

Concentration and Solubility

Reading Preview

Key Concepts

- How is concentration measured?
- Why is solubility useful in identifying substances?
- What factors affect the solubility of a substance?

Key Terms

- dilute solution
- concentrated solution
- solubility
- saturated solution
- unsaturated solution
- supersaturated solution

Target Reading Skill

Building Vocabulary As you read, carefully note the definition of each Key Term. Also note other details in the paragraph that contains the definition. Use all this information to write a meaningful sentence using the Key Term.

Making Maple Syrup ▼



Collecting sap



Boiling sap



Syrup



Discover Activity

Does It Dissolve?

1. Put half a spoonful of soap flakes into a small plastic cup. Add about 50 mL of water and stir. Observe whether the soap flakes dissolve.
2. Clean out the cup. Repeat the test for a few other solids and liquids provided by your teacher.
3. Classify the items you tested into two groups: those that dissolved easily and those that did not.

Think It Over

Drawing Conclusions Based on your observations, does the physical state (solid or liquid) of a substance affect whether or not it dissolves in water? Explain.

Have you ever had syrup on your pancakes? You probably know that it's made from the sap of maple trees. Is something that sweet really made in a tree? Well, not exactly.

Concentration

The sap of a maple tree and pancake syrup differ in their concentrations. That is, they differ in the amount of solute (sugar) dissolved in a certain amount of solvent (water). The sap is a **dilute solution**, a mixture that has only a little solute dissolved in a certain amount of solvent. The syrup, on the other hand, is a **concentrated solution**—one that has a lot of solute dissolved in the same amount of solvent.

Changing Concentration You can change the concentration of a solution by adding more solute. You can also change it by adding or removing solvent. For example, fruit juices are sometimes packaged as concentrates, which are concentrated solutions. In making the concentrate, water was removed from the natural juice. When you make juice from the concentrate, you add water, making a dilute solution.

Measuring Concentration You know that maple syrup is more concentrated than maple sap. But you probably do not know the actual concentration of either solution. **To measure concentration, you compare the amount of solute to the amount of solvent or to the total amount of solution.**

Often, the method used to describe concentration depends on the type of solution. For example, you might measure the mass of a solute or solvent in grams. Or you might measure the volume of a solute or solvent in milliliters or liters. You can report concentration as the percent of solute in solution by volume or mass.



Reading Checkpoint

How can you change the concentration of a solution?

Solubility

If a substance dissolves in water, a question you might ask is, “How much can dissolve?” Suppose you add sugar to a glass of iced tea. Is there a limit to how “sweet” you can make the tea? The answer is yes. At the temperature of iced tea, several spoonfuls of sugar are about all you can add. At some point, no matter how much you stir the tea, no more sugar will dissolve. **Solubility** is a measure of how much solute can dissolve in a solvent at a given temperature.

When you’ve added so much solute that no more dissolves, you have a **saturated solution**. If you add more sugar to a saturated solution of iced tea, the extra sugar just settles to the bottom of the glass. On the other hand, if you can continue to dissolve more solute, you still have an **unsaturated solution**.

FIGURE 6

Dissolving Sugar In Tea

At some point, this boy will not be able to dissolve any more sugar in his tea.

Applying Concepts What term describes how much sugar can dissolve in a solvent?



Math

Skills

Calculating a Concentration

To calculate the concentration of a solution, compare the amount of solute to the amount of solution and multiply by 100 percent.

For example, if a solution contains 10 grams of solute dissolved in 100 grams of solution, then its concentration can be reported as 10 percent.

$$\frac{10 \text{ g}}{100 \text{ g}} \times 100\% = 10\%$$

Practice Problem A solution contains 12 grams of solute dissolved in 36 grams of solution. What is the concentration of the solution?



FIGURE 7

Each compound listed in the table dissolves in water, but in different amounts.

Interpreting Tables Which compound is the most soluble? Which is the least soluble?

Solubility in 100 g of Water at 0°C	
Compound	Solubility (g)
Carbon dioxide (CO ₂)	0.348
Baking soda (NaHCO ₃)	6.9
Table salt (NaCl)	35.7
Table sugar (C ₁₂ H ₂₂ O ₁₁)	180

Working With Solubility The solubility of a substance tells you how much solute you can dissolve before a solution becomes saturated. Solubility is given for a specific solvent (such as water) under certain conditions (such as temperature). Look at the table in Figure 7. It compares the solubility of some familiar compounds. In this case, the solvent is water and the temperature is 0°C. From the table, you can see that 6.9 grams of baking soda will dissolve in 100 grams of water at 0°C. But the same mass of water at the same temperature will dissolve 180 grams of table sugar!

Lab
zone

Skills Activity

Predicting

Make a saturated solution of baking soda in water. Add one small spoonful of baking soda to about 250 mL of cool water. Stir until the baking soda dissolves. Continue adding baking soda until no more dissolves. Keep track of how much baking soda you use. Then predict what would happen if you used warm water instead. Make a plan to test your prediction. With approval from your teacher, carry out your plan. Did your results confirm your prediction? Explain.

Using Solubility Solubility can be used to help identify a substance because it is a characteristic property of matter. Suppose you had a white powder that looked like table salt or sugar. You wouldn't know for sure whether the powder is salt or sugar. And you wouldn't use taste to identify it. Instead, you could measure its solubility in water at 0°C and compare the results to the data in Figure 7.



Reading
Checkpoint

What does the solubility of a substance tell you?

Factors Affecting Solubility

Which dissolves more sugar: iced tea or hot tea? You have already read that there is a limit to solubility. An iced tea and sugar solution quickly becomes saturated. Yet a hot, steaming cup of the same tea can dissolve much more sugar before the limit is reached. The solubilities of solutes change when conditions change. **Factors that affect the solubility of a substance include pressure, the type of solvent, and temperature.**

Pressure Pressure affects the solubility of gases. The higher the pressure of the gas over the solvent, the more gas can dissolve. To increase the carbon dioxide concentration in soft drinks, the gas is added under high pressure. Opening the bottle or can reduces the pressure. The escaping gas makes the sound you hear.

Scuba divers are aware of the effect of pressure on gases. Air is about 80 percent nitrogen. When divers breathe from tanks of compressed air, nitrogen from the air dissolves in their blood in greater amounts as they descend. This occurs because the pressure underwater increases with depth. If divers return to the surface too quickly, nitrogen bubbles come out of solution and block blood flow. Divers double over in pain, which is why this condition is sometimes called “the bends.”

Solvents Sometimes you just can’t make a solution because the solute and solvent are not compatible. Have you ever tried to mix oil and vinegar, which is mostly water, to make salad dressing? If you have, you’ve seen how the dressing quickly separates into layers after you stop shaking it. Oil and water separate because water is a polar compound and oil is nonpolar. Polar compounds and nonpolar compounds do not mix very well.

For liquid solutions, the solvent affects how well a solute dissolves. The expression “like dissolves like” gives you a clue to which solutes are soluble in which solvents. Ionic and polar compounds usually dissolve in polar solvents. Nonpolar compounds do not usually dissolve in polar solvents. If you work with paints, you know that water-based (latex) paints can be cleaned up with just soap and water. But cleaning up oil-based paints may require a nonpolar solvent, such as turpentine.



FIGURE 8
Pressure Changes Solubility
Opening a shaken bottle of soda water may produce quite a spray as dissolved gas comes out of solution.



Just after
shaking...



...a little
while later



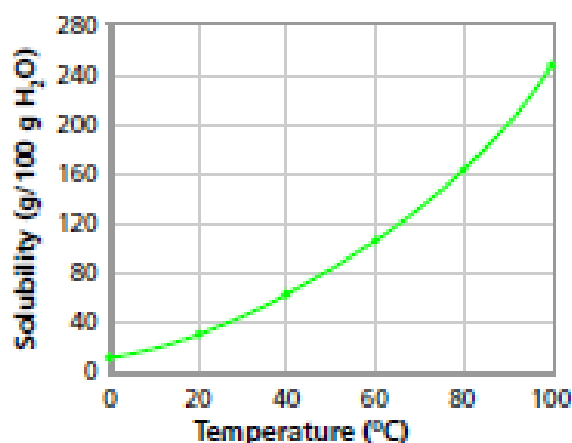
FIGURE 9
Solvents and Solubility
Try as she might, this girl cannot get oil and vinegar to stay mixed. Nonpolar and polar compounds don’t form solutions with each other.

Temperature and Solubility

The solubility of the compound potassium nitrate (KNO_3) varies in water at different temperatures.

1. **Reading Graphs** At which temperature shown in the graph is KNO_3 least soluble in water?
2. **Reading Graphs** Approximately what mass of KNO_3 is needed to saturate a water solution at 40°C ?
3. **Calculating** About how much more soluble is KNO_3 at 40°C than at 20°C ?
4. **Interpreting Data** Does solubility increase at the same rate with every 20°C increase in temperature? Explain.

Solubility of KNO_3



Temperature For most solids, solubility increases as the temperature increases. That is why the temperature is reported when solubilities are listed. For example, the solubility of table sugar in 100 grams of water changes from 180 grams at 0°C to 231 grams at 25°C to 487 grams at 100°C .

Cooks use this increased solubility of sugar when they make desserts such as rock candy, fudge, or peanut brittle. To make peanut brittle, you start with a mixture of sugar, corn syrup, and water. At room temperature, not enough of the required sugar can dissolve in the water. The mixture must be heated until it begins to boil. Nuts and other ingredients are added before the mixture cools. Some recipes call for temperatures above 100°C . Because the exact temperature can affect the result, cooks use a candy thermometer to check the temperature.

Unlike most solids, gases become less soluble when the temperature goes up. For example, more carbon dioxide will dissolve in cold water than in hot water. Carbon dioxide makes soda water fizzy when you pour it into a glass. If you open a warm bottle of soda water, carbon dioxide escapes the liquid in greater amounts than if the soda water had been chilled. Why does warm soda taste “flat”? It contains less gas. If you like soda water that’s very fizzy, open it when it’s cold!



FIGURE 10

Temperature Changes Solubility

Some hard candy is made by cooling a sugar water solution. **Interpreting Photographs** Why does sugar precipitate on the string when the solution is cooled?



FIGURE 11

A Supersaturated Solution
Dropping a crystal of solute into a supersaturated solution (left) causes the excess solute to rapidly come out of solution (center). Soon, the precipitation is complete (right).

When heated, a solution can dissolve more solute than it can at cooler temperatures. If a heated, saturated solution cools slowly, sometimes the extra solute will remain dissolved. A **supersaturated solution** has more dissolved solute than is predicted by its solubility at the given temperature. When you disturb a supersaturated solution by dropping in a crystal of the solute, the extra solute will come out of solution.



Reading Checkpoint

As temperature increases, what happens to the solubility of a gas?



For: Links on solubility
Visit: www.SciLinks.org
Web Code: scm-1232

Section 2 Assessment

- Target Reading Skill Building Vocabulary**
Use your sentences about the Key Terms to help answer the questions.

Reviewing Key Concepts

- Reviewing** What is concentration?
 - Describing** What quantities are compared when the concentration of a solution is measured?
 - Applying Concepts** Solution A contains 50 g of sugar. Solution B contains 100 g of sugar. Can you tell which solution has a higher sugar concentration? Explain.
- Defining** What is solubility?
 - Explaining** How can solubility help you identify a substance?
 - Calculating** Look back at the table in Figure 7. At 0°C, about how many times more soluble in water is sugar than salt?

- Listing** What are three factors that affect solubility?
 - Summarizing** How does temperature affect the solubility of most solids?
 - Relating Cause and Effect** When you heat water and add sugar, all of the sugar dissolves. When you cool the solution, some sugar comes out of solution. Explain.

Math

Practice

- Calculating a Concentration** What is the concentration of a solution that contains 45 grams of sugar in 500 grams of solution?
- Calculating a Concentration** How much sugar is dissolved in 500 grams of a solution if the solution is 70 percent sugar by mass?