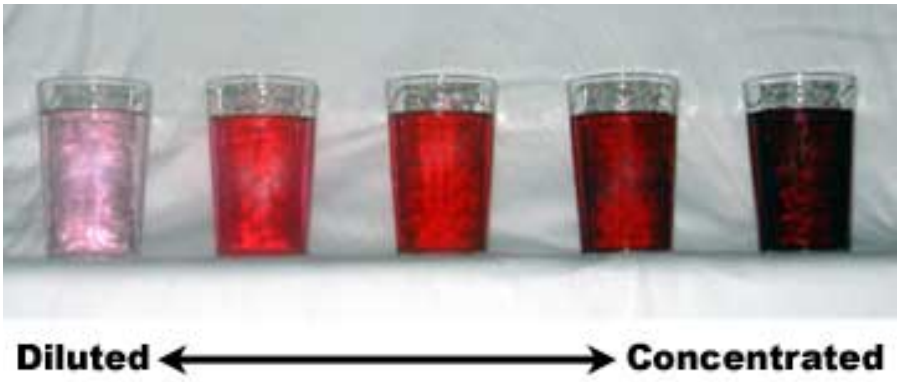
4.2 Concentration

pg 117-120 in Heath
pg 462-466 in Matter and Change



Solution Concentration Handout

SOLUTION CONCENTRATIONS

There are many different ways to express concentrations:

1. **Using Percents to Describe Concentrations:**

i) Percent by mass:

- Also called weight percent or percent by weight.
- Usually describes solutions in which a solid is dissolved in a liquid.
- $$\text{Percent by Mass} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$
- the mass of the solution is equal to the mass of the solute plus the mass of the solvent .

Example 1: A solution consists of 30 grams of sodium chloride and 70 grams of water would be 30% sodium chloride by mass

$$\frac{30\text{g NaCl}}{(30\text{g NaCl} + 70\text{g of water})} \times 100 = 30\%$$

ii) Percent by Volume:

- Typically used for mixtures of liquids.

$$\text{Percent by Volume} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100$$

Example: If we mix 30mL of ethanol and 70mL of water, the percent ethanol by volume will be 30%. Note that 30mL of ethanol and 70mL of water will NOT be exactly 100mL but is will be close – this is because of the molecules of ethanol and water will behave differently with each than they do with themselves.

2. **Mass per unit volume:**
   - Often used when describing how soluble a material is in water.
   - Ex. The solubility of a substance *X* is 3 grams per litre.
   - Units: mg/mL, mg/cm^3 (note that 1mL = 1cm^3)

3. **Molarity (*M*)**
   - The number of moles of solute dissolved in 1 litre of solution.

$$\text{Molarity}(M) = \frac{\text{moles of solute}}{\text{litres of solution}}$$

   - Changes slightly with temperature because volume can change with temperature.

Example: If we have 90 grams of glucose (molar mass = 180grams per mole) this would be 0.50 moles of glucose. If we place this in a flask and add water until the total volume is 1L we would have a 0.5 molar solution.

4. **Molality (*m*)**
   - The number of moles of solute dissolved in one kilogram of solvent. *Key difference from molarity is that molality uses mass rather than volume and uses solvent rather than solution.
   - Does not change with temperature because mass remains constant.

$$\text{Molality}(m) = \frac{\text{moles of solute}}{\text{kilograms of solven}}$$

SOLUTION CONCENTRATIONS

5. **Parts per million (PPM)**
   - Works like percent by mass but makes more sense when there is only a small amount of solute present.

$$\text{PPM} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 1000000$$

   - A solution with a concentration of 1ppm has 1 gram of substance for every million grams of solution or think of it as 1ppm implies one milligram of solute per litre of solution.
     - 1ppm = 1mg/L
   - 1% = 10 000ppm, therefore – something that has a concentration of 300ppm could also be said to have a concentration of (300ppm)/(10 000ppm/percent)=0.03% by mass.

6. Parts per billion (PPB)
   - One particle of a given substance for every 999,999,999 other particles.

$$PPB = \frac{mass\ of\ solute}{mass\ of\ solvent}\ x\ 10^9$$

7. **Mole Fraction**
   - The ratio of the number of moles of a solute in solution to the total number of moles of solute and solvent.
   - X is commonly used for mole fraction with a subscript to indicate the solvent or solute.

$$X_A = \frac{n_A}{n_A + n_B}$$

Often, we are concerned with how much solute is dissolved in a solvent.

A solution with a relatively small amount of solute dissolved is called a **dilute** solution.

Likewise, we call a solution with a relatively large amount of solute a **concentrated** solution.

Note that these terms are strictly qualitative. They do not tell us anything about the actual amount of solute but are useful in comparing solutions. However; there are multiple ways that we can quantitatively express the concentration of a solution (see handout)

1a. Percent by Mass: In order to maintain a sodium chloride concentratior similar to ocean water, an aquarium must contain 3.6g NaCl per 100.0g of water. What is the percent mass of NaCl in the solution?

1b. Percent by Volume: What is the percent by volume of ethanol in a solution that contains 35 mL of ethanol dissolved in 115mL of water?

3. Molarity (M): the amount of moles dissolved in 1 liter of a solution. This is a measure of concentration. The units for this are M, mols/L, or mols L^{-1}.

$$C = \frac{\#\ of\ moles\ of\ solute}{V} \qquad where\ C = concentration\ or\ molarity\ \left(\frac{moles}{L}\right)$$
$$V = volume\ of\ solution\ (L)$$

Ex) What is the molarity of a 3.50 L solution containing 2.86 moles of NaCl?

Keep in mind that molarity takes into account the volume of **both** the solute and the solvent, and not **just** the solvent. Or, the volume of the **solution**.

We can express the concentration of a solution as "0.50 M NaOH".

Square brackets may also be used to express concentration.

Ex) [NaOH] = 0.50 M

Another equation to calculate molarity is:

$$C = \frac{\text{wt}}{\text{mm}V}$$

where: C = concentration or molarity $\left(\frac{moles}{L}\right)$

wt = mass (g)

mm = molar mass of solute $\left(\frac{g}{mol}\right)$

V = volume of solution (L)

Ex) Antifreeze is a solution of ethylene glycol, $C_2H_6O_2$ in water. If 4.50 L of antifreeze contains 27.5 g of ethylene glycol, what is the concentration of the solution?

Ex) What mass of sodium carbonate, Na_2CO_3 is present in 50.00 mL of a 0.750 M solution?

Ex) What volume of 1.50 mol/L HCl solution contains 10.0 g of hydrochloric acid?

5. Parts per Million (ppm) - ppm is defined as the number of parts solute for every million parts of a solution.

For example, 1 ppm means there is 1 gram of solute per 1 million grams of solution.

$$ppm = \frac{\text{grams of solute}}{\text{grams of solution}} \times 10^6$$

6. Parts per Billion (ppb) - defined as the number of parts solute for every billion parts of solution

$$ppb = \frac{\text{grams of solute}}{\text{grams of solution}} \times 10^9$$

Ex) You add 11 mg of sulfuric acid to 2,000 grams of water. What is the resulting concentration of sulfuric acid, in ppm?

We can convert these quantities to molarity. Most of the time the solvent will be water. Recall that molarity is measured in mols/L, so we need to always work our way towards L.

Note - 1 g H_2O = 1 mL H_2O (1kg H_2O = 1L H_2O)

We can also convert ppm into a molarity using a conversion process. The relationship above will be very important. The molar mass of the substance will be needed for this process.

PPM to Molarity:

$$\text{molarity} = \frac{\text{concentration in mg/L}}{\text{(molecular weight of the solute) X 1,000}}$$

**1 ppm = 1mg/L

Ex) A sample of water contains 25 ppm of lead ions, Pb^{2+}. Convert this concentration to M. The molar mass for Pb^{2+} is 206.2 g/mol.

Molarity to PPM:

Ex) A solution contains Cu^{2+} ions at a concentration of 3.0×10^{-4} M. What is the Cu^{2+} concentratrion in ppm? The molar mass of Cu is 63.55 g/mol

Preparing a Standard (Stock) Solution:

Standard Solutions: solutions containing a precise mass of solute are called standard solutions are prepared using a volumetric flask

Example: How could you prepare a 1L solution of a 1.50M aqueous solution of sucrose ($C_{12}H_{22}O_{11}$) for an experiment?

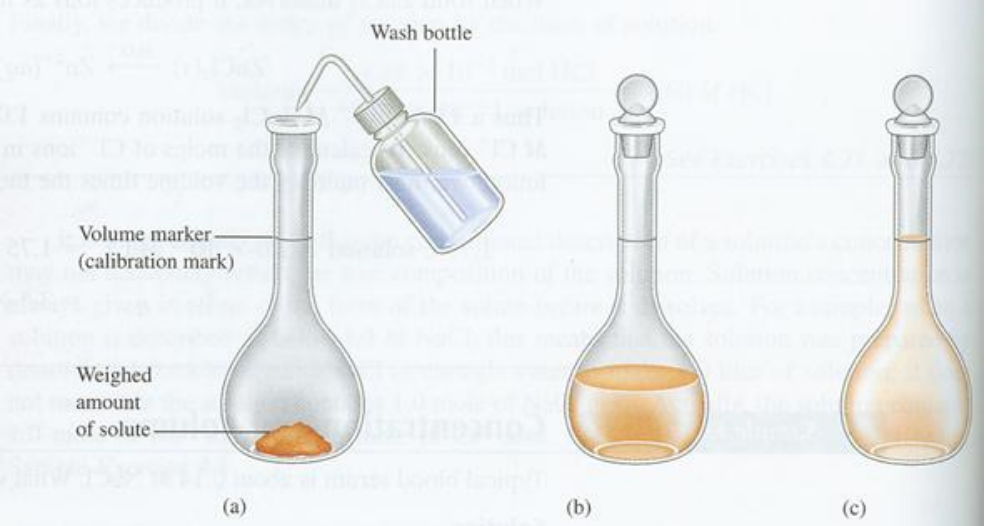


FIGURE 4.10
Steps involved in the preparation of a standard aqueous solution. (a) Put a weighed amount of a substance (the solute) into the volumetric flask, and add a small quantity of water. (b) Dissolve the solid in the water by gently swirling the flask (*with the stopper in place*). (c) Add more water (with gentle swirling) until the level of the solution just reaches the mark etched on the neck of the flask. Then mix the solution thoroughly by inverting the flask several times.

What if you only need 100 mL of a 1.5 M solution of sucrose?

2.2 – Concentration Assignment

1. A 0.750 L aqueous solution contains 90.0 g of ethanol, C_2H_5OH. Calculate the molar concentration of the solution in mol $\cdot L^{-1}$.

2. What mass of NaCl are dissolved in 152 mL of a solution if the concentration of the solution is 0.364 M?

3. How many grams of $CaCl_2$ would be dissolved in 1.0L of a 0.10M solution of $CaCl_2$?

4. A mass of 98 g of sulfuric acid is dissolved in water to prepare a 0.500 M solution. What is the volume of the solution?

5. A solution of sodium carbonate, Na_2CO_3, contains 53.0 g of solute in 215 mL of solution. What is its molarity?

6. What is the volume of a solution of 0.0400 M HNO_3 that contains 12.6 g of solute?

7. Calculate the concentration in ppb of 670.3 mg of chlorine mixed into a pool containing 151 000 000 mL of water.

8. A sample of water contains 20.0 ppm of NaOH. What is the molarity?

9. What mass of dextrose, $C_6H_{12}O_6$ is dissolved in 325 mL of 0.258 M solution?

10. If you have 100.0 mL of a 30.0% aqueous solution of ethanol, what volumes of ethanol and water are in the solution?

Attachments

Solution Concetration Handout.doc