Experiment 8 Thermochemistry

CH204 Spring 2006

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What is Thermochemistry?

The study of heat in chemical reactions.

Forming chemical bonds releases energy.
Breaking chemical bonds requires energy.
How much energy? Depends on the bond.

Add up all the energies to get the heat of reaction, ΔH_{rxn}.

Δ Delta means change

In science, the Greek letter Δ means we're talking about a change in something.

ΔH means we're talking about a change in heat. The reaction is either giving off heat ($-\Delta H$) or absorbing heat from its environment ($+\Delta H$).

This week in lab

This week we will measure the amount of heat given off by a piece of hot metal and by two chemical reactions

$Mg + 2H^{+} \rightarrow Mg^{2+} + H_2$ + heat

$MgO + 2H^{+} \rightarrow Mg^{2+} + H_2O$ + heat

using a thermally insulated reaction vessel called a ~~coffee cup.~~ *calorimeter.*

What is a calorimeter?

An ideal calorimeter is a container that

- traps 100% of the heat generated within it
- absorbs no heat itself.

The basic operation of calorimetry

Start with a known volume of a solution of known temperature in the calorimeter.

Drop in something hot, or start a reaction that generates heat.

Immediately close the calorimeter and measure the increase in temperature as heat is generated.

Keep measuring the temperature until it finally levels out.

99% ~~100%~~ Foolproof

- Put solution in coffee cup
- Measure temp every 30 seconds until constant (3-4 min)
- Start reaction
- Record temperature every 15 seconds until constant or slow decline

How not to screw this up

1) Start recording temps *before* starting the reaction
2) Cover and swirl immediately!
3) Continue recording temps on the same timeline throughout the experiment.
4) Keep taking temperature readings until the temp is constant or declining

Measuring temperature

- The tip of the probe should be IN THE SOLUTION, not resting on the bottom or stuck through the bottom.

Yes, we have no data table

There's no Time/Temperature data table in your lab manual.

Make one in your lab notebook. One table per run, all data for each run goes on the *same* timeline.

Part 1

Ideally, a calorimeter traps all of the reaction heat without absorbing any, but our styrofoam calorimeters will absorb a small amount of heat.

In Part 1 we will measure how much heat our calorimeters absorb. We will use that information in our calculations for the other three parts of the lab. Goof this part up and you are hosed throughout.

Part One: Add hot water to cold

50 mL of cold water (5ºC) and add 50 mL of hot water (75ºC). Final temp should be

$(75 + 5) \div 2 = 40^{\circ}C$

But the final temp will actually be *lower* than that because the cup itself will absorb a little bit of the heat.

Heat Capacity

We will use the data in part 1 to calculate the *heat capacity* of the cup, in units of J/K. This will tell us how many Joules of heat the cup absorbs for every degree K (or C) the water heats up.

We know how many Joules of heat we added with the hot water, and we can calculate how many Joules were absorbed by the cold water as it warmed up. The "unused" heat was absorbed by the cup.

(The initial and final temperature of the cup is the same as that of the water.)

A quick comment on notation

T_C = Temperature of the cold water

T_H = Temperature of the hot water

T_M = Temperature of the mixture of hot and cold water

T_0 = Initial temperature before mixing. This is the *same thing* as T_C

$$T_0 = T_C$$

Part 2

In Part 2 we will determine the identity of an unknown metal by calculating its *specific heat capacity*.

Specific heat capacity is how much heat (in Joules) it takes to heat up *one gram* of something by one degree Kelvin.

A word on heat capacities

SPECIFIC HEAT CAPACITY is an *intensive* property. Specific heat capacity tells how much heat (in Joules) is required to raise the temperature of *one gram* of the substance by one degree Kelvin.

HEAT CAPACITY is an *extensive* property. It takes into account how much mass you have.

Part 2 – hot metal

You will need to fill out an unknown sign-out slip to get your metal unknown. Put both names on the slip.

You must return the unknown metal to the stockroom before you leave.

In Part 2 you will go through a lot of boiling water. Use both hot plates and keep your beaker with the metal full.

Part 2 again

We know the mass of the water, T_C and T_M, and we know how much energy is required to heat 1 gram of water by 1 degree Kelvin (c_s = 4.184 J/gK).

With this information (and the heat capacity of the calorimeter calculated from Part 1), we can calculate how much heat energy the hot metal supplied to the water.

Every equation is a sentence

The total heat given up by the metal is equal to the amount of heat absorbed by the water plus the amount of heat absorbed by the calorimeter: $Q_{total} = Q_{water} + Q_{calorimeter}$

The amount of heat absorbed by the water is equal to the mass of the water times its specific heat capacity times the change in temperature: $Q_{water} = m_w \times c_w \times \Delta T$

The amount of heat absorbed by the calorimeter is equal to its heat capacity times the change in temperature: $Q_{cal} = C_{cal} \times \Delta T$

Identifying the unknown metal

Since we know the mass of the metal, its initial and final temperatures, and how much heat it gave up to the water, we can calculate its specific heat capacity.

$$c_m = \text{Joules}/(\text{mass}_{metal} \times \Delta T)$$

↑ Q_{total}

Parts 3 and 4

The reactions of magnesium and magnesium oxide with HCl. Mix these continuously, expecially the MgO.

IMPORTANT: Use 2.0M HCl to react with the Mg metal (Part 3). Use 6.0M HCl to react with the MgO (Part 4).

HCl in the hood is 6.0 M.

Making graphs in Excel

Draw lines on the graphs yourself or have Excel do it for you.

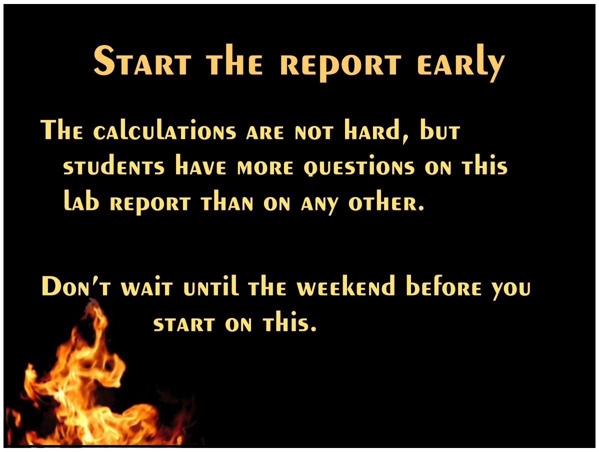
Get equation for the line, plug in time of mixing to get T_H and T_C (remember $T_C = T_0$).

Four Things to Remember

1) The Alamo
2) Return digital thermometers to the beaker of water in the hood as soon as you finish with them.
3) Put both lab partners' names on the unknown sign-out sheet.
4) Return your metal unknown to the stockroom before you leave.

Fatherly Advice

Your lab partner is a scheming backstabber who will withhold the data from you until the end of the semester. Trust him or her like you would a rattlesnake.


Start the report early
The calculations are not hard, but students have more questions on this lab report than on any other.
Don't wait until the weekend before you start on this.