Experiment 7: Solution Preparation

Purpose

Scientists in many different fields use solutions for their laboratory work. Solutions have a solute dissolved in a solvent, and the mixture is homogeneous. For our general chemistry laboratory experiments, the solutions are aqueous, meaning that the solute is dissolved in water.

This experiment is an exercise in preparing solutions, starting with the preparation of a stock solution. Serial dilution solutions will then be prepared with the stock solution. These solutions will let you practice solution preparation. A spectrophotometer will be used to measure the amount of light absorbed by your solutions. This will let you "see" how well your solutions were prepared, and to check the linear working range of the spectrophotometer. You will also need to prepare standard solutions (solutions of known concentration) to make a calibration curve that lets you determine the concentration of a red dye solution of unknown concentration.

Background

Solution preparation will involve the dilution of the concentrated stock solution. The dilution equation will be used to determine the concentration of the new, diluted solution.

$(M_c)(V_c) = (M_d)(V_d)$ where M_c is the concentration of the concentrated stock solution, V_c is the pipeted volume of the stock solution, M_d is the concentration of the new diluted solution, and V_d is the volume of the new diluted solution. The concentration unit does not have to be molarity. However, M_c and M_d must be the same concentration unit. V_c and V_d do not have to be in the unit of liters, but they both have to be the same volume unit.

The absorbance of light by the solute in solution will follow the Beer-Lambert Law (Beer's Law), which states that the absorbance of light is directly proportional to its concentration. The mathematical equation is $A = abc$, where A is absorbance, a is the molar absorptivity coefficient, b is the path length, and c is concentration.

Calibration curves are graphs that show the relationship between concentration and absorbance of light by the solute. Absorbance is dependent on the concentration of solute in the solution. Therefore, concentration is on the x-axis and absorbance is on the y-axis. The data points obtained in lab are plotted using Excel or Google Sheets. The computer program will put a best-fit line through the data points. The equation of the linear line is obtained, and this equation shows the mathematical relationship in the

$y = mx + b$ format which translates to Absorbance = m(concentration) + b

(Note: The b in this mathematical equation is not the same b as in Beer's Law. b is the y-intercept and m is the slope of the best-fit-line.)

The spectrophotometers that are in the general chemistry laboratory cover the wavelength range of visible light. Therefore, in order to measure the absorbance of light by the solute in solution, the solute must absorb visible light. So, we work with colored solutions.

Chemicals

Red food dye #1 (liquid form) Deionized water

Equipment

Pipets and pipettors	Volumetric flasks, 100 mL
Parafilm	Plastic droppers
Beakers, small sizes	Laboratory balance

Procedure

Part A: Preparation of the stock solution

(Save this solution until the end of the experiment.)

1) Bring your laboratory notebook, pen, plastic dropper, and a clean, dry, 150 mL beaker to the laboratory balance.
2) Place the beaker on the balance pan, and tare the balance so the beaker has a mass of zero grams.
3) Use your clean plastic dropper to put 0.25 g of liquid red dye into your beaker. (This will be approximately 6 drops.) Record the exact mass of the red dye in your notebook worksheet. Do not tare the balance again.
4) Remove the beaker from the balance pan, and add approximately 40 mL of deionized water using a graduated cylinder.
5) Return the beaker to the balance pan, and gently add deionized water to the beaker until the total mass in the beaker is 50 g. The mass does not have to be exactly 50 grams, but the exact total mass must be recorded in your notebook worksheet. (Use all digits displayed on the balance.)
6) Return to your lab bench. Use a clean, dry, glass stir rod to mix your stock solution well.
7) Calculate the concentration of the stock solution, in units of % wt.

Part B: Serial Dilutions

(Save these solutions until the end of the experiment.)

1. Use a calibrated pipet to measure and dispense your stock solution for this part of the experiment (*do not use a plastic dropper*). Rinse the pipet with your stock solution, and then dispense the rinse into a waste beaker.

2. Prepare serial dilution (1). Draw up your stock solution into the pipet and adjust the bottom of the meniscus to pipet exactly 5.0 mL. Dispense this volume to a 100 mL volumetric flask. (The flask should already have been rinsed with DI water. The flask does not have to be dry, since you will be adding water to it.) Dilute the contents of the flask with DI water until the bottom of the meniscus sits exactly on the calibration mark on the neck of the flask. The total volume of solution in the flask will now be 100.0 mL. Cover and seal the flask with Parafilm. Invert to mix fifty times. Calculate the concentration of serial dilution (1). Use the dilution equation, Mc·Vc=Md·Vd. *(The %wt unit works fine for Mc and Md.)*

3. Prepare serial dilution (2). Rinse the pipet with DI water, and then rinse with your serial dilution (1) solution. Draw up your (1) solution into the pipet and adjust the bottom of the meniscus to pipet exactly 5.0 mL. Dispense this volume to a 100 mL volumetric flask. Dilute the contents of the flask with DI water until the bottom of the meniscus sits exactly on the calibration mark on the neck of the flask. The total volume of solution in the flask will now be 100.0 mL. Cover and seal the flask with Parafilm. Invert to mix fifty times. Calculate the concentration of serial dilution (2). Use the dilution equation, Mc·Vc=Md·Vd.

4. Prepare serial dilution (3). Rinse the pipet with DI water, and then rinse with your serial dilution (2) solution. Draw up your (2) solution into the pipet and adjust the bottom of the meniscus to pipet exactly 5.0 mL. Dispense this volume to a 100 mL volumetric flask. Dilute the contents of the flask with DI water until the bottom of the meniscus sits exactly on the calibration mark on the neck of the flask. The total volume of solution in the flask will now be 100.0 mL. Cover and seal the flask with Parafilm. Invert to mix fifty times. Calculate the concentration of serial dilution (3). Use the dilution equation, Mc·Vc=Md·Vd.

5. After you have completed Part C, determine the absorbance for each of the serial dilution solutions.
    a. Make sure the spectrophotometer is set to your λ_{max} for the wavelength.
    b. Use the DI water as the blank to zero the spectrophotometer.
    c. Transfer each serial dilution solution into its own test tube, about ¾ full.
    d. Measure the absorbance of light for each solution, and record these values into your notebook worksheet.

Part C: Determining the λ_{max}

(finding the best wavelength for absorbance of light by red dye)

1) Use the Serial Dilution (1) solution for this part of the experiment. Place some of this solution into a small test tube, about ¾ full. Put DI water into another test tube, also about ¾ full. The DI water is your blank that will be used to zero the spectrophotometer.
2) Red dye looks red because it absorbs light in the blue-green region of visible light (see Figure 1). You need to determine the best absorbance. Turn on the spectrophotometer and set the wavelength to 470 nm.

Figure 1

Coloured absorbed	Visible (Complementary)
Violet	Yellow-Green
Blue	Yellow
Green-Blue	Orange
Blue-Green	Red
Green	Purple
Yellow-green	Violet
Yellow	Blue
Orange	Green-Blue
Red	Blue=Green

https://www.slideshare.net/GranchBerheTseghai/2-fundamentals-of-color

3) Put the test tube with the DI water into the sample compartment of the spectrophotometer, and close the lid. Press the zero Abs button. This sets the zero point on the spectrophotometer, which subtracts out any absorbance of light by the glass test tube and DI water.
4) Put the test tube of red dye solution into the sample compartment and close the lid. Record the absorbance readout in your notebook.
5) Repeat steps 3 and 4 after increasing the nm setting by 10 nm. Continue to do this until you have absorbance readings up to 540 nm. You must set the blank each time the nm setting is changed.
6) Report the best wavelength to use, λ_{max}, when measuring the absorbance of light by the red dye solution.

Part D: Preparing Standard Solutions and a Calibration Curve

Solutions of known concentration will be prepared to make a calibration curve.
Use the stock solution you prepared in Part A to prepare the standard solutions.

1) Standard Solution 1: Pipet 1.0 mL of stock solution into a 100 mL volumetric flask and dilute to the mark with DI water. Seal the flask and invert 50 times to mix.
2) Standard Solution 2: Pipet 2.0 mL of stock solution into a 100 mL volumetric flask and dilute to the mark with DI water. Seal the flask and invert 50 times to mix.
3) Standard Solution 3: Pipet 3.0 mL of stock solution into a 100 mL volumetric flask and dilute to the mark with DI water. Seal the flask and invert 50 times to mix.
4) Standard Solution 4: Pipet 4.0 mL of stock solution into a 100 mL volumetric flask and dilute to the mark with DI water. Seal the flask and invert 50 times to mix.

Measure the absorbance of light for each standard solution and the unknown solution.

1) Make sure the spectrophotometer is set to your λ_{max} for the wavelength.
2) Use the DI water as the blank to zero the spectrophotometer.
3) Transfer each standard solution and the unknown solution into its own test tube, about ¾ full.
4) Measure the absorbance of light for each solution, and record these values into your notebook.

Prepare a calibration curve.

Follow the instructions in the Calibration Curve video and use Excel or Google Sheets to prepare a calibration curve. The concentration is the independent variable, so that is your X axis. Absorbance is the dependent value, so that is the Y axis. Plot a scatter plot, linear, and put the best-fit line on the graph. Show the equation of the line and the R^2 value on the graph also. The R^2 value gives some indication as to how well the standard solutions were prepared.

Determine the concentration of your unknown.

Use the equation of the best-fit line to solve for the unknown concentration. The equation of the line is in the y=mx+b format. Y is the absorbance and X is the concentration. You know the absorbance of the unknown solution, so solve for X. Show this calculation in your notebook worksheet, and report the concentration of the unknown with correct significant figures and units.