

Experiment 22 - Concentration of Solutions

The purpose of this experiment is to acquaint you with the concept of concentration of solutions. 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. The experiment will also give you a chance to see how differences in concentration affect the behavior of a solution, making it react faster or slower, and making it able to react with more or less of some other substance (for the same volume of solution).

"Prepare a tenth of a liter (0.10 L) of a 1 M solution of $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$." What, exactly, does this statement mean? First of all, a tenth of a liter needs to be expressed as a certain number of milliliters, since our laboratory graduated cylinders are marked off in milliliters. You will be making, then, 100 mL of solution.

What does the "1 M" mean? It means one mole of the material that you are going to dissolve – in this case, $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ – would be present in one liter of a solution that has the concentration described as "1 M." (M really says, "moles of dissolved material per liter of solution.") However, we will not need a full liter, so we will make only 0.10 L (100 mL). Question: If you need 170.05 grams (which is one mole of $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$) to make one liter of 1 M solution, then how much will you need to make just one-tenth as much solution? _____ grams, or _____ moles.

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 - Part 1: Preparing solutions of known concentration

1. Prepare 100 mL of 1 M $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ solution by weighing out exactly 17.00 grams of the crystals (the instructor will explain how we can weigh it so exactly), then transferring them from the weighing paper into a 100-mL graduated cylinder. Dissolve them by adding about 50 mL of deionized water and mixing. Then, add more deionized water to bring the volume up to the 100-mL mark. Finally, mix the solution thoroughly by pouring it back and forth into a clean beaker. Label the graduate "1 M."
2. 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.
3. Next we will turn some of the 1 M solution into a 0.5 M solution. Question: How does the concentration compare – is a 0.5 M solution twice as concentrated as a 1 M solution, half as concentrated, or what? Logically, then, to make a 0.5 M solution from a 1 M solution you would need to do what to the 1 M solution – add water, add more $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$, or what?
Pour 50 mL of the 1 M solution from the graduate into a second 100-mL graduate, 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."
4. 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."

- Compare the darkness of the color in the two test tubes. Which solution is darker – 1 M or 0.5 M? Since the color comes from the CuCl_2 , it is logical that the more CuCl_2 there is per drop of solution, the _____ (darker or lighter?) the color is.

Save all solutions until the end of the experiment!

- Take the graduate of 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. Since you have diluted the 0.5 M solution in half, what happened to the concentration? Therefore, the new solution that you prepared has a concentration of _____ moles/liter, or _____ M. Label the graduate of the new solution “0.25 M.” Pour some of it into a test tube, and label that “0.25 M.”
- Compare the colors (depth of blue color) in the three tubes: 1M, 0.5 M, and 0.25 M. Which is darkest? Lightest? Is this logical?
- 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. You have diluted it how many times over? _____ Since you have made a “fivefold” dilution, the new solution is _____ (five times, or one-fifth?) as concentrated as it was before the dilution. Label the new solution _____ M. Pour some into a test tube (match the first 3 for height of solution) and label the test tube the same molarity.
- Now pour 5 mL of the 0.1 molar solution that you make in step 8, into a 10-mL graduate, measuring it by the 5-mL mark in the little graduate. Then add enough water to make 10 mL of solution total. The new solution must have a concentration that is _____ (what fraction?) of the concentration of the 0.10 M solution? Label the new solution “0.05 M.” Pour some into a test tube and label that “0.05 M” also.
- Now line up all 5 test tubes in the rack, putting the darkest at the right and the lightest at the left. Now look at the labels. What order of concentration are the tubes in? Arrange the concentrations on the line below, in the same order they are in your rack:
 _____ M _____ M _____ M _____ M _____ M

Save all of the solutions!

Answer these questions before going on to Part B.

- All the test tubes above contain the same (volume of liquid/number of moles of CuCl_2). (Circle one)
- Which tube above contains the most actual CuCl_2 itself?
- How does the amount of CuCl_2 itself in the tube of 0.5 M solution compare with the amount in the tube of 1.0 M solution?
- To make the actual amount of CuCl_2 in the tube of 1.0 M solution equal that in the tube of 0.50 M solution what could you do? (Circle one)
 - Dump out half of the 0.50 M solution.
 - Dump out half the 1.0 M solution
 - Add some more CuCl_2 to the 1.0 M solution.
 - Pour all the 1.0 M solution into the 0.50 M solution.
 - Dump both out, and start over.
- How many moles of CuCl_2 do you have dissolved in:
 - One liter of 1 M solution? _____
 - One-tenth liter of 1 M solution? _____
 - One liter of 0.5 M solution? _____
 - One-tenth liter of 0.5 M solution? _____
 - 20 mL of 1 M solution? _____
 - 20 mL of 0.5 M solution? _____

g. 20 mL of 0.20 M solution? _____

Procedure - Part B: Identifying the Concentration of an Unknown Solution

Obtain an unknown from the instructor or the stockroom. It is a solution of CuCl_2 which has a concentration that must be one of these values: 1 M, 0.5 M, 0.25 M, 0.1 M, or 0.05 M. Decide which concentration it has by comparing its color intensity with the solutions you made which you kept in the test tube rack. To get an accurate comparison, pour some of the unknown into a test tube to the same depth as in the other tubes. Looking down into the tubes often works better than looking at them from the side. Report the concentration you found, and see if you got it right.

Part C: How the Concentration of a Solute Affects its Reaction with Other Chemicals

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 also to observe the relative amounts of aluminum which react with the same volumes of the three solutions.

Procedure

1. 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. Any way you do it, 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 of the pieces should have the same mass to two significant figures.)
2. 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.
3. Label one of the beakers "1 M," one "0.5 M," and the third "0.1 M." (You can write this on the etched portion of the beaker with a pencil after erasing anything that is already written there.)
4. Pour 20 mL of the 1 M solution into the beaker marked 1 M. Likewise, pour 20 mL of the 0.5 M solution into the beaker marked 0.5 M and pour 20 mL of the 0.1 M solution into the beaker marked 0.1 M.
5. Judging by appearance, which solution is reacting fastest with the aluminum? Which is reacting the slowest? Does this seem logical?
6. 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.
7. When the reactions have pretty much stopped, which solution do you notice has used up most of the aluminum? Has most of the copper (II) chloride also been used up? How can you tell?
8. When the reactions have pretty much stopped, the beaker containing the 0.5 M solution and the beaker containing the 0.1 M solution should have a lot of aluminum left over. Is this logical? Remember, we used the same volume of solution in all three beakers. Why wasn't there enough copper (II) chloride to take care of all the aluminum in these two beakers, since there was enough in the beaker of 1 M solution?
Test that hypothesis: add 20 mL *more* of the 0.5 M solution to the beaker that already has 20 mL of 0.5 M solution in it. Poke and stir the mixture, and wait a few minutes. Does most of the aluminum get used up?

9. Clean-up: Use a stirring rod to remove any unreacted 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

1. The solution that reacted at the greatest rate was the: 1 M, 0.5 M, 0.1 M (Circle one)
 2. In general, the rate of a reaction will be greater if the concentration is _____.
- Answer each of the following questions TRUE or FALSE.**
3. 500 mL of 0.1 M CuCl_2 (aq) will react faster with a gram of Al than will 100 mL of 1.0 M CuCl_2 (aq).
 4. A 0.5 M solution will always have to be used in twice the volume of a 1 M solution to react with the same amount of aluminum.
 5. 20 mL of 0.1 M solution will never be able to use up all the aluminum that you happen to put into it.
 6. To react with the same amount of aluminum as 20 mL of 1 M solution reacted with, the 0.1 M solution would have to be used in ten times the volume: 200 mL.
 7. The more concentrated a solution is, the less of it you will need to react with the same amount of aluminum.
 8. In general, the more concentrated any solution is, the less of it you will need to react with some other chemical.
 9. In every drop of 1 M copper (II) chloride solution there are twice as many atoms of Cu^{2+} ions as there are in every drop of 0.5 M solution.
 10. In general, the more concentrated a solution is, the more atoms or ions or molecules there are per drop of it.
 11. A 1 M solution contains 1 mole of solute per liter of solution.
 12. A 1 M solution contains 0.5 mole of solute per 0.5 liter of solution.