Determining the Coordination Number of Ni^{2+} and Cu^{2+} by Enthalpy (#3.1)

The CCLI Initiative
Computers in Chemistry Laboratory Instruction

Learning Objectives

The objectives of this experiment are to ...

- investigate the formula of the complexes formed between Ni^{2+} and ethylenediamine (en) and between Cu^{2+} and en.
- determine the maximum number of en molecules that will bind to Ni^{2+} and Cu^{2+} by making heat of reaction measurements with the ***MicroLAB*** interface.
- calculate heats of reaction for the various Ni^{2+}/en and Cu^{2+}/en complexes to determine their coordination numbers.

Background

When a metal ion such as Ni^{2+} is present in aqueous solution, it interacts with solvent water molecules and forms what is called a complex ion. For Ni^{2+} the complex ion has the formula $[Ni(OH_2)_6]^{2+}$. The complex has an octahedral geometry as shown in Figure 1.

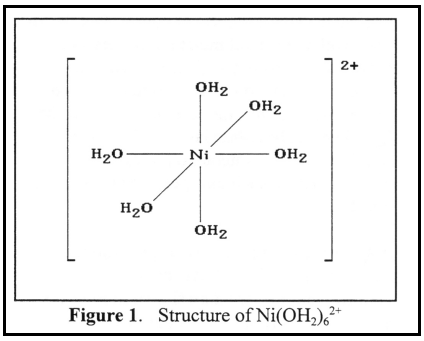

Figure 1. Structure of $Ni(OH_2)_6^{2+}$

Terminology such as the **central metal ion**, **ligands** and **coordination number** are defined. Hence the coordination number of Ni^{2+} is six in Figure 1. Six is a very common coordination number but certainly not the only possibility. If ligands other than water molecules are available in solution, they can selectively bond to the central metal ion and displace the original water ligands. Some ligands have a structure which allows them to form more than one bond with the central metal ion. An example is the molecule ethylenediamine (abbreviated en), which can bond with each nitrogen atom in **en.** A table of data gives the enthalpy of the reaction between $[Ni(OH_2)_6]^{2+}$ and en .

Cu^{2+} ion, like Ni^{2+} ion, has a coordination number of six. In $[Ni(OH_2)_6]^{2+}$, however, all six Ni–O bonds have the same length. Such is not the case for $[Cu(OH_2)_6]^{2+}$. The $[Cu(OH_2)_6]^{2+}$ octahedron is distorted with four Cu–O bonds much shorter than the other two Cu–O bonds.

Experiments Performed

Temperature Probe Calibration: The temperature probe is calibrated at a minimum of three temperatures from near freezing to 80 °C.

Experiment 1: Reaction of $[Ni(OH_2)_6]^{2+}$ with **en** in aqueous solution in a **1:1** molar ratio. Since the reaction is exothermic, the temperature of the reaction mixture will increase. When the temperature increase is measured with the ***MicroLAB*** interface, the heat of reaction in kJ/mol Ni can be calculated.

Experiment 2: Reaction of $[Ni(OH_2)_6]^{2+}$ with en in a **1:2** molar ratio.

Experiment 3: Reaction of $[Ni(OH_2)_6]^{2+}$ with en in a **1:3** molar ratio.

Experiment 4: Reaction of $Ni(OH_2)_6]^{2+}$ with en in a **1:4** molar ratio.

A major goal of this exercise is to carry out the above experiments and determine the maximum number of en molecules that will bind to Ni^{2+}.

A second major goal of this laboratory exercise is to carry out this experimental scheme and determine the maximum number of en molecules that will bind to Cu^{2+}.

Experiments 5 through 8: These experiments are repeated in the same manner as 1 through 4using a copper solution.

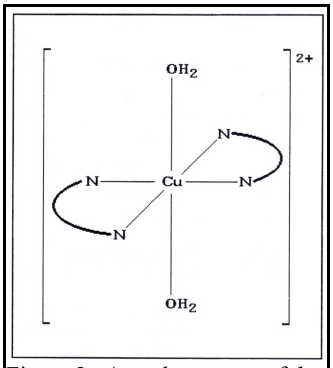

Figure 2. Actual structure of the $[Cu(en)]^{2+}$ complex.

Data Analysis

Guidance is given on how to interpret the graphs and calculate the results as follows:

- Determine the final and initial temperatures for the reaction and calculate ΔT.
- Calculate the heat of reaction, ΔH, for each trial.
- Based on your results, indicate the maximum number of moles of ethylenediamine which can bind to one mole of metal ion. Write the correct equation for this reaction and the formula for the complex ion.

Instructor Resources Provided

- Sample Report Sheets providing the format to organize the data collection with sample data.
- Questions to consider, answer and turn-in with suggested answers.
- Tips and Traps section to assist the instructor with potential problems and solutions.
- Sample ***MicroLAB*** screen shots and graphs.
- Laboratory preparation per student station.

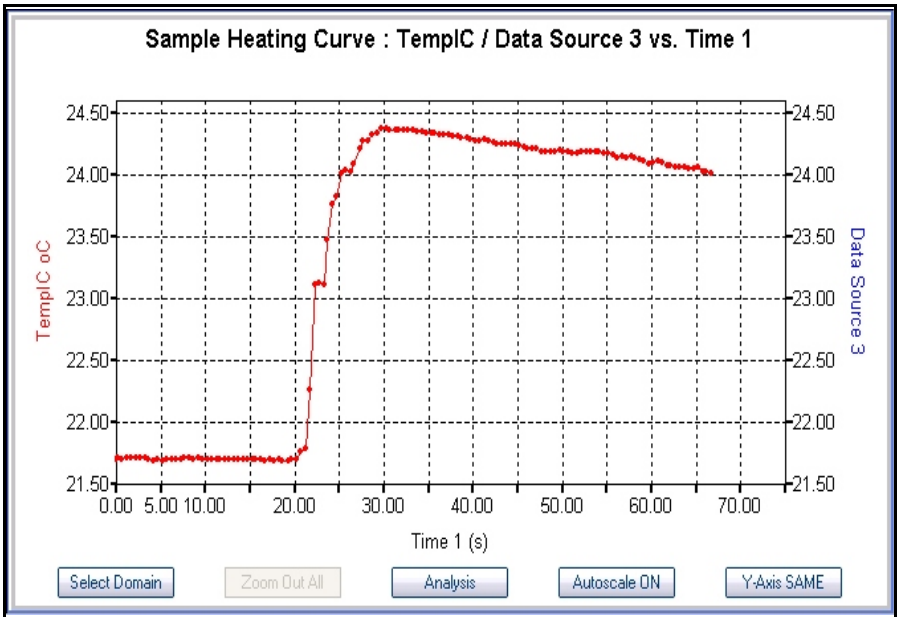

Figure 2. Sample MicroLAB heating curve.

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