ENTHALPY AND ENTROPY OF ZINC WITH COPPER SULFATE (#1.5)

The CCLI Initiative
Computers in Chemistry Laboratory Instruction

Learning Objectives

The learning objectives of this experiment are to...

- determine changeΔS in enthalpy and entropy of the reaction of zinc with copper sulfate using two methods: electrochemistry and calorimetry.
- compare the enthalpy values obtained by the two methods.

Background

Thermodynamics is concerned with energy changes that occur in chemical and physical processes. The enthalpy and entropy changes of a system undergoing such processes are interrelated by the change in free energy, ΔG, according to the equation $\Delta G = \Delta H - T\Delta S$ (1) This investigation focuses on the reaction

$$Zn_{(S)} + CuSO_{4(aq)} \Rightarrow ZnSO_{4(aq)} + Cu_{(S)} \qquad (2)$$

ΔG will be calculated from the ΔH and ΔS values obtained electrochemically. The validity of Equation (1) will be tested by comparing the value of ΔH obtained electrochemically with the value of ΔH obtained calorimetrically for the same reaction.

The electrochemical method

The electrochemical method utilizes a simple electrochemical cell, Cu(S)/$CuSO_{4\,(aq)}$ ‖ Zn(S)/$ZnSO_{4(aq)}$ constructed in a Chem-Carrou-Cell™ plate or a multiwell plate. The quantity of the electrical energy, $\mathscr{F}$, produced or consumed during the electrochemical reaction is a constant measured per mole of electrons, and can be accurately measured. The free energy change, ΔG, of an electrochemical reaction is related to the voltage, $\mathscr{E}$, of the electrochemical cell by the equation $\Delta G = -n\mathscr{F}\mathscr{E}$ (3) where n = the number of moles of electrons transferred in a redox reaction, and $\mathscr{F}$ = Faraday's constant of 96,500 C/mole of electrons . Combining equations (1) and (3), and dividing both sides by the constant "n", we obtain a linear relationship between the voltage change, $\Delta\mathscr{E}$, and the enthalpy and entropy changes at different temperatures

$$\mathscr{E} = -\frac{\Delta H}{n\mathscr{F}} + \frac{T\,\Delta\Delta S}{n\mathscr{F}} \qquad (4)$$

or

$$\mathscr{E} = \frac{\Delta S}{n\mathscr{F}}(T) - \frac{\Delta H}{n\mathscr{F}} \qquad (5)$$

Assuming that ΔH and ΔS remain constant over a small temperature range, by measuring the voltage $\mathscr{E}$, of our electrochemical cell, at several temperatures , we can obtain a plot of the voltage *versus* temperature, from which we can calculate the ΔS and ΔH from the slope and the intercept of the straight line. ΔG can then be calculated by means of Equation (1). We can verify its value using Equation (3). Please note that in both cases , ΔG must be calculated for the same temperature. If the calculations are done for 298 K (25 °C), we can also verify the experimental value of $\mathscr{E}°$ for this temperature by employing the Nernst equation. When the concentrations of the $ZnSO_4$ and $CuSO_4$ solutions are equal, the log term of the Nernst equation becomes zero. Under these conditions , the standard voltage, $\mathscr{E}°$, of the cell is equal to the measured voltage, $\mathscr{E}$

The calorimetric method

The heat of the chemical reaction can be measured in the normal calorimetric manner. The heat capacity of the calorimeter solution is obtained by multiplying the specific heat of the solution (3.8 J g^{-1} $°C^{-1}$ for $CuSO_4$) by the weight of the solution in the calorimeter. The estimated cup heat capacity, is 30 J $°C^{-1}$.

Experimental Procedures

The ***MicroLAB*** experiment: A special program, ***delta.G .experiment*** is supplied in Instructor Resources.

Electrochemistry

Temperature probe Calibration: The temperature probe is calibrated at a minimum of three separate temperatures with ice-cold water and hot tap water.

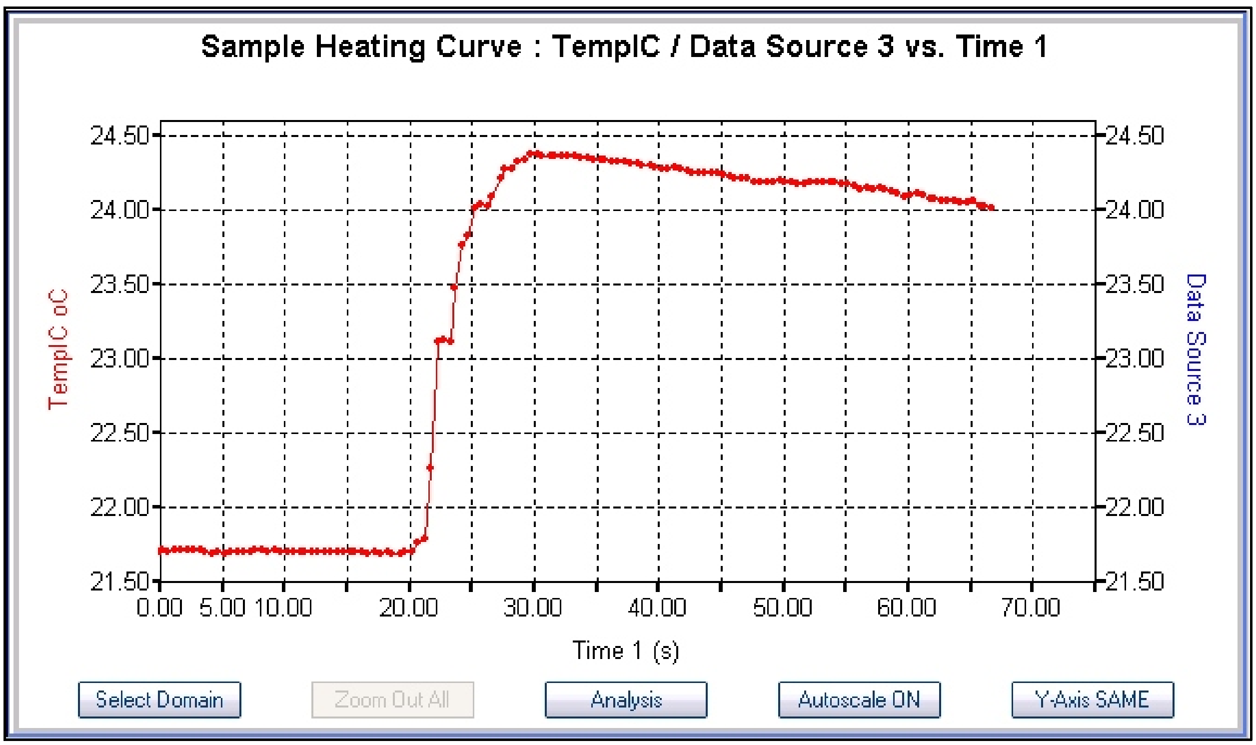
Cell Potential / Temperature: The potential of the cell at a minimum of three temperatures is measured, the data plotted, and ΔH and ΔS calculated.

Calorimetry: ΔH is measured by the addition of a weighed amount of fine granules of Zn metal are added to a CuSO4 solution while the temperature is monitored.

Data Analysis: Guidance is provided in both the electrochemistry and the calorimetry to help the students obtain and understand what is necessary to complete the experiment.

Instructor Resources Provided

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



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