

Name: _____

Period: _____

Seat#: _____

Required Sections: (Refer to R-15 for guidelines and requirements. Make note of any specific changes given by your teacher in class.)

Prelab: Prelab Questions, Materials, Reagent Table, Procedures, and set up Data Tables before you get to class.

During Lab: Data section – Fill out your data table that is already set up from the prelab.

Post-lab: Calculation section, Discussion Questions Section (both done in lab notebook), Post-Lab Two Pager (done on separate worksheet).

REMINDER - USE R-15 TO ENSURE YOU FOLLOW ALL GUIDELINES/EXPECATIONS/ REQUIREMENTS

Introduction

When studying thermodynamics, the equation for free energy of a reaction, $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$, is often encountered. In this experiment, you will use this equation to estimate the *minimum* entropy change required to bring about a reaction. The enthalpy change, ΔH , and the initial temperature will be determined for a reaction during the lab. You will be able to infer/assume something conceptually which allows you to determine what ΔG is. From these values and the equation for free energy, the *minimum* entropy change to bring about a *spontaneous reaction* will be estimated. *Hint* - think about what value of ΔG is between a spontaneous reaction and a non-spontaneous reaction...what value is between a negative number and a positive number???

Purpose

The purpose of this experiment is to estimate the minimum entropy change required for a reaction.

Prelab Questions – do not recopy the questions, just paraphrase them into your answers!

For the following questions – show all work, include proper units in your work, and box final answers with units so the answers are easy to find during the lab.

1. Calculate the mass of NH_4NO_3 needed to prepare 15.0 mL of a 1.00 M solution. Repeat for NH_4Cl and NH_4NO_3 .
2. When using the Gibbs-Helmholtz equation to find the minimum entropy change required to bring about a reaction, what value do you set ΔG equal to? Explain.

Materials – don't forget to use an MSDS to do your reagent table! Remember that a * means it should be in your reagent table!

Chemicals

- * Solid NH_4NO_3
- * Solid NaNO_3
- * Solid NH_4Cl

Equipment

- Thermometer
- Micro Calorimeter

- 25mL graduated cylinder

- Weigh Boat
- Distilled water

[Google Folder with Most MSDS Files](https://tinyurl.com/2cyva3ku)

<https://tinyurl.com/2cyva3ku>

To help speed up your reagent table!



[Flinn's MSDS Website](https://www.flinnsci.com/sds/)

<https://www.flinnsci.com/sds/>

For anything that isn't in my Google folder.



Procedure – Remember to make a flow chart, include diagrams/drawings of steps/equipment etc. Google “flow chart procedures” if you are not familiar with how to make a flow chart. You aren't just drawing boxes around all your sentences!

NOTE You will only be using one of the three chemicals. Your group will be assigned a chemical in class. You do not need to gather data for the other compounds used by the other groups. You will still do the prelab questions for each chemical, still do the reagent table for all chemicals, and will still add your data to a shared spreadsheet.

Shared Data Spreadsheet: <https://tinyurl.com/2p894e48> Must be logged in with SRVUSD email to open file



- 1) Obtain and wear goggles.
- 2) Using the graduated cylinder, measure 15mL of distilled water and add it to the calorimeter. Observe whether your calorimeter is large enough to hold a full 15mL without being so full it might spill. If your calorimeter is too small, empty and dry it, and measure out a slightly smaller amount of water to determine what an appropriate volume will be for your calorimeter. Be sure to record the total amount of water used. Use the density of water to determine and record the mass of the water you actually ended up using in your calorimeter.
- 3) Measure the temperature of the water. Make sure you wait long enough to obtain a stable temperature.
- 4) Record which solid your group was assigned to use. In the prelab you calculated the mass of solid needed to prepare 15.0 mL of a 1.00 M solution. Weigh out this mass of your solid, as closely as possible. Record the actual mass of solid weighed out. (It is ok if you are using a different volume of water, you will be doing calculations with the number of *moles* of solid used, not the concentration, so as long as you know how many grams of water and grams of your solid chemical you added to your calorimeter then you are fine!).

- 5) Make sure someone is holding the calorimeter stable, while gently and carefully stirring the water with the thermometer.
- 6) As quickly as possible, (**while still being safe!**) add the solid to the water, continuing to stir as you monitor the temperature reading on the thermometer. Continue stirring and monitoring the temperature until the temperature readings are no longer changing. Record the final temperature at the point at which the entire solid has dissolved.
- 7) Repeat the procedure one more time.
- 8) Make sure to add your data to the shared spreadsheet.

Disposal and Cleanup

Your teacher will provide disposal and cleanup instructions.

Data Table

1. Make your own data table! Remember, you need to make sure your data table has all required elements! A sample is provided below. You will need to add a descriptive title, units on all rows/columns, and a spot for qualitative data, the one below is not adequate! Remember to use enough space, make it look professional, etc!

Descriptive Title	Trials	
	1	2
Solid Used:		
Volume of water		
Mass of water		
Mass of solid		
Moles of solid		
Initial temperature		
Final temperature		
Temp. change ($\Delta^{\circ}\text{C}$)		

Calculations - Show all calculations, use proper dimensional analysis, units everywhere, proper sig figs, etc.

Reminder You can either average your trial data and then perform the calculations once, or you can do the calculations for each trial and then average your results. Either way, be clear about what you are doing by showing all work, and be mindful of rounding issues. Do not forget to box final answers with units.

1. Calculate the magnitude of heat transfer, q , in Joules, for the dissolution reaction that took place. Assume the specific heat of the solution is the same as water.
2. Calculate the enthalpy of reaction, ΔH_{rxn} , in $\text{kJ/mol}_{\text{rxn}}$ using q and the number of moles of solid used. Pay close attention to the algebraic sign on your final answer!
3. Calculate the ΔS for the reaction in $\text{J/mol}\cdot\text{K}$. *Hint* use prelab question 2 to help you do this!

Post Lab Discussion Questions – Do not recopy the questions, just paraphrase them into your answer.

1. Write a balanced net ionic equation for the disassociation reaction your group studied. (include heat written into the balanced equation as either a reactant or product).
2. List the units for enthalpy, entropy, and Gibbs free energy (in that order).
3. What is the algebraic sign on ΔG for a spontaneous reaction? For a nonspontaneous reaction?
4. What can you use as the value of ΔG for the tipping point when a reaction switches from nonspontaneous to spontaneous?
5. Was the reaction spontaneous? How do you know this from your observations during the lab?
6. From the temperature change of your trials, was the reaction endothermic or exothermic? What should the algebraic sign be for for ΔH_{rxn} ?
7. Based on questions 4/5/6, what must be true about the sign for ΔS ? Explain why with support. *hint* you should be referencing the Gibbs-Helmholtz equation conceptually, not just by showing your calculations again.
8. Many students believe that a reaction must be exothermic to be spontaneous. Comment on this in terms of this experiment. Looking for detailed thoughts about why someone would think a reaction must be exothermic to be spontaneous, if they are correct or not, and why.
9. Contrary to what many students would predict, the dissolution of calcium hydroxide in water has a negative entropy. Provide an explanation for why a student would wrongly assume it was a positive entropy, and why it does in fact have a negative entropy.

