Experiment 8
Thermochemistry

CH 204 Fall 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}.

This week in lab

We will measure the amount of heat given off by 50 ml of hot water, by some chunks of hot metal, and by two chemical reactions

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

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

We'll do all these reactions in a coffee cup calorimeter.

The basic operation of calorimetry

- Start with a known volume of a solution in the calorimeter.
- Drop in something hot, or start a reaction that generates heat.
- Close the calorimeter and measure the increase in temperature as heat is generated.
  - Keep measuring the temperature until it finally levels out.

Part One: Add hot water to cold

50 mL of cold water (5°C). Add 50 mL of hot water (75°C). Final temp should be

$$(75 + 5) \div 2 = 40°C$$

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 K (or degree 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" Joules were absorbed by the cup.

$$C_{cal} = \text{Joules}/\Delta T$$

Part 2
Unknown Metal

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 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 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 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, 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_M and T_C.

Get it right the first time

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.

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 request slip.
4) Return your metal unknown to the stockroom before you leave.

Some Fatherly Advice

Start the report early

Don't wait until all the TA's office hours have passed before you start on this.

The calculations are not hard, but students have more questions on this lab report than on any other.

Post-Lab Typo

Problem 4:

$CO_{2(g)} + 2\ H_2O_{(l)} \longrightarrow CH_{4(g)} + \underline{2}\ O_{2\ (g)}$

Next Week's Quiz

Hess's Law

Calculate a heat capacity given some reaction data