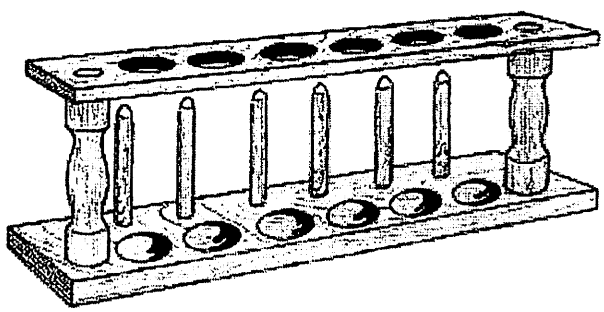
Factors Affecting Solubility



Introduction:

Why is it that some soluble solids take so much longer to dissolve than others? What factors affect the rate of dissolving? Understanding solutions is important when studying chemistry since solutions are used to perform so many chemical reactions. In this laboratory activity, you will test several factors and observe how each factor affects the rate of a solute dissolving in a solvent.

Chemical Concepts:

- Solutions
- Solubility
- Rate of Dissolving

Materials:

Chemicals

Ice, several cubes

Sodium chloride, rock salt, 2 crystals

Sodium chloride, salt crystals, 2 g

Water, distilled or deionized, 150 mL

Equipment

Balance

Beakers, 100-mL or other small size, 3

Hot plate or Bunsen burner

Mortar and pestle

Stopper, Size #0

Test tubes, 16 × 125 mm, 3

Test tube rack

Thermometer

Weighing boat

Safety Precautions:

Wear chemical splash goggles.

Background:

Solvation Is a Surface Phenomenon

The process of a solid solute dissolving in a solvent is a surface phenomenon. Dissolving is a surface phenomenon because it is those molecules or ions at the surface of the solid, not those in the interior, or bulk, of the solid, that interact and dissolve in the surrounding solvent.

In aqueous solutions, the solvent is water. Some of the water molecules dissociate to form hydrogen ions, H^+, and hydroxide ions, OH^-. If an ionic crystal is added to water, the H^+ and OH^- ions interact with the ions at the surface of a crystal, pulling them from the crystal lattice into the solution. For example, if a sodium chloride crystal is added to water, the sodium ions, Na^+, and chloride ions, Cl^-, on the surface of the crystal dissociate (move from the crystal lattice to solution) to form aqueous Na^+ and Cl^- ions. The positively charged Na^+ ions will be surrounded by the negatively charged OH^- ions, while the negatively charged Cl^- ions are surrounded by the positively charged H^+ ions. These ionic attractions between the crystal's ions and water's ions make it favorable for the sodium chloride crystal to dissolve in water.

As the surface ions dissolve, the next layer of ions now becomes the surface layer. This new surface layer interacts with the ions already in solution as described above. This interaction at the surface of a crystal continues until the crystal is completely dissolved, or until the solution can accept no more solute.

Factors Affecting the Rate of Dissolving

The rate at which a substance dissolves in water depends upon four factors: stirring, temperature, surface area, and the amount of solute already dissolved in solution. Each of these is addressed in detail below.

Stirring. Stirring helps to dissolve a solute by bringing fresh solvent in contact with the solute crystal at a faster rate. As the surface layer of a solute crystal dissolves, the solution surrounding the crystal tends to have a high concentration of dissolved solute, which tends to slow down the rate of dissolving. By stirring the solution, the dissolved solute is transferred to other regions of the solution more quickly and fresh solvent is made available so that the next surface layer on the undissolved solute crystal can now dissolve.

Temperature. When the temperature of a solution is increased, the average kinetic energy of the molecules and ions in solution is also increased. This means that both the solvent and dissolved solute particles are travelling from one region of the solutio. to another region more quickly as the temperature is raised. This increased movement increases the rate at which fresh solvent is brought into contact with the undissolved solute crystal. Just as with stirring, bringing fresh solvent in contact with the undissolved solute crystal at a faster rate increases the rate at which the solute crystal will dissolve. In addition, the solvent particles have more energy to remove particles from the surface layer of the solute crystal.

Surface Area. Because dissolving occurs at the surface of a crystal, the more solute surfaces that are exposed to solvent, the faster the solute will dissolve. Therefore, increasing the surface area of the solute to be dissolved increases the rate at which it will dissolve. The surface area is increased, for example, by grinding up one large crystal into many small crystals or granules. Each of the small pieces is surrounded by a surface layer which can dissolve in solution as soon as the solute is added to solution.

Amount of Solute Already Dissolved in Solution. As a solute dissolves, the concentration of dissolved solute is greatest in the region directly adjacent to the solute crystal. This slows the rate at which additional solute can be dissolved. Stirring or raising the temperature helps to distribute these dissolved solute particles into other regions of solution more quickly, which increases the rate of dissolving. Why does the concentration of solute already dissolved affect the rate at which additional solute can dissolve? Each substance has a given solubility in water. Its solubility determines how much of that solute can dissolve in a given volume of water at a given temperature. Solubility varies from solute to solute. Some solutes are extremely soluble, while others are only slightly soluble. This means that the water surrounding the solute can only accept a certain number of grams of solute in a given volume. Imagine that the water has a specific number of seats in which dissolved solute particles can sit. As these seats become filled, it is harder for an undissolved solute particle to find an empty seat, and it takes that particle longer to find an empty seat before it can dissolve.

Different solutes dissolve at different rates depending on the four factors mentioned above. However, keep in mind that the *rate* at which a solute dissolves does not change *how much* of that substance can dissolve or whether it even *can* dissolve in a particular solvent. These ideas encompass higher level solubility concepts which are beyond the scope of this laboratory activity.

Procedure:

Part A: Preparation

1. Fill a small beaker half-full with water. Warm on a hot plate to about 80 °C.
2. Fill a second small beaker half-full with water. Add several ice cubes and allow the ice-water to cool to about 5 °C.
3. Fill a third small beaker half-full with water. Let this water sit on the lab bench and come to room temperature.
4. These beakers of water will be used in Part C. Proceed with Part B while they are coming to the desired temperatures.

Part B: Effect of Stirring on the Rate of Dissolving

5. Place two test tubes in a test tube rack. Label the tubes 1 and 2. Place about 0.2 g of salt crystals in each test tube. The amount added is not as important as adding equal amounts to each tube.
6. Add enough water to fill each test tube about two-thirds full. Pour the water carefully down the side of the tube so that little mixing occurs as the water is added.
7. Stopper test tube 2 and invert it. If all of the salt does not dissolve, invert it again. Continue inverting until all of the salt is dissolved. Count the number of inversions required. One inversion consists of turning the stoppered test tube upside down, then bringing it back right-side-up.
8. Compare the rate of dissolving between the two tubes. Record your observations in Data Table 1.
9. Rinse the contents of both test tubes down the drain. Rinse and dry each test tube.

Part C: Effect of Temperature on the Rate of Dissolving

10. Place three test tubes in a test tube rack. Label the tubes 1, 2, and 3. Add about 0.2 g of salt crystals to each tube. The amount added is not as important as adding equal amounts to each tube.
11. Measure the temperature of the water in the beakers from Steps 1, 2, and 3 with a thermometer. Once they have reached the desired temperatures, record the temperatures in Data Table 2 and proceed with Step 12.
12. Fill the first test tube about two-thirds full with the cold ice-water. Pour the water carefully down the side of the tube so that little mixing occurs as the water is added. Stopper the tube and invert it to dissolve all of the salt. Count the number of inversions required. Record your observations and the number of inversions required in Data Table 2.
13. Fill the second test tube about two-thirds full with room temperature water. Pour the water carefully down the side of the tube so that little mixing occurs as the water is added. Stopper the tube and invert it to dissolve all of the salt. Count the number of inversions required. Record your observations and the number of inversions required in Data Table 2.
14. Fill the third test tube about two-thirds full with the hot water sample. Pour the water carefully down the side of the tube so that little mixing occurs as the water is added. Stopper the tube and invert it to dissolve all of the salt. Count the number of inversions required. Record your observations and the number of inversions required in Data Table 2.
15. Rinse the contents of each test tube down the drain. Rinse and dry each test tube.

Part D: Effect of Surface Area on the Rate of Dissolving

16. Place three test tubes in a test tube rack. Label the tubes 1, 2, and 3.
17. Obtain two rock salt crystals that are approximately the same mass. Weigh them on a balance. Place one of the rock salt crystals into the first test tube.
18. Grind the second rock salt crystal with a mortar and pestle until it is a fine powder. Transfer the powdered salt to the third test tube.
19. Add the same mass of salt crystals to the second test tube.
20. Fill the first test tube containing the rock salt crystal about two-thirds full with water. Pour the water carefully down the side of the tube so that little mixing occurs as the water is added. Stopper the tube and invert it to dissolve all of the salt. If the number of inversions required to dissolve the crystal is greater than 25, stop and record ">25" for the number of inversions in Data Table 3.

21. Fill the second test tube containing the salt crystals about two-thirds full with water. Pour the water carefully down the side of the tube so that little mixing occurs as the water is added. Stopper the tube and invert it to dissolve all of the salt. Count the number of inversions required. Record your observations and the number of inversions required in Data Table 3.

22. Fill the third test tube containing the powdered salt about two-thirds full with water. Pour the water carefully down the side of the tube so that little mixing occurs as the water is added. Stopper the tube and invert it to dissolve all of the salt. Count the number of inversions required. Record your observations and the number of inversions required in Data Table 3.

23. Rinse the contents of each test tube down the drain. Rinse and dry each test tube.

Part E: Effect of Already Dissolved Solute on the Rate of Dissolving

24. Place two test tubes in a test tube rack. Label the tubes 1 and 2.

25. Place about 0.2 g of salt crystals in test tube 1. Fill this tube about two-thirds full with water. Pour the water carefully down the side of the tube so that little mixing occurs as the water is added. Stopper the tube and invert it to dissolve all of the salt. Count the number of inversions required. Record your observations and the number of inversions required in Data Table 4.

26. Add 0.4 g of salt crystals to test tube 2. Fill this tube about two-thirds full with water and invert (without counting) until all of the salt is dissolved.

27. Now add about 0.2 g of additional salt crystals to test tube 2. Stopper test tube 2 and invert until all of the salt is dissolved. Count the number of inversions required. Records your observations and the number of inversions required in Data Table 4.

28. Rinse the contents of each test tube down the drain. Rinse and dry each tube.

Name: ______________________

Data Tables

Data Table 1: Effect of Stirring on the Rate of Dissolving

	Observations	Number of Inversions Required
Uninverted Solution		Test tube not inverted.
Inverted Solution		

Data Table 2: Effect of Temperature on the Rate of Dissolving

	Temperature (°C)	Observations	Number of Inversions Required
Cold Solution			
Room Temperature Solution			
Warm Solution			

Data Table 3: Effect of Surface Area on the Rate of Dissolving

	Observations	Number of Inversions Required
Rock Salt		
Salt Crystals		
Powdered Salt		

Data Table 4: Effect of Already Dissolved Solute on the Rate of Dissolving

	Observations	Number of Inversions Required
Solution Containing *No* Already Dissolved Solute		
Solution Containing lready Dissolved Solute		

Name: ______________________________

Questions:

1. What is the effect of inverting the test tube on the rate of dissolving? Explain.

2. What is the effect of temperature on the rate of dissolving? Explain.

3. What is the effect of surface area on the rate of dissolving? Explain.

4. What is the effect of already dissolved solute on the rate of dissolving? Explain.

5. Why is solvation a surface phenomenon?

6. Give three examples of solutions you encounter on an everyday basis. List the solute and solvent for both examples.