ChemQuest 53

Molarity

Name: ______________________________

Date: ________________

Hour: _____

Introductory Questions

1. Consider two solutions:

Solution A	Solution B
Made by dissolving 4 grams of	Made by dissolving 6 grams

a) Which solution contains the most salt?

b) Which solution would taste the saltiest if you drank some?

c) You've probably heard the term "concentrated" before. There's concentrated orange juice and concentrated dish soap. Above, the solution that tastes the saltiest is the most concentrated. What does it mean to say that a solution is "concentrated"?

2. Consider two more solutions:

Solution X	Solution Y
Made by dissolving 12 grams	Made by dissolving 20 grams

Why can't you tell which solution is the most concentrated?

Information: Concentration

In the introductory questions, hopefully you have discovered that you need two pieces of information to know how concentrated a solution is—(1) the amount of solute dissolved and (2) the volume of the liquid.

Here's a formula to calculate the concentration of a solution. Concentration is given in units called, "molarity."

$$Molarity = \frac{moles\ of\ solute}{liters\ of\ solution} \qquad \text{or in symbols: } M = \frac{mol}{L}$$

Also, remember that to get moles from grams you can use this equation: $mol = \frac{grams}{molar\,mass}$

Critical Thinking Questions

3. A solution is made by dissolving 24 g of NaCl to make 475 mL of solution. Calculate the concentration in units of molarity by following these steps:

    a) Convert the grams of NaCl to moles of NaCl.

    b) Calculate the liters of solution by dividing the given milliliters by 1000.

    c) Divide moles by the liters of solution.

4. Calculate the concentration (in units of molarity) of the following solutions:

    a) 42.1 g of $Ca(NO_3)_2$ in 700 mL of solution.

    b) 25.9 g of Na_2SO_4 in 575 mL of solution.

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

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

7. 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?

Information: Dissociation (Breaking Into Ions)

When an ionic compound dissolves it dissociates, or breaks up into ions. Calcium chloride dissociates as follows: $CaCl_2 \rightarrow Ca^{+2} + 2\ Cl^-$

Note that for each $CaCl_2$ that dissolves there are two Cl^- ions and one Ca^{+2} ion in the solution. So if one mole of calcium chloride ions dissolve you will have two moles of Cl^- ions and one mole of Ca^{+2} ions in solution. Notice also that chloride ions are written "Cl^-" and NOT "Cl_2". The reason for this is that chlorine *atoms* are diatomic, but chlorine *ions* are not.

Critical Thinking Questions

8. If you dissolve 3.5 moles of $CaCl_2$ in solution, how many moles of Ca^{+2} ions and Cl^- ions will there be in the solution?

9. Consider a 2.5 M solution of $CaCl_2$. (The "M" stands for molarity, so the concentration of $CaCl_2$ is 2.5 M—meaning that there are 2.5 moles of $CaCl_2$ in each liter of solution.)

   a) What is the concentration of Ca^{+2} ions in the solution?

   b) What is the concentration of Cl^- ions in the solution? (Hint: remember that there is twice as much Cl^- as there is $CaCl_2$ because of the balanced equation.)

10. Write the dissociation equation for dissolving Na_3P.

11. Calculate the molarity of a solution of Na_3P formed by dissolving 85 grams of it to make 720 mL of solution.

12. Given your answer to question 11 and the reaction you wrote in question 10, calculate the molarity of the sodium ions (Na^+) in the solution.

13. Write the dissociation equation for $Al(NO_3)_3$.

14. Calculate the molarity of a solution of $Al(NO_3)_3$ formed by dissolving 65 grams of it to make 875 mL of solution.

15. Given your answer to question 14 and the reaction you wrote in question 13, calculate the molarity of the nitrate ions (NO_3^-) in the solution.

ChemQuest 54

More Units of Concentration

Name: ____________________________

Date: ________________

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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

1. 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?

2. Considering the data given in question 1, is this enough data to find the molarity? If so, calculate the molarity. If not, explain why not.

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

4. 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.

5. 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.

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

6. 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.

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

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

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

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:

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

Critical Thinking Questions

10. Prove that the mass percent of salt is 14.36% in the solution described in question 6.

11. 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.)

ChemQuest 55

Colligative Properties

Name: ______________________________

Date: ________________

Hour: _____

Introduction Question: Melting Ice

1. In colder climates during the winter, people put salt on the roads and walkways to melt ice. Why do people do this? Why does salt melt the ice?

Information: Dissociation and Total Molality of Particles

When you dissolve a solute in a solvent, the resulting solution has slightly different properties than the original solvent. For example, salt water has a different freezing point and boiling point than pure water. The salt interferes with water's ability to freeze and boil.

When ionic compounds dissolve, they dissociate. When an ionic compound dissociates that means that it breaks up into ions. For example, salt (sodium chloride) breaks up into sodium ions and chloride ions. This process is represented in the following balanced equation:

$$NaCl \rightarrow Na^{+} + Cl^{-}$$

Note for the above equation that Cl^{-} does not need to be written as Cl_2 because Cl^{-} is a chloride ion and not a lone chlorine atom.

Since calcium nitrate is an ionic compound it also dissociates as shown below:

$$Ca(NO_3)_2 \rightarrow Ca^{2+} + 2\ NO_3^{-}$$

Covalent molecules do not dissociate. Although they may dissolve, they do not break up into ions.

Critical Thinking Questions

2. Write the balanced equation for the dissociation of magnesium chloride.

3. Write the balanced equation for the dissociation of ammonium sulfate.

4. Consider calcium nitrate. Each calcium nitrate breaks up into one calcium ion and two nitrate ions according to the balanced equation given in the information section. If you take one mole of calcium nitrate and put it in water, it will dissociate.
   a) How many moles of calcium ions and how many moles of nitrate ions will there be in the solution?

   b) What is the total number of moles of all ions in the solution?

5. A solution is made so that it is 2.5 M $Ca(NO_3)_2$. Therefore the concentration of Ca^{2+} is 2.5 M and the concentration of NO_3^- is 5.0 M. The total concentration of all particles is 7.5 M. Explain.

6. A solution is made so that it the concentration is 3.0 m $MgCl_2$. What is the molality of Mg^{2+} and Cl^- ions? What is the total molality of all particles in the solution?

   Mg^{2+} ________ Cl^- _________ Total molality of all particles: _____________

7. A solution is prepared by dissolving 45.7 g of sodium carbonate in 200 g of water.
   a) What is the molality of the sodium carbonate?

   b) What is the total molality of all particles in the solution?

8. Consider sugar ($C_6H_{12}O_6$) , a covalent molecule. If a solution is made so that the concentration is 3.5 m in sugar, then what is the total molality of particles?

Information: Total Molality of Particles and Changes in Boiling/Freezing Points

You may be wondering how all of this ties together. We have seen that adding a solute changes the boiling and freezing points of solvents. The amount of the change depends on how much solute is added. Equations relating the change in boiling or freezing point and the molality is shown below:

$\Delta T_{bp} = (m_T)(K_{bp})$ for boiling point $\Delta T_{fp} = (m_T)(K_{fp})$ for freezing point

Note: m_T is the total molality of particles. K_{bp} and K_{fp} are constants called the molal boiling point elevation constant and the molal freezing point depression constant respectively. K_{bp} for water is 0.515 $^oC/m$ and K_{fp} for water is 1.853 $^oC/m$.

Critical Thinking Questions

9. What is the freezing point of a 2.5 m solution of salt water. Hints: first find ΔT_{fp} and then subtract the change from the original freezing point (0^oC for water). Also, remember m_T is not 2.5 m in this problem.

10. Find the boiling point of a 3.7 m solution of calcium chloride.

11. What is the freezing point of a sugar solution in which the concentration of sugar is 2.25m? Note: sugar is covalent so it dissolves but it does not dissociate.

Information: Raoult's Law

A solution will almost always have a lower vapor pressure than the pure solvent. For example, salt water will have a lower vapor pressure than pure water. The vapor pressure of a solution ($P_{solution}$) is related to the vapor pressure of the pure solvent ($P_{solvent}$) by the mole fraction of the solvent ($X_{solvent}$) in an equation known as Raoult's Law:

$$P_{solution} = (X_{solvent})(P_{solvent})$$

Critical Thinking Questions

12. What is the vapor pressure of water at 20^oC is 2.3 kPa. What is the vapor pressure of a solution formed by dissolving 21.5g of LiCl in 84.3g of H_2O?