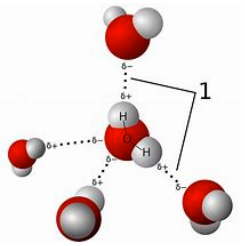
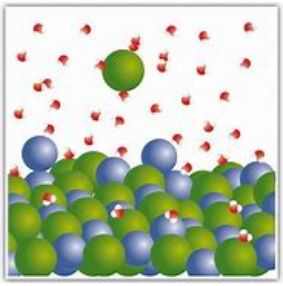
# Experiment 22 – Aqueous Solutions, Dilutions, Limiting Reagent

Solutions are homogeneous mixtures in which the particle size is less than 1 nm. The particles are invisible to the naked eye, do not invoke a Tyndall effect[1], and can not be separated from the solution using filter paper. A solution comprises two parts: the solute and the solvent. The solute, the smaller quantity, is dissolved in the larger component, the solvent. In an aqueous solution, the solvent is water. Solvents have an important role in the reaction process. Solvents distribute the solute into individual particles. This can be done passively through Brownian motion,[2] or, in the case of water, actively using intermolecular forces, such as ion-dipole interactions, dipole-dipole interactions, and hydrogen bonding.

Water is a polar molecule; the molecule has an uneven distribution of charge. As you can see from the picture[3], there is a positive end near the hydrogens, and a negative end near the oxygens. Ionic compounds are held together by electrostatic attractions. There are three interactions that are occurring here for the solution process to occur: the interactions between the soluvent, called solvent-solvent interactions, the interactions between the solute, called solute-solute interactions, and the interactions between the solute and the solvent, called solute-solvent interactions. For the solution to form, solute-solute, and solvent-solvent interactions must be overcome, and solute-solvent interactions must prevail.



Water separates the ions by aligning on the surface of the ionic compound in such a way that the positive end of the water is near the negative ion, and the negative end of the water is near the positive ion. If the attraction of the water to these ions is stronger than the attraction of the ions to the ionic compound, the solid will dissolve in the water. with the charges (either positive or negative) and exerting a stronger force on the ion in than the ionic compound.[4] Aqueous solutions have biological and chemical importance. We are "bags of mostly water", with solutes coursing through our cells. Without an aqueous highway, we would die: no digestion, no movement of blood cells, our lymphatic system could not do its job.

In this experiment, we will examine the relationship of concentrated and diluted solutions, the relationship of concentration and limiting reagent, and how concentration qualitatively affects the rate or speed of a reaction. Although there are a variety of ways of describing a solution's concentration, we will use just one system in this experiment that of "molarity, or moles per liter," abbreviated mol/L or *M*. Aqueous solutions are prepared by dissolving a known quantity of the solute in enough water to make a desired final volume. A concentrated solution (the *stock* solution), one with a higher concentration than needed, can

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[1] Light scattering

[2] Brownian motion; random motion of particles due to collisions. This was studied using colloids, but applys to all molecules in any system.

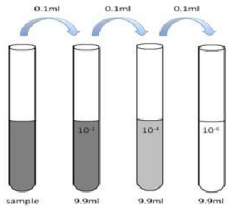
[3] Google images, water molecules

[4] Google image: Ionic compound and water

be diluted to make a desired concentration. Notice that the stock solution has a higher molarity, and therefore more solute particles, than the dilute solution.

In **Part 1A**, you will make a *standard* solution of copper(II) chloride dehydrate. The concentration of a standard solution is known very precisely. We will assume that the sample is pure $CuCl_2 \bullet 2H_2O$ so you can make a standard solution by weighing a precise amount of $CuCl_2 \bullet 2H_2O$ and dissolving it in water to make a precise volume of solution. You will calculate the exact concentration of your $CuCl_2 \bullet 2H_2O$ solution to four significant figures.

In **Parts B-E,** you will prepare a series of diluted solutions using the process of serial dilution. A serial dilution is a step wise dilution of a stock solution. The dilutions are generally logarithmic in nature. In this experiment, you will dilute the stock solution 4 times, to create a total of 5 solutions needed to perform the lab. The terminology often used in a serial dilution is 'fold'. Imagine folding a piece of paper in half. This is would represent a 1-fold dilution, in which you would take one portion of stock and one portion of water to make the diluted solution. This is also called a one in two dilution. Notice that the volume was doubled, so the dilution factor is 2.




Dilution factors are ratios and are based on $M_1V_1=M_2V_2$ formulas. They are faster than doing individual calculations to get the concentration of the final dilution that is highly diluted. In many serial dilutions, the factor stays constant. The dilution factor is determined by dividing the initial volume by the final volume (shades of $M_1V_1=M_2V_2$). For example, adding 1 mL of stock to 9 mL of water creates a 1:10 dilution because the initial volume is 1 mL and the final volume is 1 mL + 9 mL.

Sample: what is the dilution factor if you add 0.2 mL of stock solution to 3.8 mL of water? Answer: 0.2 mL/4.0 mL = 1:20 dilution.

What is the final dilution factor if you diluted this solution 3 more times (a total of 4 dilutions)?

Answer: Let's call the first dilution Tube 1: you would transfer 0.2 mL Tube 1 to Tube 2 and add 3.3 mL of water creating a final volume of 4.0mL. We repeat this process transferring 0.2 mL of Tube 2 into Tube 3 and adding enough water to make 4.0 mL. We do the same transfer one more time to create Tube 4, the final solution.

The dilution factor (DF) is $\frac{1}{20} x \frac{1}{20} x \frac{1}{20} x \frac{1}{20} = \frac{1}{160{,}000}$ $or$ $1{:}160{,}000$

Putting this together, DF = $D_1$x $D_2$ x $D_3$ x $D_4$. To obtain the final concentration, multiple the DF by the stock concentration.

Dilutions such as these are important because small dilutions such as the example are often difficult to do using common glassware. These types of calculations are often done in biology, so dilution calculations are good skill to acquire.

Using the solutions made in Parts 1A-E, you will test how concentration impacts reactions and limiting reagent.

**Pre-lab question:**

1. If you need 170.05 grams (which is one mole of $CuCl_2 \bullet 2H_2O$) to make one liter of 1 M solution, how many moles and grams of $CuCl_2 \bullet 2H_2O$ will you need to make 1/10 as much solution?
2. Your stock solution is 6 *M* $CuCl_2 \bullet 2H_2O$. How do you make 1.00 L of 0.200 *M* $CuCl_2 \bullet 2H_2O$ solution using the stock in 3 serial dilution (serial dilution with 3 dilution steps) if your total volume at each dilution step is 1L?
    a. Draw the steps.
    b. What's the dilution factor at each dilution?
    c. What's the dilution factor from stock to 0.2 M solution?

**Safety Precautions:**

- Wear your safety goggles.

**Waste Disposal:**

- All solutions from this experiment should be collected and placed in an **inorganic waste** bottle (with a blue label) in one of the fume hoods.

## PROCEDURE

## SAVE ALL SOLUTIONS UNTIL THE END OF THE EXPERIMENT! YOU WILL NEED THESE SOLUTIONS FOR PART 2

**Part 1: Preparing solutions of known concentration**

Pre-preparation: You will need 5 clean, dry test tubes for the dilution process.

**Part 1 A: PREPARING A 1.00O M SOLUTION OF $CuCl_2 \bullet 2H_2O$ and $CuCl_{2(aq)}$**

Prepare 100 mL of 1 M $CuCl_2 \bullet 2H_2O$ solution by weighing out exactly 17.00 ± 0.05 grams of the crystals. Transfer this mass into a clean 150-mL beaker. Add 25-mL de-ionized water to the beaker. Swirl until the water turns blue, and some of the crystals disappear. Transfer the liquid into a clean 100-mL graduated cylinder. Add another portion of water to the solid that remains in the beaker; swirl again and transfer the liquid into the 100-mL graduated cylinder. Repeat this process one more time. Rinse the beaker of any remaining solid/liquid into the graduated cylinder adding no more than 20-mL of water into the graduated cylinder. Add more de-ionized water to bring the volume up to the 100-mL mark. Cover the graduated cylinder with para-film and carefully mix by inverting the cylinder. Label the graduate "1 M." Pour enough of the solution into a dry test tube that it stands about 2 inches deep. Label the tube "1 M" also. Save it in your test tube rack. Also save the graduate with the remaining 1 M solution.

**Part 1 B: PREPARING A 0.5 M SOLUTION**.

Pour 50.0 mL of the 1.0 M solution from the graduate into a second 100-mL graduate, and then carefully add enough water to bring the solution up to the 100-mL mark. Mix by pouring back and forth between a dry beaker and the graduated cylinder. Label the graduate "0.5 M." Pour enough of this 0.5 M solution into a test tube that it stands at the same depth as the liquid in the first test tube. Label this test tube "0.5 M."

**Part 1 C: PREPARING A 0.25 M SOLUTION**.

Take the graduate cylinder containing 0.5 M solution and pour 25 mL of it into a 50-mL graduate. Add water to make 50 mL of diluted solution. Mix by pouring back and forth, as you did before. Label the graduate of the new solution "0.25 M." Pour some of it into a test tube, and label that "0.25 M."

**Part 1 D:0 PREPARING A 0.1 M SOLUTION**.

Pour enough of the 0.5M solution into a 25-mL graduate to reach the 5-mL mark. Then add water until the solution level reaches the 25-mL mark. Pour some into a test tube (match the first 3 for height of solution) and label the test tube 0.1 M.

**Part 1 E: PREPARING A 0.05 M SOLUTION**.

Now pour 5 mL of the 0.1 molar solution that you make in step 4, into a 10-mL graduate. Then add enough water to make 10 mL of solution total. Label the new solution "0.05 M." Pour some into a test tube and label that "0.05 M" also.

**PART 2: How the concentration of a solute affects its reaction with other chemicals & limiting reagent**

In this part, three of the solutions of copper (II) chloride that you prepared in Part A will be allowed to react with aluminum foil. You will be asked to observe the rates of the reactions (which is fastest, which is slowest), and to observe the relative amounts of aluminum that react with the same volumes of the three solutions.

**Procedure**

Cut three squares of aluminum foil, all the same size: 10 cm by 10 cm. An easy way to do this is to first fold the foil into three layers, then measure and mark with a pencil, then cut through all 3 layers at once. Finally, cut the layers apart. (You can, if you wish, cut the 3 pieces separately. Make sure that all pieces are the same size.

Weigh each of the pieces of aluminum foil to make sure that the mass of each piece is between 0.25 g and 0.30 g, preferably 0.27 g. All the pieces should have the same mass to two significant figures.

Label one of the beakers "1 M," one "0.5 M," and the third "0.1 M." Put the 3 pieces of foil into three separate beakers (either 400-mL beakers or 250-mL beakers). Push each to the bottom of its beaker with a stirring rod.

Pour 20.0 mL of the 1 M solution into the beaker marked 1 M. Likewise, pour 20.0 mL of the 0.5 M solution into the beaker marked 0.5, and pour 20.0 mL of the 0.1 M solution

into the beaker marked 0.1 M. Start timing the reactions. Stop the timing when one of the beakers shows no more evidence of aluminum metal. Take the intial and final temperature of the reactions.

Observe what happens when the copper(II) chloride solution is added to the respective beakers. Record the solution that is the slowest, the solution that is the fastest, and the one in the middle. Poke and stir the solutions. Eventually, in a few minutes, the reactions will quiet down, as one or the other of the reactants (aluminum or copper (II) chloride) gets used up.

When the reactions have pretty much stopped, add 20.0 mL *more* of each solution to the appropriate beaker. Poke and stir the mixture, and wait a few minutes. Record your observations.

**Clean up:** Use a stirring rod to remove any un-reacted aluminum and discard it into the waste basket (**not** the sink!). Pour all solutions in the **inorganic waste** bottles in the hood. Wash the beakers and graduated cylinders that you used with soap and water. Rinse them, shake them dry, and return them to the area from which you borrowed them.

## Questions: SEE PRE-LAB FOR POST LAB QUESTIONS