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Stoichiometry: Job's Method Analysis and Zinc-Iodide Stoichiometry

Goals/Objectives:

There are two separate objectives of this skills challenge. The first objective is to perform a Job's method analysis using a common water-soluble amino acid to determine the stoichiometry formed by the reaction of the amino acid with copper (II) ions. The second objective is to determine the stoichiometry of the reaction between elemental zinc metal and iodine crystals.

Background:

Job's Method Analysis:

Job's method, the method of continuous variation, is a simple method to determine the reactant stoichiometry of a chemical reaction. In the following format, the ratio of the n and m coefficients are determined: nA +mB $\rightleftharpoons$ A_nB_m. A series of solutions of A and B over a range of volume ratios (n and m) with the same constant total volume each provide their own color wavelength. With colored reactant solutions it is possible to test the absorbance % per ratio, which is evaluated using the spectrophotometer. A Job plot of the regularly spaced mole fractions should normalize the concentrations of the complex (ie. A_nB_m) to maximum values (the peak).[(4)] In this lab the increasing mole fraction of the $Cu(NO_3)_2$ (copper II nitrate) would be plotted against the absorbance of the complex of the reaction between $Cu(NO_3)_2$ and $C_2H_5NO_2$ (the amino acid glycine). The highest concentration of the complex will have the highest absorbance and thus represent the maximum value on the plot and give the stoichiometric ratio.

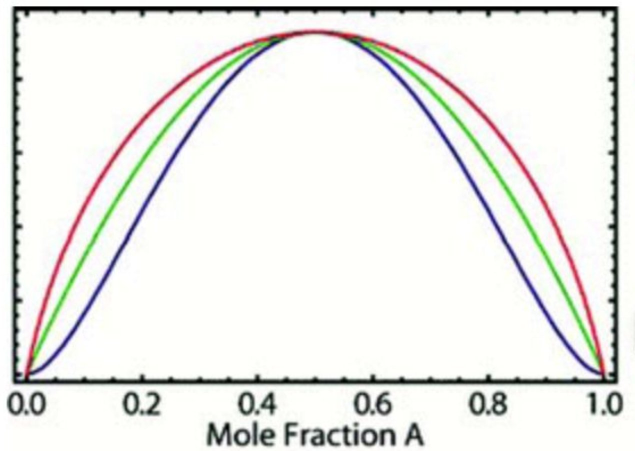

Figure 1: Example of a Job plot of mole fraction of a reactant plotted against the absorbance of the produced complex.[4]

Zinc-Iodide Stoichiometry:

Without testing the color wavelength, it is possible to test mole ratios through classical stoichiometry. This is done by measuring the mass of each compound or element that is used. The mass is then converted to moles, and the mole ratios between the substances in the reaction are used to determine the empirical chemical formula. If the formula of the compound is known, then theoretical weight percentages can be calculated and a comparison can be made to the experimental data. The first step to any classical stoichiometry problem is to find the full balanced equation of the two reactants, in our case Zinc and Iodine ($Zn+I_2 \rightarrow ZnI_2$).[5] From there, the methodology is linear. The masses of Zn, I_2, and ZnI_2 will be recorded during the experiment, and these masses can easily be converted to moles by dividing by the molar masses of the substances. This algorithm allows the comparison of the moles per substance to compute the formula of a chemical reaction similarly to the classical chemists.

Procedure:

Job's Method Analysis:

Assuming that $Cu(NO_3)_2$ has a molar mass of 187.56 g/mol, and $C_2H_5NO_2$ (Glycine) has a molar mass of 75.07 g/mol. In a 100 mL volumetric flask, add 1.256 grams of copper (II) nitrate and fill to the line with deionized water. This should result in a .1M solution of $Cu(NO_3)_2$. In another 100 mL volumetric flask add .7507 grams glycine and fill to the line with deionized water to obtain a .1M solution. Using a sample of the .1M solution of glycine, calibrate the spectrophotometer and record this as the baseline “0” relative absorbance. In a 10 mL graduated cylinder, add 1 mL of $Cu(NO_3)_2$ and 9 mL of glycine. Pour this into a beaker and swirl for about 3 minutes. Place this sample into the spectrophotometer and record the relative absorbance. Repeat this process for samples of 2 mL of the $Cu(NO_3)_2$ solution through 10 mL of the $Cu(NO_3)_2$ solution in 1 mL increments, and adding the remainder of the 10 mL in each solution with the glycine solution. Using the data points, plot the relative absorbance of the complex against the mole fraction of $Cu(NO_3)_2$ used in each sample to create a Job plot.

Zinc-Iodide Stoichiometry:

Mass a dried 125 mL erlenmeyer flask as accurately as possible. Mass approximately 2 g of zinc powder and record the mass. Then add the Zn to the erlenmeyer flask. Mass about 2 g of iodine and record the mass. Add the I to the erlenmeyer flask as well. Fill the flask with about 25 mL of methanol and place the flask on a hot plate. Gently stir and bring the alcohol to a gentle boil until the brown color of the I disappears and a colorless solution remains with the unreacted Zn. Mass a washed and dried 250 mL beaker while the solution boils. Once the solution becomes colorless, wait for it to cool and decant liquid (zinc iodide product) into the beaker without removing any Zn from the erlenmeyer flask. Add about 5 mL of alcohol, swirl in erlenmeyer flask, and decant into beaker again. Repeat this Zn washing twice to remove all zinc iodide product from the unreacted Zn. After washing, place the erlenmeyer flask back onto the hot plate and boil off the remaining alcohol. Mass the erlenmeyer flask with unreacted zinc and calculate the mass of unreacted zinc. Place the 250 mL beaker on hot plate and boil off alcohol until there is none left in beaker. Mass the 250 mL beaker to obtain the mass of the product.

Safety Analysis:

Broken glassware must be disposed of properly into a designated bin.

The substances used in this lab are relatively safe, however there are general precautions that cannot be ignored:

Copper

- Keep containers tightly closed in a dry, cool and well-ventilated place. Store under an inert atmosphere.[1]
- Wear appropriate eye (safety goggles/glasses) and skin (lab coats and pants) protection.[1]

- Immediately wash skin if contaminated.[1]
- Remove clothing that becomes wet or significantly contaminated.[1]
- Seek medical attention if eyes are irritated, coughing or wheezing is induced, or breathing is difficult.[1]

Iodine

- Wear appropriate eye (safety goggles/glasses) and skin (lab coats and pants) protection.[2]
- Immediately wash eyes or skin if contacted.[2]
- Remove clothing that becomes wet or significantly contaminated.[2]
- Seek medical attention if eyes, skin, or nose are irritated, substance is swallowed, tears are discharged, headache is induced, chest tightens, skin burns, or rash appears.[2]
- If person breathes large amounts, immediately remove to fresh air.[2]
- May cause damage to organs through prolonged or repeated exposure.[2]

Methanol

- Highly flammable liquid and vapour.[3]
- Wear appropriate eye (safety goggles/glasses) and skin (lab coats and pants) protection.[3]
- Immediately wash eyes or skin if contacted.[3]
- Toxic if inhaled.[3]
- Causes damage to organs.[3]

References:

1) NOAA Office of Response. (n.d.). Copper. Retrieved November 4, 2018, from https://cameochemicals.noaa.gov/chemical/16146.

2) NOAA Office of Response. (n.d.). Iodine. Retrieved November 4, 2018, from https://cameochemicals.noaa.gov/chemical/25035.

3) NOAA Office of Response. (n.d.). Methanol. Retrieved November 4, 2018, from https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/education/regulatory-documents/sds/chemicals/chemicals-m/S25426A.pdf

4) Olsen, E. J., & Buhlmann, P. (2011, September 7). *Getting More out of a Job Plot: Determination of Reactant to Product Stoichiometry in Cases of Displacement Reactions and n:n Complex Formation*. Retrieved November 6, 2018, from https://pubs.acs.org/doi/10.1021/jo201624p.

5) Stockton University. (n.d.). *Determination of a chemical formula: the synthesis of zinc iodide* [PDF].