Solution Concentrations

Strand Molar Relationships

Topic Determining of the concentration of a solution

Primary SOL CH.4 The student will investigate and understand that chemical quantities are based on molar relationships. Key concepts include
- c) solution concentrations.

Related SOL CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include
- b) safe use of chemicals and equipment;
- f) mathematical and procedural error analysis;
- g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis;
- h) use of appropriate technology including computers, graphing calculators, and probeware for gathering data, communicating results, and using simulations to model concepts.

CH.2 The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of
- h) chemical and physical properties.

CH.3 The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include
- a) nomenclature;
- b) balancing chemical equations;
- d) bonding types.

Background Information

Two basic measurements of solution concentration are percent composition and molarity. **Percent composition** is often used in household products and consumables. For example, the concentration of vinegar is listed as a percent composition. In the laboratory, however, we generally use molarity as the concentration measurement. **Molarity (M)** is moles of solute per liter of solution.

Materials

- Electronic balances
- Evaporating dishes
- Calculators
- Hot plates
- 10 mL pipettes
- Sodium chloride solution (about 1 Molar)

- Worksheet - Making a Molar Solution

Vocabulary

molarity, moles, percent composition, solute, solution, solvent

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

In this activity, students evaporate the water from a specific volume of salt solution, leaving the salt behind. They convert the mass of the salt into moles of the salt and then determine both the percent composition and the molarity of the original solution.

The dehydration method that follows is one example of how students can obtain the percent composition of a solution as well as calculate the molarity of the solution. Prepare the sodium chloride solution by dissolving about 58 grams of sodium chloride in one liter of water. (Other chlorides could be used, but many are hydroscopic and may not evaporate to complete dryness.)

(The molarity of a solution can also be found by titrating with a known solution, e.g., titrating a sodium chloride solution with a known concentration of silver nitrate. Many such activities are available in laboratory books and online.)

1. Obtain a clean, dry evaporating dish. (If it is not clean, wash it with hydrochloric acid, rinse it, and dry it before use.)
2. Mass the clean, dry evaporating dish. Record this mass.
3. Pipette 10 mL of sodium chloride solution into the evaporating dish.
4. Mass the evaporating dish and solution. Record this mass.
5. Slowly heat the evaporating dish on the hot plate to evaporate the water. Do not boil the water because some of the solution could splatter out of the dish, thus reducing the amount of solution. Also, it could possibly burn someone.
6. When the liquid has evaporated, heat the evaporating dish at a higher temperature for 3 minutes to make sure that it is completely dry.
7. Allow the evaporating dish to cool completely.
8. Mass the evaporating dish and salt. Record this mass.
9. Subtract the mass of the clean, dry evaporating dish from the mass of the dish with the salt to get the mass of the salt.
10. Subtract the mass of the clean, dry evaporating dish from the mass of the dish with the solution to get the mass of the solution.
11. Divide the mass of the salt by the mass of the solution to obtain the percent composition of the solution.
12. Divide the mass of the salt by the molar mass of the salt (58.5 g/mol for sodium chloride) to obtain the number of moles.
13. Divide the number of moles by 0.01 L (10 mL) to obtain the molarity (M).

Assessment

- **Questions**
  - What are the molar masses of $CaCl_2$, KCl, and KI? Show your calculations.

  - How would you make a 0.9% solution of sodium chloride from a 1.00 M solution of sodium chloride? Explain.
  - If more water is added to a solution, what happens to the molarity of the solution?
  - What volume in liters of 33.6 M formic acid is needed to make 5.0 L of 2.0 M formic acid (HCOOH)?
  - Concentrated sulfuric acid has a molarity of 18.0 M. About how much water should be added to the concentrate to make 360 mL of 4.5 M sulfuric acid?
  - What volume of 2.0 M phosphoric acid can be made from 300 mL of concentrated phosphoric acid (14.8 M)?
  - What volume of 3.0 M ammonium hydroxide is required to neutralize 10 mL of concentrated nitric acid (15.9 M)?
- **Journal/Writing Prompts**
  - Calcium chloride is deliquescent. Explain why that makes it unsuitable for use in the experiment.
  - Municipal water systems treat the water before it is delivered to users. Identify and explain the chemicals that are added, including their concentrations. Explain what may need to be reduced in your local water system, and why.
- **Other**
  - Have students calculate the masses of the identified chemicals that are needed to make the following solutions:
    - 1.0 liter of a 1.0 M Iron (II) chloride ($FeCl_2$) solution
    - 2.5 liters of a 1.5 M sodium nitrate ($NaNO_3$) solution
    - 3.0 liters of a 0.5 M $Mg(OH)_2$ solution
    - 100 mL of a 1.5 M $(NH_4)_2SO_4$ solution
  - Have students calculate the molarity of the following solutions:
    - 12 g of sodium hydroxide (NaOH) in 1.0 L of solution
    - 198 g of barium hydroxide [$Ba(OH)_2$] in 2.0 L of solution
    - 54 g of calcium sulfate ($CaSO_4$) in 2.0 L of solution
  - Have students calculate the volume in liters of each of the following solutions:
    - 0.10 M solution containing 25 g of silver nitrate ($AgNO_3$).
    - 0.50 M solution containing 250 g of iron (II) sulfate ($FeSO_4$).
    - 1.5 M solution containing 235 g of aluminum nitrate [$Al(NO_3)_3$].

Extensions and Connections (for all students)

- Solutions of drinks like lemonade and orange juice are made from concentrated solids. Ask students how the addition of water affects the drink's taste when (1) too much water is added or (2) when too little water is added.
- Have students explain why it is important for substances like saline solution and liquid cough medication to be prepared with precise measurements.
- Have students complete the attached Making a Molar Solution activity.

Strategies for Differentiation

- Have high ability students use a photo spectrometer, if available, to analyze solutions to determine concentrations in comparison to a known standard.

Making a Molar Solution

Purpose

To become familiar with the concept of molarity and practice making solutions of different volumes and concentrations.

Procedure

You will make and compare three solutions, using an unknown compound with a molecular mass of 58.5 g/mol.

Solution A: 50.0 mL of a 1.00 M solution
Solution B: 75.0 mL of a 2.00 M solution
Solution C: ___ mL of a 0.50 M solution

1. Calculate the grams of solute needed to complete each solution. Show your work!
2. Mass out the grams of solute needed for solutions A and B into a 150 mL beaker.
3. Add the correct volume of water to make each solution, and stir each solution thoroughly.
4. Make a second solution A exactly like the first.
5. Determine how many moles of solute are in this second solution A. Using this mixture, calculate how many mL of water are needed to form a 0.50 M solution.
6. Dilute your second solution A to the calculated volume. Record this volume for solution C.
7. Compare the color of the solutions, using a scale of 1 to 3 with 1 being the lightest.

Data Table

Solution	Concentration (M)	Volume (mL)	Mass of Solute (g)	Color Intensity (Scale 1–3)
A				
B				
C				

Conclusion

1. Answer the following questions in paragraph form with no personal pronouns.
   - What did you accomplish in this lab?
   - What did you find?
2. What is the relationship between concentration and color intensity?
3. Does color intensity depend on the amount of solute, the volume, or both? Explain.