Key

ChemQuest 39

Concentration

Name: _____

Date: _____

Hour: _____

Information: Molarity

Concentration is a term that describes the amount of solute that is dissolved in a solution. Concentrated solutions contain a lot of dissolved solute, but dilute solutions contain only a little.

Critical Thinking Questions

1. Consider the terms "concentrated" and "dilute". Are these qualitative or quantitative terms?
   These are qualitative terms: very general and do not include the magnitude or quantity.

2. One way of quantitatively measuring solution concentration is with units of molarity, symbolized by M. You see 1.7 liters (L) of a sodium chloride and water solution. The label on the bottle reads "1.5 M NaCl". You don't know what molarity is, but you decide to find out. After evaporating the water out of the solution you discover that there are about 149 grams of salt. Using this information, which of the following formulas is/are correct for finding molarity?

   A) $\text{Molarity} = \frac{\text{grams of solute}}{\text{moles of solute}}$

   149g ÷ 58.5g/mol = 2.547 mol

   (B) $\text{Molarity} = \frac{\text{moles of solute}}{\text{liters of solution}}$

   1.5 = 2.547 mol ÷ 1.7 L

3. Using the equation you discovered in question two, calculate the molarity of each of the following solutions.

   A) A solution is prepared by dissolving 24.9 g of $CaCl_2$ in 210 mL (which 0.210 L) of solution.

   1.07 M

   Change g to mol: 24.9g ÷ 111.1g/mol = 0.224 mol
   Molarity = mol ÷ L = 0.224 ÷ 0.210 = **1.07 M**

   B) A solution contains 12.9 g of Na_2SO_4 in 325 mL of solution.

   0.279 M

   Change g to mol: 12.9 ÷ 142.1g/mol = 0.09078 mol
   Molarity = mol ÷ L = 0.09078mol ÷ 0.325L = **0.279 M**

4. Verify that I need 2.15 moles of $Ca(NO_3)_2$ to make 358 mL of a 6.00 molar solution.

   mol = (Molarity)(Liters) = (6.00M)(0.358L) = 2.15 mol

5. Verify that it takes 80.8 g of sodium chloride to make 425 mL of a 3.25 M solution.

   mol = (Molarity)(Liters) = (3.25M)(0.425L) = 1.38 mol
   (1.38 mol)(58.5g/mol) = 80.7 g

6. Consider 670 mL of a 4.10 M solution of $Mg(NO_3)_2$ setting in a beaker. If you evaporate all 670 mL of the solution, how many grams of solute would be left in the beaker?

407.8g mol = (Molarity)(Liters) = (4.10M)(0.670L) = 2.747 mol
convert mol to g: (2.747mol)(148.3g/mol) = **407.8g**

Information: Molality

Molality is another way of expressing solution concentration. The symbol for molality is m. Whereas molarity (M) represents the ratio of moles solute to liters of solution, the molality (m) is the ratio of moles solute to kilograms of solvent. It can be expressed using the following formula:

$$\text{molality} = \frac{\text{moles of solute}}{\text{kg solvent}}$$

Critical Thinking Questions

7. Consider a solution that is prepared by adding 1.34 moles of sodium nitrate to 2.5 kg of water. What is the molality of the solution?

0.536 m m = 1.34mol ÷ 2.5kg = 0.536 m

8. Considering the data given in question 7, is this enough data to find the molarity? If so, calculate the molarity. If not, explain why not.

No, because we don't know the total volume of the solution.

9. What is the molality of a solution that is made by dissolving 32.6 g of Na_2SO_4 in 475 g of water?

0.483 m Convert g to mol: 32.6g ÷ 142.1g/mol = 0.229 mol
molality = mol/kg = 0.229mol ÷ 0.475kg = **0.483 m**

10. Consider 2.35 moles of sodium chloride are dissolved in 1.21 kg of solution to make 1.29 liters. Calculate and compare the molarity and molality.

Molarity: 1.82 M M = mol ÷ L = 2.35mol ÷ 1.29 L = 1.82 M

molality: 1.94 m m = mol ÷ kg = 2.35mol ÷ 1.21 kg = 1.94 m

11. If 26.45g of Na_2SO_4 are dissolved in 1.10 kg of solution to make 1.24 L, calculate both the molarity and the molality of the resulting solution.

Convert g to mol: 26.45g ÷ 142.1g/mol = 0.186mol

Molarity: 0.150 M M = mol ÷ L = 0.186mol ÷ 1.24 L = 0.150 M

molality: 0.169 m m = mol ÷ kg = 0.186mol ÷ 1.10kg = 0.169 m

Information: Mole Fraction

Another way of expressing solution concentration is called "mole fraction". The mole fraction (symbolized by X) of the solute or of the solvent can be calculated using the following equations:

$$X_{solute} = \frac{mol_{solute}}{(mol_{solute} + mol_{solvent})} \qquad X_{solvent} = \frac{mol_{solvent}}{(mol_{solute} + mol_{solvent})}$$

Note: both the solute and the solvent must be converted to moles when finding the mole fraction!

Critical Thinking Questions

12. Prove that the mole fraction of salt (X_{NaCl}) equals 0.049 when 14.25 g of NaCl is dissolved in 85.0 g of H_2O.

    14.25g ÷ 58.5g/mol = 0.2436 mol NaCl 85.0g ÷ 18.0g/mol = 4.722 mol H_2O

$$X_{NaCl} = \frac{mol_{NaCl}}{(mol_{NaCl} + mol_{H_2O})} = \frac{0.2436}{(0.2436 + 4.722)} = 0.049$$

13. Find the mole fraction of water (X_{water}) for the solution described in question 12.

$$X_{H_2O} = \frac{mol_{H_2O}}{(mol_{H_2O} + mol_{NaCl})} = \frac{4.722}{(0.2436 + 4.722)} = 0.951$$

14. Prove that $X_{solute} + X_{solvent} = 1$.

    The answer from question 12 ÷ answer to question 13 = 1

15. In a certain salt water solution, the mole fraction of salt is 0.18. Find the mole fraction of water.

    1.00 – 0.18 = 0.82

Information: Mass Percent Composition

Mass percent composition is similar to the mole fraction except the amounts of solute and solvent are in grams instead of moles. Here is the formula for finding the mass percent of a solute:

$$mass\%_{solute} = \frac{mass_{solute}}{(mass_{solute} + mass_{solvent})} \cdot 100$$

Critical Thinking Questions

16. Prove that the mass percent of salt is 14.36% in the solution described in question 12.

$$mass\%_{NaCl} = \frac{mass_{NaCl}}{(mass_{NaCl} + mass_{H_2O})} \cdot 100 = \frac{14.25}{14.25 + 85.0} \cdot 100 = 14.36\%$$

17. Calculate the mass percent of sodium phosphate if 12.5g of it are dissolved in 250 mL of water. (Note: 1 mL of water has a mass of 1 g.)

    Because 1 mL = 1g, the mass of H_2O = 250 g

$$mass\%_{Na_3PO_4} = \frac{mass_{Na_3PO_4}}{(mass_{Na_3PO_4} + mass_{H_2O})} \cdot 100 = \frac{12.5}{12.55 + 250} \cdot 100 = 4.76\%$$

Skill Practice 39

Concentration Practice

Name: _____

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1. What is the mass percent of calcium chloride if 45 g of $CaCl_2$ is dissolved in 320 g of water?
   12.3%

2. A solution is prepared by dissolving 32 g of salt in 278 g of water.
   A) What is the mole fraction of salt in the solution?
   0.034

   B) What is the mole fraction of water in the solution?
   0.966

3. How many grams of calcium nitrate needs to be added to 400 g of water to make a solution that is 12.5% by mass of $Ca(NO_3)_2$?
   57.1 g

4. A certain solution of salt water has a molality of 3.25 m.
   a) What is the mole fraction of salt in the solution?
   0.0554

   b) What is the mass percent of salt in the solution?
   16.0%

5. If 325 mL of a solution was prepared by dissolving 83.8g of Na_3PO_4 in 310 g of water…
   a) What is the molarity of the solution?

   1.57 M

   b) What is the molality of the solution?

   1.65 m

6. Describe how you could prepare 200 mL of a solution that is 1.2 M NaCl.

   14.0 g of NaCl dissolved in water, then dilute to 200 mL