarity

1. What mass of K₃PO₄ is required to prepare 4.00 liters of 1.50 M solution?

\[ 1.50 \text{ M} = \frac{x}{4.00 \text{ L}} \Rightarrow \frac{6.00 \text{ mol } \text{K}_3\text{PO}_4}{1 \text{ mol}} = 212.27 \text{ g} \]

\[ x = 1270 \text{ g K}_3\text{PO}_4 \]

2. What mass of CH₃OH is required to prepare 1.50 liters of 3.00 M solution?

\[ 3.00 \text{ M} = \frac{x}{1.50 \text{ L}} \Rightarrow \frac{4.50 \text{ mol } \text{CH}_3\text{OH}}{1 \text{ mol}} = 32.042 \text{ g} \]

\[ x = 144 \text{ g C}_2\text{H}_5\text{OH} \]

3. What volume of 0.750 M solution can be prepared using 90.0 grams of NH₄Cl?

\[ 0.750 \text{ M} = \frac{1.68}{x} \Rightarrow \frac{90.0 \text{ g } \text{NH}_4\text{Cl}}{1 \text{ mol}} = 53.493 \text{ g} \]

\[ x = 2.24 \text{ L} \]

4. What is the molarity of a solution that contains 85.0 grams Na₂SO₄ in 325 mL of solution?

\[ 85.0 \text{ g } \text{Na}_2\text{SO}_4 = \frac{1 \text{ mol}}{142.05 \text{ g}} = 0.598 \text{ mol} \]

\[ M = \frac{0.598 \text{ mol}}{0.325 \text{ L}} = 1.84 \text{ M} \]

5. What is the molarity of a solution that contains 210 grams of Al₂(SO₄)₃ in 2.75 liters of solution?

\[ 210 \text{ g } \text{Al}_2(\text{SO}_4)_3 = \frac{1 \text{ mol}}{342.17 \text{ g}} = 0.61 \text{ mol} \]

\[ M = \frac{0.61 \text{ mol}}{2.75 \text{ L}} = 0.22 \text{ M} \]

6. If a 0.750 M aqueous solution of sodium hydroxide is to be prepared using 18.5 grams NaOH, how many mL of solution can be produced?

\[ 18.5 \text{ g } \text{NaOH} = \frac{1 \text{ mol}}{34.998 \text{ g}} = 0.463 \text{ mol} \]

\[ 0.750 \text{ M} = \frac{0.463 \text{ mol}}{L} \]

\[ L = 0.617 \text{ L} = \frac{1000 \text{ mL}}{L} \]

7. What is the molarity of a solution that contains 125 grams C₂H₅OH in 0.250 liters of solution?

\[ 125 \text{ g } \text{C}_2\text{H}_5\text{OH} = \frac{1 \text{ mol } \text{C}_2\text{H}_5\text{OH}}{46.069 \text{ g } \text{C}_2\text{H}_5\text{OH}} = 2.71 \text{ mol} \]

\[ M = \frac{2.71 \text{ mol}}{0.250 \text{ L}} = 10.8 \text{ M} \]

8. What volume of 1.40 M HC₂H₃O₂ solution contains 0.400 moles of HC₂H₃O₂?

\[ 1.40 \text{ M} = \frac{0.400 \text{ mol}}{x} \]

\[ x = 0.286 \text{ L} \]
9. A solution of aluminum nitrate is 2.00 M. What volume of this solution contains 0.250 moles of aluminum nitrate?

\[
\frac{2.00 \text{ M} \times 0.250 \text{ moles}}{2.00 \text{ M}} = 0.125 \text{ L}
\]

10. A solution of ammonium sulfate is to be prepared that is 2.25 M. What volume of solution can be produced using 50.0 grams ammonium sulfate?

\[
\frac{50.0 \text{ g} \times (\text{NH}_4)_2\text{SO}_4}{132.154 \text{ g}} = 0.378 \text{ moles}
\]

\[
2.25 M \times \frac{0.378 \text{ moles}}{x} = 0.168 \text{ L}
\]

**Answers:**

1. 1270 g
2. 144g
3. 2.24 L
4. 1.84 M
5. 0.22 M
6. 617 mL
7. 10.8 M
8. 0.286 L
9. 0.125 L
10. 0.168 L

**Worksheet #2: Dilution**

1. What is the final volume of a solution if it is necessary to make a 0.0500 M solution using 10.0 mL of a 2.00 M solution of NaCl?

\[
10.0 \text{ mL} \times 2.00 \text{ M} = x \times 0.0500 \text{ M}
\]

\[
x = 400.0 \text{ mL}
\]

2. To prepare 250.0 mL of a 0.100 M solution, how many mL of a 4.00 M Ca(NO₃)₂ solution must be used?

\[
4.00 \text{ M} \times x = 0.100 \text{ M} \times 250.0 \text{ mL}
\]

\[
x = 6.25 \text{ mL}
\]

3. Calculate the molarity of 500 mL of NaC₂H₃O₂ if it was prepared by diluting 100 mL of a 4.00 M solution.

\[
100 \text{ mL} \times 4.00 \text{ M} = 500 \text{ mL} \times x
\]

\[
x = 0.8 \text{ M}
\]
4. Calculate the molarity of a solution if 10.0 mL of a 6.00 M solution of NaCl is diluted to a volume of 200.0 mL?

\[
(10.0 \text{ mL})(6.00 \text{ M}) = (x)(200.0 \text{ mL})
\]

\[x = 0.300 \text{ M}\]

ANSWERS:
1. 400 mL  2. 6.25 mL  3. 0.8 M  4. 0.300 M