Key

Solutions and Molarity

(When is it dissolved, and when is it suspended?)

Suggested demonstration: Solutions, colloids, and suspensions

Information:

When two substances are mixed together and the mixture is homogeneous, we call the mixture a **solution**. The component of a solution in the greater amount is the **solvent**, and the component in the lesser amount is the **solute**. The most common solvent on earth is water. Solutes that dissolve in water may be solids (*e. g.*, salt or sugar), liquids (*e. g.*, alcohol) or gases (*e. g.*, ammonia or oxygen).

Each solute has a particular ***solubility*** *in water—often reported as the maximum number of* grams of the solute that will dissolve in 100 grams of water. A solution containing the maximum amount of dissolved solute is called a **saturated solution**.

If the solute particles are large enough to be seen (they scatter light, making the mixture *cloudy*) but not to settle out, the mixture is called a **colloid**. If the particles are larger still and can settle out over time, the mixture is called a **suspension**.

Critical Thinking Question:

1.* Label each of the following as a solution, colloid, or suspension. * Assume each sample was vigorously shaken, so that only 1 phase appears initially.

a. tomato juice

b. fog colloid

c. apple juice solution for filtered, suspension for unfiltered

d. Italian salad dressing suspension

e. tea sol'n

f. muddy water suspension

g. homogenized milk sol'n

h. cola sol'n (ignore CO_2 bubbles)

2. In each of the following mixtures, name the solvent and at least one solute.

Mixture	Solvent	Solute(s)
fog	air	H_2O
apple juice	H_2O	glucose
cola	H_2O	glucose
NaCl(aq)	H_2O	Na^+, Cl^-

Information:

The measure of the amount of solute dissolved in a specified amount of solution is called the **concentration** of the solution. The most common measure of concentration is **molarity**.

Molarity (M) – the moles of **solute** per liter of **solution**: $M = \frac{moles\ of\ solute}{L\ of\ solution} = \frac{mol}{L}$

For example, battery acid is approximately 6 M H_2SO_4. This means that there are 6 moles of sulfuric acid in every liter of solution. We can write two conversion factors:

$$\frac{6 \text{ moles } H_2SO_4}{1 \text{ L}} \text{ and } \frac{1 \text{ L}}{6 \text{ moles } H_2SO_4}$$

Note how we assume—but didn't actually *write*—the word "solution" with the "1 L."

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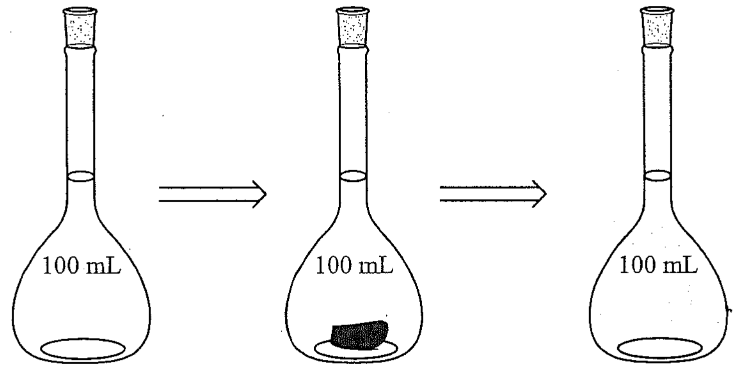
Suggested Demonstration: How to make a solution of a particular molarity

Model 1: How to make 100 mL of a 2.0-molar (2.0 M) aqueous solution of a solid



empty 100-mL volumetric flask — place 0.200 moles of solid in flask — dilute to the mark with water and mix well

Note: volumetric flasks come in standard sizes, such as 25 mL, 50 mL, 100 mL, 250 mL, 500 mL, 1 L, *etc.*

Critical Thinking Questions:

3. In Model 1, only two-tenths of a mole of a solid was used to make a 2.0-molar solution. Explain how this is possible.

   $\frac{.2\text{ mole}}{} \left| \frac{L}{2.0\text{ mol}} \right.$ = only 0.1 L of sol'n can be prepared

4. An experiment calls for 50. mL of a 0.50 M aqueous solution of sodium hydrogen carbonate (sodium bicarbonate, or baking soda). *Describe* (with amounts) the steps you would use in order to make up such a solution, such that you have none left over.

   $\frac{50\text{ mL}}{} \left| \frac{1\text{ L}}{10^3\text{ mL}} \right| \frac{0.50\text{ mol } NaHCO_3}{1\text{ L}} \left| \frac{84.01\text{ g}}{1\text{ mol } NaHCO_3} \right. = 2.1\text{ g } NaHCO_3$

   Weigh 2.1g $NaHCO_3$ to a 50mL volumetric flask. Add deionized water to the 50mL mark. Cap & mix well.

Information:

When **diluting** a solution, the moles of the solute do not change. Therefore,

$$\text{moles (before)} = \text{moles (after)} \quad \textit{or} \quad mol_1 = mol_2$$

Since M= mol/L, (M × L) is equal to moles. So we can write:

$$M \times L\text{ (before)} = M \times L\text{ (after)}$$

or

$$M_1V_1 = M_2V_2 \text{ (where V = volume)} \quad \text{or } C_1V_1 = C_2V_2 \qquad (1)$$

This is an equation that can be used for **dilutions**. It may also be rearranged to give:

$$M_2 = \frac{M_1V_1}{V_2} \qquad (2)$$

Hypotonic and Hypertonic Solutions

(Is it more concentrated or more dilute?)

Information: Units of concentration

The *concentration* of a solution is a measure of the amount of solute dissolved in a specified amount of solution. A solution that is more *concentrated* has more solute per unit of volume than one that is more *dilute*.

We saw in ChemActivity 24 that the most common measure of concentration is molarity.

Molarity (M) – the moles of solute per liter of solution: $M = \frac{moles\ of\ solute}{L\ of\ solution} = \frac{mol}{L}$

The other common measures of concentration are not done using moles, but using either mass (weight) or volume. These are commonly reported in percent. "Percent by weight" and "percent by volume" are common terms, and may be represented as %(w:w) or %(v:v). Weights (or masses) are in grams, and volumes in milliliters. The first letter in the parenthesis represents the units of the **solute**, and the second is for the **solution**.

Since *percent* means "*per hundred*," a 3.2%(v:v) aqueous solution of alcohol would mean 3.2 mL of alcohol are in every 100 mL of solution. We can write this as a conversion factor:

$$\frac{3.2\text{ mL alcohol}}{100\text{ mL}} \quad \text{and} \quad \frac{100\text{ mL}}{3.2\text{ mL alcohol}}$$

Note how we assume—but didn't actually *write*—the word "solution" with the "100 mL."

Critical Thinking Questions:

1. Write the two conversion factors for each of the following concentrations.
   a. 10%(v:v) acetone in water $\frac{10\text{ mL acetone}}{100\text{ mL sol'n}}$ or $\frac{100\text{ mL soln}}{10\text{ mL acetone}}$
   b. 0.90%(m:v) NaCl(aq) $\frac{.90\text{ g NaCl}}{100\text{ mL sol'n}}$ or $\frac{100\text{ mL sol'n}}{.90\text{ g NaCl}}$
   c. 5.0%(w:w) $NaHCO_3$(aq) $\frac{5.0\text{ g } NaHCO_3}{100\text{ g sol'n}}$ or $\frac{100\text{ g sol'n}}{5.0\text{ g } NaHCO_3}$
   d. 5.0%(w:v) $NaHCO_3$(aq) $\frac{5.0\text{ g } NaHCO_3}{100\text{ mL sol'n}}$ or $\frac{100\text{ mL}}{5.0\text{ g } NaHCO_3}$
2. The solutions in CTQ 1 (c) and (d) are often considered to be the same concentration even though the units are different. Explain how this can be. (Hint: What is the density of water?)

   $d_{H_2O} = \frac{1\text{ g}}{\text{mL}}$ ∴ $1\text{ g } H_2O \approx 1\text{ mL } H_2O$

3. Sometimes when concentrations are reported for aqueous solutions of solids, they do not say whether they are by mass or by volume. Explain why it is probably okay to assume they are %(m:v).

   b/c $1\text{ g } H_2O \approx 1\text{ mL } H_2O$

4. Percent means parts per hundred. We can also report concentrations in parts per thousand (ppt), parts per million (ppm), or parts per billion (ppb). The EPA safe limit for lead in drinking water is 15 ppb. Write the two conversion factors for this concentration.

$15\ ppb = \frac{15\ g\ Pb}{1{,}000{,}000{,}000\ mL\ soln}$* or $\frac{1{,}000{,}000{,}000\ mL\ soln}{15\ g\ Pb}$

* see previos question

Information: Hypotonic and hypertonic solutions

Osmotic pressure (π) is the pressure that water exerts against a semipermeable membrane, such as a cell membrane. *The* ***higher*** *the* ***solute*** *concentration, the* ***lower*** *the osmotic pressure.* Red blood cells have an osmotic pressure equal to that of a 0.90% (m:v) solution of sodium chloride. In this solution, since there are 2 moles of ions per mole of NaCl, the concentration of **ions** is twice as much, or 1.8% (m:v).

A solution that has a higher ion concentration than this is called **hypertonic**; one with a lower ion concentration is called **hypotonic**. It is important when giving fluids intravenously that they be isotonic, to avoid hemolysis (bursting) or crenation (shriveling) of red blood cells.

Critical Thinking Questions:

5. Given the definitions of the terms *hypotonic* and *hypertonic*, what do you suppose an *isotonic* solution would be?

A solution w/ the same total solute concentration as RBC (red blood cells).

6. Is a 1.0 M solution of NaCl hypotonic, hypertonic, or isotonic to red blood cells? (Hint: Convert to % m:v—make a unit plan!)

$\frac{0.90\ g\ NaCl}{100\ mL} \times \frac{1\ mol}{58.35\ g} \times \frac{10^3\ mL}{mol} = 0.15\ M\ NaCl$

1.0 M NaCl is hypertonic.

7. An experiment calls for 10.0 mL of a 4.00% aqueous solution of sodium tetraborate ("borax"). Describe how you would make up such a solution so that you will not have any left over.

$10.0\ mL\ soln \times \frac{4.00\ g\ borax}{100\ mL} = 0.400\ g\ borax$ dissolved in a 10 mL volumetric flask

Information:

Electrolytes in blood are often measured in equivalents per liter (Eq/L). An *equivalent* of an ion is the amount of that ion that gives 1 mole of positive or negative charge. This gives rise to conversion factors such as:

1 mol Na^+ = 1 Eq Na^+ 1 mol Ca^{2+} = 2 Eq Ca^{2+} 1 mol SO_4^{2-} = 2 Eq SO_4^{2-}

Critical Thinking Questions:

8. A patient has a blood calcium level of 4.6 mEq/L.
   a. Write the two conversion factors for converting moles of calcium into equivalents of calcium.

   $\frac{4.6 \text{ mEq } Ca^{2+}}{1 \text{ L}}$ or $\frac{1 \text{ L}}{4.6 \text{ mEq } Ca^{2+}}$

   b. Write a **unit plan** to convert mEq/L into mol/L.

   $\frac{\text{mEq}}{\text{L}} \Big| \frac{1 \text{ mmol}}{2 \text{ mEq}} \Big| \frac{1 \text{ mol}}{10^3 \text{ mmol}}$

   c. What is the patient's blood calcium level in molarity?

   $\frac{4.6 \text{ mEq } Ca^{2+}}{1 \text{ L}} \Big| \frac{1 \text{ mmol } Ca^{2+}}{2 \text{ mEq } Ca^{2+}} \Big| \frac{1 \text{ mol}}{10^3 \text{ mmol}} = 2.3 \times 10^{-3} \text{ M } Ca^{2+}$

$1 \text{ mmol } Ca^{2+} = 2 \text{ mEq } Ca^{2+} = 40.08 \text{ mg } Ca^{2+}$

Exercises:

1. What is the blood calcium level of the patient in CTQ 8 in mg/dL? (Unit plan!)

   $\frac{4.6 \text{ mEq } Ca^{2+}}{\text{L}} \Big| \frac{40.08 \text{ mg } Ca^{2+}}{2 \text{ mEq}} \Big| \frac{1 \text{ L}}{10 \text{ dL}} = 9.2 \text{ mg/dL}$

2. If the lead level in some drinking water is 15 ppb, how many mL of the water would a person have to drink in order to ingest one gram of lead? (Unit plan!)

   $\frac{1 \text{ g Pb}}{} \Big| \frac{10^9 \text{ mL water}}{15 \text{ g Pb}} = 6.7 \times 10^7 \text{ mL water}$

3. Is a 0.9 M $CaCl_2$ solution isotonic to red blood cells? Explain why or why not, without doing a calculation.

   If 1.0 M NaCl is hypertonic, then 0.9 M $CaCl_2$ is also hypertonic since there are 3 moles of ions released.

   $NaCl \rightarrow Na^+ + Cl^-$ $CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$