Dougherty Valley HS Chemistry - AP
Thermochem –Enthalpy of a Rxn using Microscale Calorimetry

Worksheet #7

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:** Purpose, 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

The reaction of magnesium metal with air in a Bunsen burner flame provides a dazzling demonstration of a combustion reaction. Magnesium burns with an intense flame that produces a blinding white light. This reaction was utilized in the early days of photography as the source of "flash powder" and later in flashbulbs.
It is still used today in flares and fireworks.

Mg burning video
Optional but fun :-)
https://tinyurl.com/3kvff36s

$$Mg(s) + \frac{1}{2} O_2(g) \rightarrow MgO(s) + heat \qquad \textit{Equation 1}$$

A great deal of heat and light is produced – the temperature of the flame can reach as high as 2400 °C. The amount of heat energy produced in this reaction cannot be measured directly in the high school lab. It is possible, however, to determine the amount of heat produced by an indirect method, using Hess's Law.

The heat or enthalpy change for a chemical reaction is called the heat of reaction (ΔH_{rxn}). The enthalpy change – defined as the difference in enthalpy between the products and reactants – is equal to the amount of heat transferred at constant pressure and does not depend on how the transformation occurs. This definition of enthalpy makes it possible to determine the heats of reaction for reactions that cannot be measured directly. According to Hess's Law, if the same overall reaction is achieved in a series of steps rather than in one step, the enthalpy change for the overall reaction is equal to the sum of the enthalpy changes for each step in the reaction series.

Consider the following three reactions:

$$Mg(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2(g) \qquad \textit{Equation A}$$

$$MgO(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) \qquad \textit{Equation B}$$

$$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l) \qquad \textit{Equation C}$$

It is possible to express the combustion of magnesium (Equation 1) as an algebraic sum of Equations A, B and C. Applying Hess's Law, therefore, it should also be possible to determine the heat of reaction for Equation 1 by combining the heats of reaction for Equations A–C in the same algebraic manner. *Note:* Chemical equations may be combined by addition, subtraction, multiplication and division.

You will use Hess's Law to determine the heat of reaction for the combustion of magnesium (Equation 1). The heats of reaction for Equations A and B will be measured experimentally by calorimetry. These heats of reaction will then be combined algebraically with the heat of formation of water (Equation C) to calculate the heat of reaction for the combustion of magnesium.

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

In this set of prelab questions you will be finding the accepted heat of reaction values for reactions A-C. You will use these values to calculate your percent error in the post-lab.

1. In 3 tables like the one shown below, write the balanced net ionic equations for each reaction. Use the table of thermodynamic data from reference sheet R-19 to calculate the molar enthalpy of the reactions. *Hint* - the net ionic reaction is the one that is actually happening! Use THAT equation to do your enthalpy calculation. And remember...products minus reactants! Show your work!

Reaction A	
Balanced Overall Equation	$Mg(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
Balanced Net Ionic Equation	
Accepted Molar Enthalpy of Reaction Calc. using R-19 data (with work shown!)	

2. Arrange equations A-C in such a way that they add up to Equation 1. In other words, show how you would manipulate the equations using Hess's Law. Make sure to show your work the way you were taught in class!
3. Using your answer to question 2, and the enthalpy of reactions calculated in your tables in question 1, calculate the accepted enthalpy of reaction for Equation 1. Once again, show your work!

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

- * 1.0 M hydrochloric acid, HCl
- * Magnesium oxide, MgO
- * Magnesium ribbon, Mg

Equipment

- Balance
- Weigh boat x 2
- Vernier computer interface
- Temperature Probe
- Microcalorimeter
- Forceps
- 25mL graduated cylinder
- Distilled H_2O
- Scoopula
- Stir plate and stir bar

Google Folder with Most MSDS Files
https://tinyurl.com/2cyva3ku
To help speed up your reagent table!

Flinn's MSDS Website
https://www.flinnsci.com/sds/
For anything that isn't in my Google folder.

SAFETY PRECAUTIONS

Handle the chemicals with care. Hydrochloric acid is toxic by ingestion and inhalation and is corrosive to skin and eyes. Magnesium metal is a flammable solid. Keep away from flames. Do not handle magnesium metal with bare hands. Wash hands thoroughly with soap and water before leaving the lab.

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!*

1) Obtain and wear goggles.

2) Connect a Temperature Probe to Channel 1 of the Vernier computer interface. Connect the interface to the computer with the proper cable.

Reaction A - Conduct the Rxn Between Magnesium with Hydrochloric Acid

3) Obtain a 7-cm strip of magnesium ribbon, and cut it into two pieces of unequal length, roughly 3cm and 4cm each.

4) Weigh and record the mass of each piece of Mg ribbon in your data table.

5) Mass a clean, dry calorimeter.

6) Using a graduated cylinder, add 15mL of 1.0 M hydrochloric acid to the calorimeter. You will weigh your calorimeter while it sits in a weigh boat in case of spills. To do this put an empty weigh boat on the scale and zero out the scale, then put the calorimeter filled with HCl into the weigh boat. Measure and record the combined mass of the calorimeter +acid. *Note:* We are weighing the calorimeter + HCl because we do not know the density of the HCl solution being used. We will need the mass of HCl used in each trial, so we will be weighing it by difference. If we did know the density of the solution then we could just use dimensional analysis to convert to grams of HCl being added.

7) Add the stir bar to the calorimeter and then position and hold the tip of the temperature probe into the calorimeter. Turn the stir plate on and get the stir bar going gently. Make sure the stir bar is not going to hit the thermometer!

8) Conduct the reaction.

a) *Chromebook:* Click bottom left corner where it says "mode." Set the start of data collection to be "manually" **AND** change the end of data collection to be "manually." ~~*LoggerPro:* Click the icon to the left of the collect button . Change data collection to 500 sec. If you end up needing more time choose "Extend Collection" from the "Experiment" menu option, and then click "append to latest."~~

b) Click ▶ Collect to begin the data collection and obtain the initial temperature of the solution in the calorimeter.

c) After three or four readings have been recorded at the same temperature, add the smaller piece of Mg ribbon to the calorimeter all at once. **Make sure all the Mg is submerged!** Stir the mixture throughout the reaction.

d) Continue data collection until you get a stable final temperature. Once the temperature readings are no longer changing, you may terminate the trial early by clicking ■ Stop.

9) Record the initial and final temperatures in your data table.

10) Remove the stir bar carefully. Then pour the contents of the calorimeter down the drain with excess water. Rinse and dry the temperature probe, calorimeter, and stir bar.

11) After drying the calorimeter to the best of your abilities, mass it again and record the new mass.

12) Between each trial – *Chromebook:* click the collect button again. It will assign a new color to the new trial. Click the y-axis label and toggle on each data set you want to be displayed. ~~*LoggerPro:* click "Experiment" → "Store Latest Run".~~ For both programs, make a note of which color data line is which trial.

13) Repeat steps 5–10 Perform another trial using the second (larger) piece of magnesium ribbon (if time allows).

Reaction B - Conduct the Rxn Between Magnesium Oxide with Hydrochloric Acid

14) Mass a clean, dry calorimeter.

15) Using a graduated cylinder, add 15mL of 1.0 M hydrochloric acid to the calorimeter. Measure and record the combined mass of the calorimeter and acid just like you did in part A, ensuring the calorimeter is sitting in the weigh boat not directly on the scale.

16) Take a small weigh boat and add 0.20 g of magnesium oxide. Measure and record the exact mass.

17) Add the stir bar to the calorimeter and then position and hold the tip of the temperature probe into the calorimeter. Turn the stir plate on and get the stir bar going gently. Make sure the stir bar is not going to hit the thermometer!

18) Conduct the reaction.

~~a)~~ *Chromebook:* Click bottom left corner where it says "mode." Set the start of data collection to be "manually" **AND** change the end of data collection to be "manually." ~~*LoggerPro:* Click the icon to left of the collect button . Change data collection to 300 sec. If you end up needing more time choose "Extend Collection" from the "Experiment" menu option, and then click "append to latest."~~

b) Click [▶ Collect] to begin the data collection and obtain the initial temperature of the solution in the calorimeter.

c) After three or four readings have been recorded at the same temperature, add the MgO to the calorimeter all at once. Stir the mixture throughout the reaction.

d) Continue data collection until you get a stable final temperature. Once the temperature readings are no longer changing, you may terminate the trial early by clicking [■ Stop].

19) Record the initial and final temperatures in your data table.

20) Remove the stir bar carefully. Then pour the contents of the calorimeter down the drain with excess water. Rinse and dry the temperature probe, calorimeter, and stir bar.

21) After drying the calorimeter to the best of your abilities, mass it again and record the new mass.

22) Between each trial – *Chromebook:* click the collect button again. It will assign a new color to the new trial. Click the y-axis label and toggle on each data set you want to be displayed. ~~*LoggerPro:* click "Experiment" → "Store Latest Run".~~ For both programs, make a note of which color data line is which trial.

23) Repeat steps 14–20 using a second sample of magnesium oxide (if time allows).

Reaction C – Formation of Water

24) You will not actually be performing this reaction! Instead, you will simply use the accepted value for the formation of water from your prelab instead of an experimentally determined one.

*****NOTE***** You may not be doing all reactions - the teacher may split it up so you perform multiple trials of one reaction and then share data with the groups. You will then be adding your data to a shared spreadsheet so that you can perform your calculations with AVERAGED data which is more accurate. Your teacher will inform you of these potential changes in class if they apply (depends on the year). ***Shared Data Spreadsheet:*** **https://tinyurl.com/2p894e48**

You will do the prelab for ALL sections. *Must be logged in with SRVUSD email to open file*

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 sample table shown below is not adequate! Remember to use enough space, make it look professional, etc!
2. Make sure you make a table for both reactions, even though you may not be doing both in the lab. You need a place to record data from your classmates!
3. Glue in a copy of your Vernier graph(s) below your data table. *Note* If there was an issue with saving one of your graphs that is ok this time – it is our first time learning to use the software! Just explain what happened and why you are missing a graph. If you lost an entire trial of data, you can use a trial from a classmate – get the data from the shared spreadsheet and just make sure to clearly indicate in your lab notebook what happened and whose data you are using!

	Reaction A		Reaction B	
Reactants:				
	Trial 1	**Trial 2**	**Trial 1**	**Trial 2**
Mass of calorimeter (g)				
Mass of calorimeter + HCl solution (g)				
Mass of Mg (Reaction A) or Mass of MgO (Reaction B) (g)				
Maximum temperature (°C)				
Initial temperature (°C)				
Temperature change (ΔT)				

<u>Calculations</u> - *Show all calculations, use proper dimensional analysis, units everywhere, proper sig figs, etc.*
Number each of your calculations to match the numbering used below. After performing all calculations, create a "Results Table" to record the final <u>results</u> of the following calculations. Put this "Results Table" AFTER your numbered calculations. Same expectations as a Data Table with regards to descriptive titles, tables, units, etc. You can either average your data and then perform the calculations once, or you can do the calculations for each trial and then average your final results. Either way, be mindful of showing all calculations, and of rounding issues.

1. Mass of Mg, or MgO used.
2. Mass of hydrochloric acid solution.
3. Total mass of the reactants.
4. Change in temperature.
5. Heat absorbed or released by the solution in the calorimeter. *Note:* $q = mC\Delta T$, where m is the total mass of reactants, and assume C is the specific heat of the solution and that it is the same as water, 4.18 J/g°C.
6. Number of moles of Mg, or MgO used.
7. Enthalpy change for each reaction in units of kJ/mol_{rxn}
8. Average enthalpy change (heat of reaction, ΔH_{rxn}) for Reactions A and B. *Note:* The enthalpy change is positive for an endothermic reaction, negative for an exothermic reaction. Make sure to include the proper algebraic sign! Remember the difference between system and surroundings! What you measure in the lab may not be the system we are actually interested in.
9. Use Hess's Law to calculate the heat of reaction for Equation 1. *Hint:* See your answer to Prelab Question 2. Remember that you will not be using an experimental value for Equation C, instead use the accepted value you obtained in your prelab.
10. The heat of reaction for Equation 1 is equal to the heat of formation of solid magnesium oxide.
    a. Look up the heat of formation of magnesium oxide in your textbook or a chemical reference source.
    b. Calculate the percent error in your experimental determination of the heat of reaction for Equation 1.

<u>Post Lab Discussion Questions</u> - *Do not recopy the questions, just paraphrase them into your answer.*

1. Identify whether each reaction A, B, C, and Equation 1 were endothermic or exothermic.
2. Identify the algebraic sign for each of the reactions, A, B, C and Equation 1.
3. Describe how this experimental process supports Hess's Law. **Hint** - it should show that Hess's Law was valid to use! Yes, we have some % error, but it should be decently close.
4. A student performs a new experiment with solutions labeled A and B. The specific heat of both solutions are 4.18 J/g°C and their densities are 1.22 g/mL. A calorimetry reaction is performed by combining 25.0 mL solution A, with 25.0 ml of solution B. Each solution was initially at 21.4°C. The final temperature of the combined solutions after the reaction is 25.3°C. Calculate the heat of reaction assuming no heat was lost to the calorimeter or the surroundings.
5. If the reaction in post-lab question 4 is $A_{(aq)} + B_{(aq)} \rightarrow AB_{(aq)}$, and the molarity of A is 0.06M and the molarity of B is 0.04M, calculate the *<u>molar</u>* enthalpy of reaction.