Measuring the Heat of Reaction for Magnesium and Hydrochloric Acid

The flow of energy in a chemical reaction can be traced by allowing a measured amount of chemicals to react with each other while the temperature of the reaction is measured. As the reaction progresses, the rise or fall of temperature of the reaction mixture and the immediate environment (in this case a calorimeter) gives a quantitative measure of the amount of heat energy flowing in or out of a chemical system. Flow of heat into a chemical system is called an **endothermic** reaction and feels cool to the touch. Flow of heat out from a chemical system is called an **exothermic** reaction and feels warm to the touch. In either case, a change in kinetic energy of the surroundings is noted by a change in the temperature.

Exothermic reactions, symbolized by a **negative ΔH**, result in a loss of energy by the reactants and a gain in heat to the environment. [The delta symbol, Δ, symbolizes change.] The products are at a lower potential energy level than the reactants. **Endothermic reactions**, symbolized by a **positive ΔH value**, result in a product that has a higher potential energy than the reactants. In this experiment, precautions must be taken to retain the heat energy in such a way that the immediate environment retains the energy so that an accurate accounting can be made. A **calorimeter** is used to isolate the reaction from the surroundings.

In the reaction below, the reaction of magnesium metal is traced. Magnesium metal reacts with the hydrogen ion of hydrochloric acid according to the following equation:

$$Mg\,(s) + 2\,H^{+}\,(aq) \rightarrow Mg^{2+}\,(aq) + H_2\,(g) + \text{heat}$$

The heat released is a direct measure of the heat of formation, ΔH_f, of the magnesium ion, Mg^{2+}. This is because the heats of formation of all the other species are zero. Why? Because, by definition, the **heat of formation for any element in its most stable state at standard conditions is defined as being zero**.

The heat released by this reaction can be calculated by following the directions outlined in the procedure. The experimental work may be checked by looking up the thermochemical data for each of the reactants and products in a Standard Table of Heats of Formation of Compounds found in most textbooks or in the CRC Handbook of Chemistry & Physics. Be sure to look up the compound or element in the correct state of matter before using the heat content values listed. Once one metal / ion pair has been determined experimentally, the information gathered can be used to extend the thermodynamic table to include many ions.

Materials needed:

3 pieces of Mg ribbon - **each** about 8 - 10 cm in length
10 ml of dilute HCl solution for each trial - use approx. 2 M HCl solution
plastic calorimeter - made from two plastic sauce cups, a lid, and a rubber band
sand paper or steel wool (if cleaning of the metal surface is needed)
electronic balance ±0.001g or ±0.01g, metric ruler, thermometer

Procedure:

Put your goggles and labcoats on now! *Hydrochloric acid is caustic and will burn your skin, eyes, and clothes. Upon contact, flush immediately with copious amounts of water. Keep the glasses on at all times!*

1. Assemble the calorimeter. If one is not already assembled, put it together as follows:
   a) take a plastic cup, wrap a rubber band around it, then insert this cup inside another cup.
   b) using a hole punch, put a single hole in a lid.
   c) make sure that their is a tight seal between the two cups - air acts as an insulator.

2. Mass the entire calorimeter (cups, rubber band and lid) to the nearest **thousandth** of a gram (or to the nearest **hundredth** of a gram, if only a centigram balance is available).

3. Take a 22 - 26 cm length of magnesium ribbon and clean it with a piece of sandpaper or steel wool. Mass the cleaned piece of magnesium ribbon to the nearest **thousandth** of a gram. Measure the length to 3 significant figures. Calculate the mass-to-length ratio for magnesium ribbon – **3 sig. figs**

4. Cut the cleaned ribbon into three approximately equal pieces. If a milligram balance is available, mass each cleaned piece of magnesium ribbon to the nearest **thousandth** of a gram.

5. Measure the length of each cleaned piece magnesium ribbon to 3 significant figures. Using the mass-to-length ratio found in Step 3, calculate the mass of each piece – **3 sig. figs**. Compare the measured mass of each piece to its calculated value based on its length. Which technique is more accurate? Explain your answer.

6. Add approximately 10 ml of the HCl solution to the calorimeter. **Record the mass and the temperature of the calorimeter and HCl solution.**

7. Add the magnesium ribbon to the calorimeter through the hole in the lid.

8. Quickly place the thermometer into the calorimeter (through the hole) and record the temperature change every ten seconds until there is no further rise in temperature. **Watch the temperature constantly, though, because you want the <u>highest temperature reading</u>.**

9. Thoroughly rinse out the calorimeter. Dry it thoroughly as well.

10. Repeat the procedure for a second trial using the second piece of Mg ribbon.

11. Repeat the procedure for a third trial using the third piece of Mg ribbon.

12. Rinse out the calorimeter and return all equipment to the proper place.

Data Table

Show ALL Sample Calculations on the last page.

	Trial #	**Trial #2**	**Trial #3**
1a. Mass of Mg ribbon(measured with balance in grams)....	___________	___________	___________
1b. Mass of Mg ribbon(calculated from length in grams)....	___________	___________	___________
2. Mass of calorimeter & HCl solution (in grams).............	___________	___________	___________
3. Mass of empty calorimeter (in grams)...........................	___________	___________	___________
4. Mass of HCl solution……..	___________	___________	___________

5. Final temperature of reaction mixture (°C).....................	___________	___________	___________
6. Initial temperature of HCl solution (°C).........................	___________	___________	___________
7. Change in temperature (°C)..	___________	___________	___________
8. Moles of magnesium	___________	___________	___________
9. Total joules lost by reactants..	___________	___________	___________
10. Total joules gained by the calorimeter..........................	___________	___________	___________
11. Kilojoules per mole of Mg (experimental)..................	___________	___________	___________
12. Kilojoules per mole of Mg (theoretical)......................	460. kJ	460. kJ	460. kJ
13. Percent error..	___________	___________	___________

Useful equations & constants:

A. 1.00 mole of magnesium metal = 24.3 grams

B. joules produced by reaction = (mass of solution)(C_p of solution)(Δ temperature)

C. $\Delta H_{rxn} = mC\Delta t$ C_p of solution is about equal to C_p of water = 4.184 joule/g·°C = 1.00 cal/g·°C

D. Heat lost by a reaction = **-** Heat gained by a system

E. Experimental heat of reaction is calculated by taking the value in C, converting to kJ and dividing by value of A.

F. percent error = $\frac{|\text{experimental - theoretical}|}{\text{theoretical}} \times 100$

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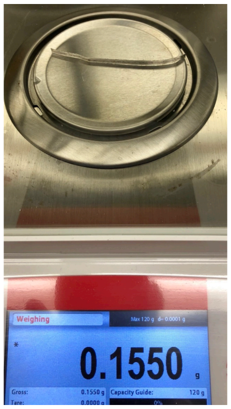
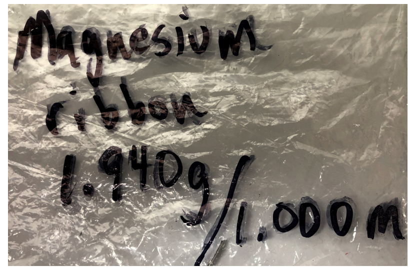
Show Sample Calculations Here!

Explanation of Sources of Error

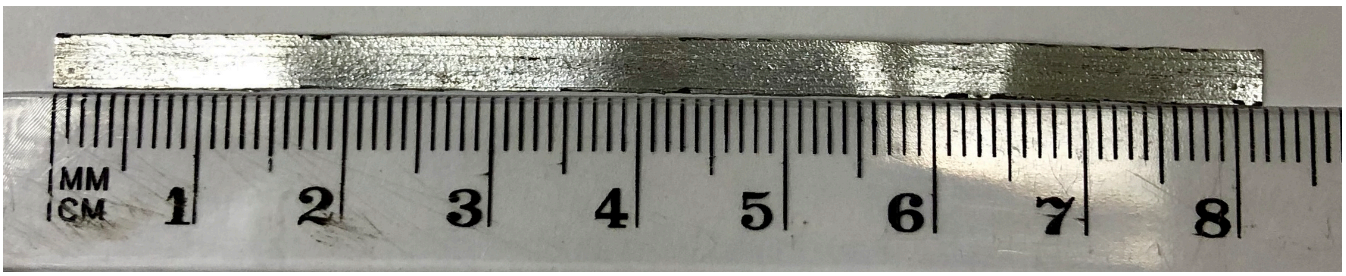
Heat of Magnesium Lab Sample Data



Mass of piece of magnesium ribbon

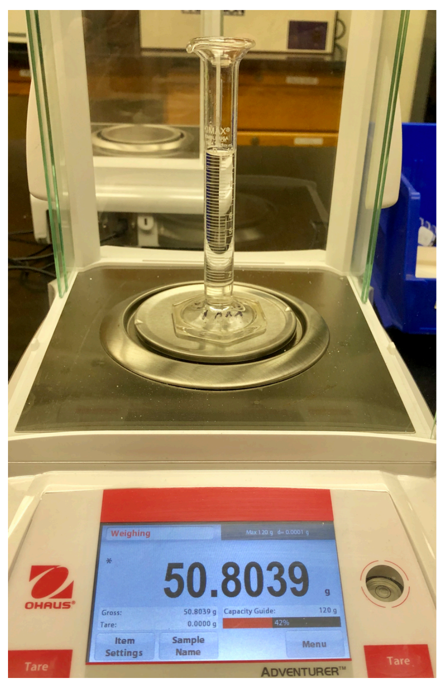


Mass of 1.000 m of Mg ribbon

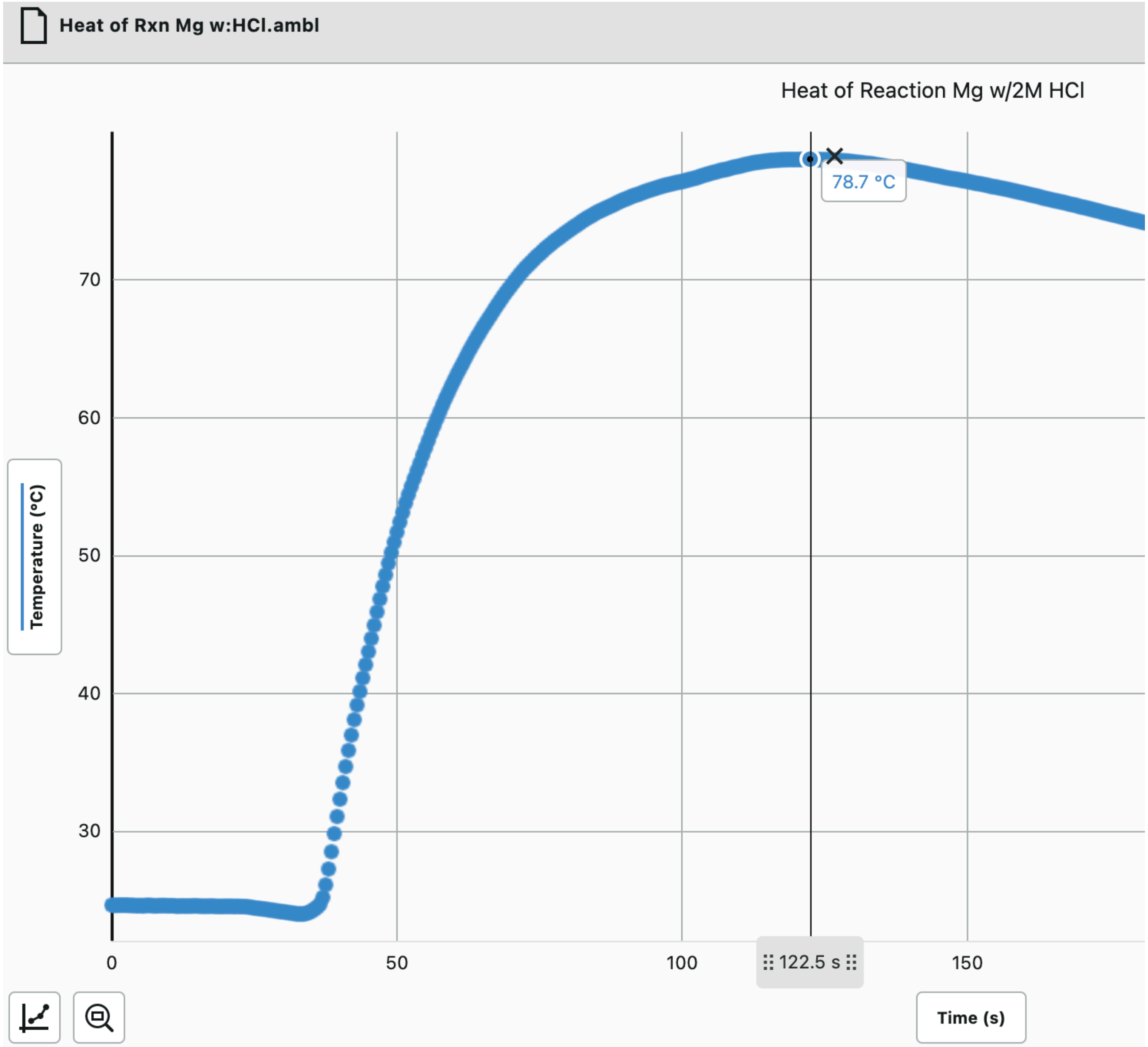


Length of Mg ribbon used in experiment

Mass of empty 10 mL graduated cylinder



Mass of cylinder and 10.0 mL of 2.0 M HCl(aq)



Heat of Rxn Mg w:HCl.ambl
Heat of Reaction Mg w/2M HCl
Temperature (°C)
70
60
50
40
30
78.7 °C
0
50
100
122.5 s
150
Time (s)