# Experiment 8
# Thermochemistry

CH 204 Fall 2008

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## Last week

Dilutions - Backward and Forward

Beer's Law: A = εcl

Determined Molecular Formula for Crystals

## Thermochemistry

The study of HEAT in chemical reactions.

Heat is produced and consumed in chemical reactions in stoichiometric amounts, just like any other reactant or product.

## Thermochem in CH204

We look at two different thermochemical situations:

**Calorimetry**

add something hot to something cold

heat lost by the hot = heat gained by the cold

**Hess's Law**

Forming chemical bonds releases energy.

Breaking chemical bonds requires energy.

Add up all the energies to get the heat of reaction, $\Delta H_{rxn}$.

## Calorimetry

Calorimeter – a container that traps heat

Put a known mass of water in the calorimeter, add something hot, and measure heat gain by the temperature increase of the water

The calorimeter itself also heats up when something hot is added

## Accounting for heat energy

The total amount of heat added is equal to the amount of heat absorbed by the water plus the amount of heat absorbed by the calorimeter: $q_{added} = q_{water} + q_{calorimeter}$

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

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

## Specific heat capacity

The amount of heat it takes to raise 1 gram of a substance by 1 degree C

Units are J/gK

$c_{subscript}$

## 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 Kelvin.

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

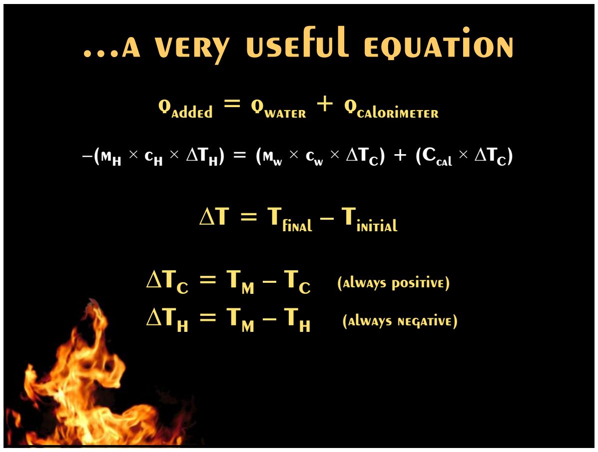
## Lots o' Variables!

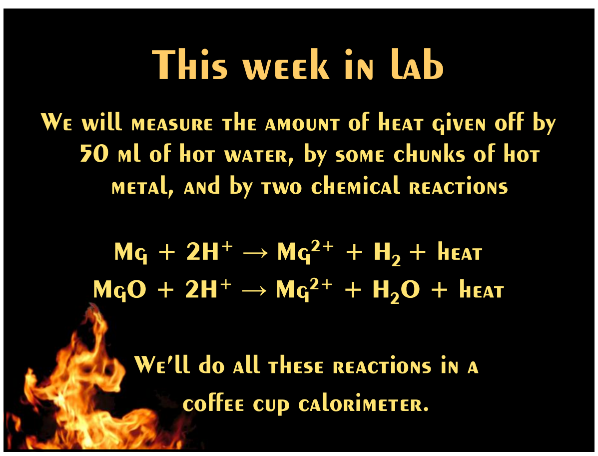
$$q_{added} = q_{water} + q_{calorimeter}$$

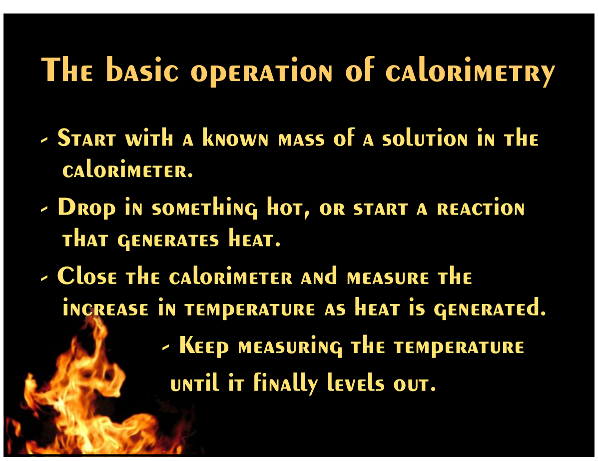
$$q_{added} = (m_C \times c_s \times \Delta T_C) + (C_{cal} \times \Delta T_C)$$

$$\text{Heat added} = -(m_H \times c_H \times \Delta T_H)$$

Combine 'em all in one equation and you get...


…a very useful equation
$Q_{added} = Q_{water} + Q_{calorimeter}$
$-(m_H \times c_H \times \Delta T_H) = (m_w \times c_w \times \Delta T_C) + (C_{cal} \times \Delta T_C)$
$\Delta T = T_{final} - T_{initial}$
$\Delta T_C = T_M - T_C$ (always positive)
$\Delta T_H = T_M - T_H$ (always negative)


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 mass 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.

## Fair warning

You will be collecting lots and lots o' data points, but there are no tables in the lab manual for all this data.

All time and temperature data gets recorded directly into the lab notebook. Any loose sheets of data belong to me, and you can start over.

## 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 cup heats up.

$$-(m_H \times c_H \times \Delta T_H) = (m_w \times c_w \times \Delta T_C) + (C_{cal} \times \Delta T_C)$$

## Part 2
## Unknown Metal

We will determine the identity of an unknown metal by calculating its specific heat capacity.

$$-(m_M \times c_M \times \Delta T_H) = (m_C \times c_s \times \Delta T_C) + (C_{cal} \times \Delta T_C)$$

## Unknown summary sheet

Specific heat capacity of your unknown metal and the identity of your metal.

Observations are valid data. What does your metal look like? Is it magnetic? What is its density?

## Parts 3 and 4

The reactions of magnesium and magnesium oxide with HCl. Mix these continuously, especially 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.

## Parts 3 and 4

Calculate how much heat is given off by the reaction:

$$\text{heat added} = (m_s \times c_s \times \Delta T_C) + (C_{cal} \times \Delta T_C)$$

Divide the heat added by the moles of Mg or MgO used to get $\Delta H$ in J/mole

## Making graphs in Excel

You'll have a total of 5 graphs (2 for Part 1, and 1 each for parts 2, 3, and 4).

You will use the graphs to determine $\Delta T_C$.

You can draw lines on the graphs yourself or have Excel do it for you.

## 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

## Working with a partner

Put your partner's name on everything, but turn in your own report, with your own graphs and your own unknown summary sheet.

You are working with a partner to collect the lab data, but you should still do the write-up by yourself.

## Some Fatherly Advice

## Start the report early

Don't wait until all the TA 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.

## The Post-Lab

Calorimetry problems and Hess's Law problems.

Post-lab problem 5 is messed up in the lab manual. It should look like the next slide.

## Correct Post-lab 5 Question

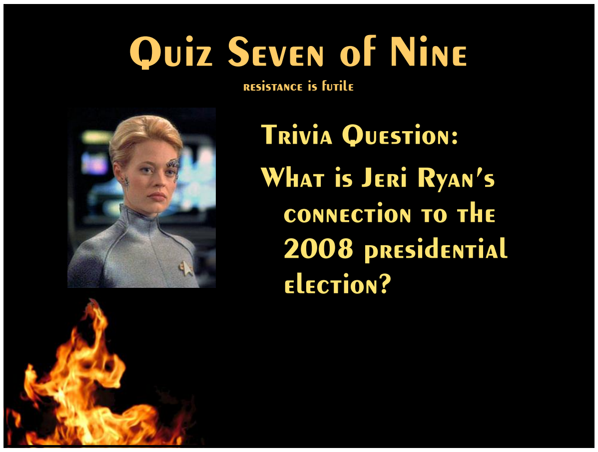
| | | |
|---|---|---|
| $CS_2$ (l) + 3 $O_2$ (g) $\longrightarrow$ | 2 $SO_2$ (g) + $CO_2$ (g) | $\Delta H^0 = -1077.0$ kJ |
| C (graphite) + $O_2$ (g) $\longrightarrow$ | $CO_2$ (g) | $\Delta H^0 = -393.5$ kJ |
| S (s) + $O_2$ (g) $\longrightarrow$ | $SO_2$ (g) | $\Delta H^0 = -296.8$ kJ |

Calculate the standard molar enthalpy of formation for $CS_2$ (l).

## Next Week's Quiz

- Know the calorimetry equation
- Be able to do Hess's Law problems
- Know the definitions of the terms we're using this week:

  heat capacity, specific heat capacity,
  enthalpy of formation,
  standard state, Hess's Law


Quiz Seven of Nine
resistance is futile
Trivia Question:
What is Jeri Ryan's connection to the 2008 presidential election?