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

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Model

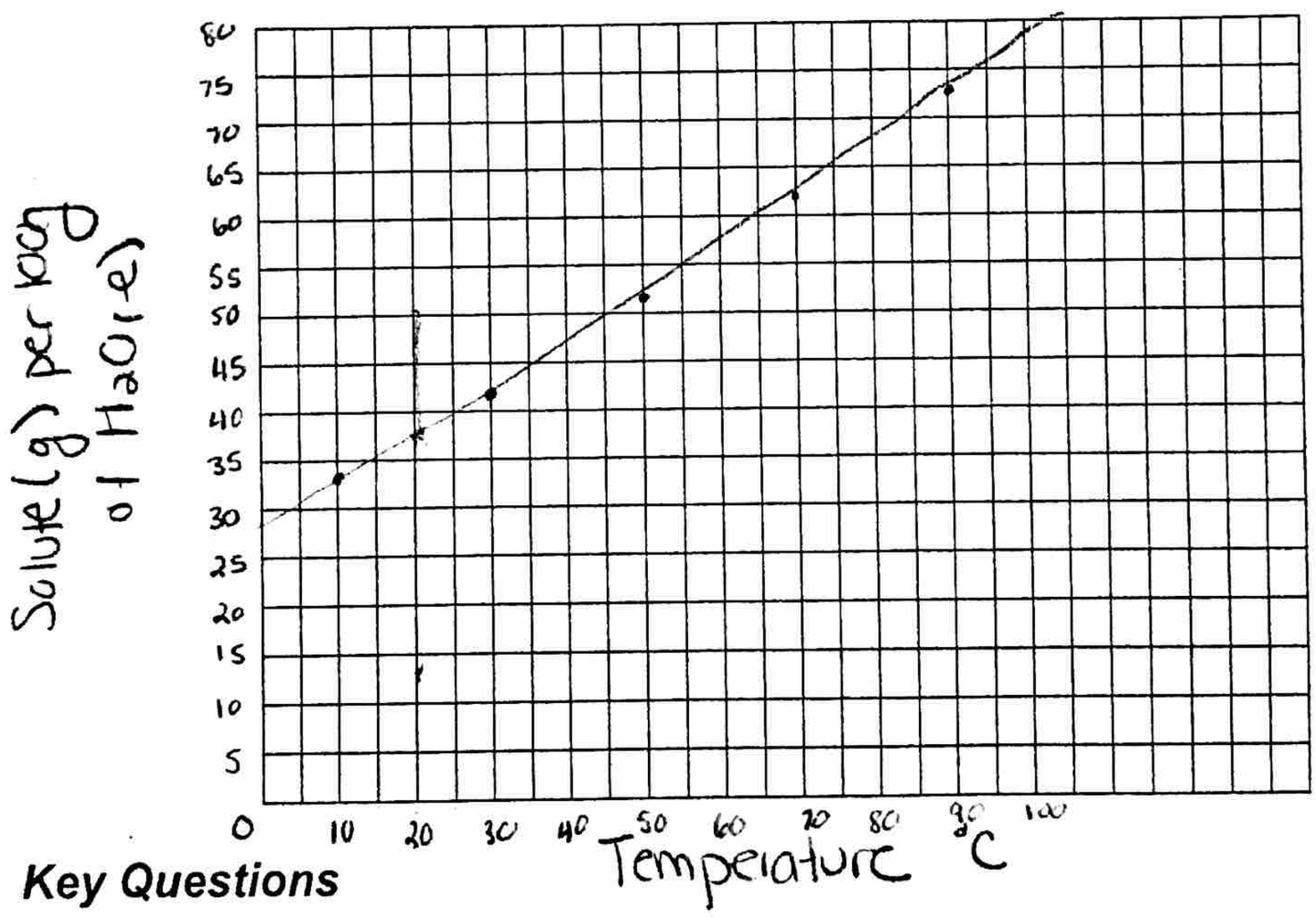
Table1. Solubility Data

Temperature (°C)	Solute (g) per 100g of H_2O (l
10	33
30	42
50	52
70	62
90	73

Task

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

a. Label x-axis, y-axis and create appropriate scales for each.
b. 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

15 minutes

talk about curves

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3. What will happen to this solute when 12 g is added to 100 g of water at 20°C?

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)?

unsaturated

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

37g

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

saturated

7. At 20°C, 50 g of this solute is added to 100 g of water. What will happen to the extra solute?

it will fall to the bottom

8. What type of solution is obtained under the conditions in Question #7 (unsaturated, saturated, or supersaturated)?

supersaturated

5 minutes

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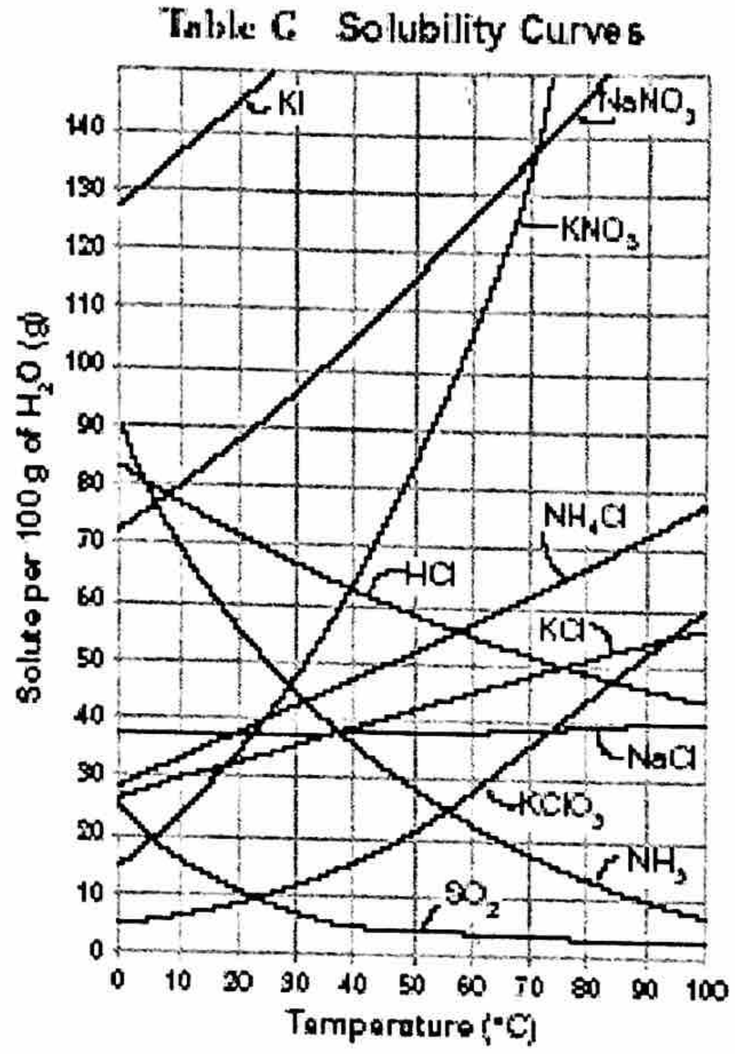
1. Exercise

Use Table G to answer the following questions.



(http://nysedregents.org/testing/reftable/archreftable/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?

   NH4Cl

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

   KI

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

   SO2

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. (NH3) (NaNO3).

   NH3 → the amount of solute that dissolves decreases as the temp increases

   NaNO3 → the amount of solute that dissolves increases as the temp increases

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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.

Gas	Solid	
SO_2	KI	NaCl
NH_3	$NaNO_3$	$KClO_3$
HCl	KNO_3	
	NH_4Cl	
	KCl	

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

gas particles spead up and escape from solution

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.)*

0°C

Volume of snow = 838750 cm^3

38 g NaCl in 100g H_2O

$$\frac{38\text{g NaCl}}{100\text{g } H_2O} = \frac{X\text{g NaCl}}{838750\text{ g } H_2O}$$

318725g 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 H_2O
2. Define solubility. the amount of solute that can be dissolved in a substance per temp at a specific temp
3. According to the graph, the solubility of any substance changes as temp changes.
4. List the substances whose solubility decreases as temperature increases. NH_3 + $Ce_2(SO_4)_3$
5. Which substance is least affected by temperature changes? NaCl
6. How many grams of ammonium chloride (NH_4Cl) at 50°C? 50 g
7. NaCl and $KClO_3$ have the same solubility at approximately 78oC.
8. Which compound is least soluble in water at 10°C? $KClO_3$
9. How many grams of KNO_3 can be dissolved at 50°C? ~~80~~ 80 g
10. Are the following solutions unsaturated, saturated, or supersaturated?
    a. 45g of $NaNO_3$ in 100 g of water at 30°C. unsaturated
    b. 60g of $KClO_3$ 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 $NaNO_3$ 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 ($KClO_3$) dissolve? 60°C
15. At what temperature would 55g of NH_4Cl dissolve? 60°C
16. 89 g $NaNO_3$ is prepared at 30°C.
    a) Will all of the salt dissolve? yes
    b) What mass of $NaNO_3$ will dissolve at this temperature? 95g
17. If 25 grams of NH_4Cl is dissolved at 50°C, how many additional grams NH_4Cl would be needed to make the solution saturated at 80°C? 39g ↳ 64 -25 =
18. At 50°C, how many grams of KNO_3 will dissolve? 80g
19. At 70°C, how many grams of cerium (III) sulfate ($Ce_2(SO_4)_3$) dissolve? 5g
20. Determine if each of the following is unsaturated, saturated, or supersaturated.
    a. 55g of NH_3 at 20°C. supersaturated
    b. 10g of $Ce_2(SO_4)_3$ at 10°C. unsaturated
    c. 125g of KNO_3 at 60°C. supersaturated
    d. 65g of NH_4Cl at 80°C. saturated
    e. 12g of NH_3 at 90°C. supersaturated
    f. 80g of $NaNO_3$ at 10°C. . saturated
    g. 145g of $NaNO_3$ at 80°C. . saturated
    h. 35g of NaCl at 100°C. . unsaturated

Worksheet #1: Molarity

1. What mass of K_3PO_4 is required to prepare 4.00 liters of 1.50 M solution?

$1.50\,M = \frac{x}{4.00\,L}$ $= 6.00\,mol\,K_3PO_4 \left| \frac{212.27\,g}{1\,mol} \right.$ $= 1270\,g\,K_3PO_4$

2. What mass of CH_3OH is required to prepare 1.50 liters of 3.00 M solution?

$3.00\,M = \frac{x}{1.50\,L}$ $= 4.50\,mol\,CH_3OH \left| \frac{32.042\,g}{1\,mol} \right.$ $= 144\,g\,CH_3OH$

3. What volume of 0.750 M solution can be prepared using 90.0 grams of NH_4Cl?

$\frac{0.750\,M}{1} = \frac{1.68}{x}$ $\quad x = 2.24\,L$

$90.0\,g\,NH_4Cl \left| \frac{1\,mol}{53.492\,g} \right. = 1.68\,mol$

4. What is the molarity of a solution that contains 85.0 grams Na_2SO_4 in 325 mL of solution?

$85.0\,g\,Na_2SO_4 \left| \frac{1\,mol}{142.05\,g} \right. = 0.598\,mol$ $\quad M = \frac{0.598\,mol}{0.325\,L}$

$M = 1.84\,M$

5. What is the molarity of a solution that contains 210 grams of $Al_2(SO_4)_3$ in 2.75 liters of solution?

$210\,g\,Al_2(SO_4)_3 \left| \frac{1\,mol}{342.17\,g} \right. = 0.61\,mol$ $\quad M = \frac{0.61\,mol}{2.75\,L} = 0.22\,M$

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?

$18.5\,g\,NaOH \left| \frac{1\,mol}{39.998\,g} \right. = 0.463\,mol$ $\quad 0.750\,M = \frac{0.463\,mol}{L}$

$L = 0.617\,L \left| \frac{1000\,mL}{1\,L} \right.$ $= 617\,mL$

7. What is the molarity of a solution that contains 125 grams C_2H_5OH in 0.250 liters of solution?

$125\,g\,C_2H_5OH \left| \frac{1\,mol\,C_2H_5OH}{46.068\,g\,C_2H_5OH} \right. = 2.71\,mol$ $\quad M = \frac{2.71\,mol}{0.250\,L}$

$M = 10.8\,M$

8. What volume of 1.40 M $HC_2H_3O_2$ solution contains 0.400 moles of $HC_2H_3O_2$?

$1.40\,M = \frac{0.400\,mol}{x}$ $\quad x = 0.286\,L$

9. A solution of aluminum nitrate is 2.00 M. What volume of this solution contains 0.250 moles of aluminum nitrate?

$\frac{2.00\ M}{1} = \frac{0.250\ mol}{X}$ $\quad \frac{2.00\ x}{2.00} = \frac{0.250}{2.00}$

$x = 0.125\ L$

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?

$\frac{50.0\ g\ (NH_4)_2SO_4}{132.154\ g} \times \frac{1\ mol}{} = 0.378\ mol$ $\quad 2.25\ M = \frac{0.378\ mol}{x}$

$x = 0.168\ L$

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?

$(10.0\ mL)(2.00\ M) = (x)(0.0500\ M)$

$x = 400.\ mL$

2. To prepare 250.0 mL of a 0.100 M solution , how many mL of a 4.00 M $Ca(NO_3)_2$ solution must be used?

$(4.00\ M)(x) = (.100\ M)(250.0\ mL)$

$x = 6.25\ mL$

3. Calculate the molarity of 500 mL of $NaC_2H_3O_2$ if it was prepared by diluting 100 mL of a 4.00 M solution.

$(100\ mL)(4.00\ M) = (500\ mL)\ x$

$x = 0.8\ M$

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?

$(10.0\,mL)(6.00\,M) = (X)(200.0\,mL)$

$X = 0.300\,M$

ANSWERS:

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