

**EXPERIMENT 8**  
**THERMOCHEMISTRY**

CH 204 SPRING 2008  
DR. BRIAN ANDERSON

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**LAST WEEK**

DILUTIONS - BACKWARD AND FORWARD

BEER'S LAW:  $A = \epsilon cl$

DETERMINED MOLECULAR FORMULA FOR CRYSTALS



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**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.



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## 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,  $\Delta H_{rxn}$ .



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## 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



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## 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:  $q_{cal} = C_{cal} \times \Delta T_c$



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## Specific HEAT CAPACITY

THE AMOUNT OF HEAT IT TAKES TO RAISE 1 GRAM OF  
A SUBSTANCE BY 1 DEGREE C

UNITS ARE J/gK

$c_{\text{subscript}}$



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## 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.



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## LOTS o' VARIABLES!

$$Q_{\text{TOTAL}} = Q_{\text{WATER}} + Q_{\text{CALORIMETER}}$$

$$Q_{\text{TOTAL}} = (m_C \times c_s \times \Delta T_C) + (C_{\text{cal}} \times \Delta T_C)$$

$$\text{HEAT ADDED} = -(m_H \times c_H \times \Delta T_H)$$

COMBINE 'EM ALL IN ONE EQUATION  
AND YOU GET...



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## ...A VERY USEFUL EQUATION

$$q_{\text{TOTAL}} = q_{\text{WATER}} + q_{\text{CALORIMETER}}$$

$$-(m_{\text{H}} \times c_{\text{H}} \times \Delta T_{\text{H}}) = (m_{\text{W}} \times c_{\text{W}} \times \Delta T_{\text{C}}) + (C_{\text{CAL}} \times \Delta T_{\text{C}})$$

$$\Delta T = T_{\text{FINAL}} - T_{\text{INITIAL}}$$

$$\Delta T_{\text{C}} = T_{\text{M}} - T_{\text{C}} \quad (\text{ALWAYS POSITIVE})$$

$$\Delta T_{\text{H}} = T_{\text{M}} - T_{\text{H}} \quad (\text{ALWAYS NEGATIVE})$$



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## 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

$$\text{Mg} + 2\text{H}^+ \rightarrow \text{Mg}^{2+} + \text{H}_2 + \text{HEAT}$$

$$\text{MgO} + 2\text{H}^+ \rightarrow \text{Mg}^{2+} + \text{H}_2\text{O} + \text{HEAT}$$

WE'LL DO ALL THESE REACTIONS IN A COFFEE CUP CALORIMETER.




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## 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.




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## 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.



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

BUT THE FINAL TEMP WILL ACTUALLY BE *LOWER* THAN THAT BECAUSE THE CUP ITSELF WILL ABSORB A LITTLE BIT OF THE HEAT.



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## 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.

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



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**PART 2**  
**UNKNOWN METAL**

WE WILL DETERMINE THE IDENTITY OF AN UNKNOWN METAL BY CALCULATING ITS SPECIFIC HEAT CAPACITY.

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


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**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?



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**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.



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## PARTS 3 AND 4

CALCULATE HOW MUCH HEAT IS GIVEN OFF BY THE REACTION:

$$\text{HEAT ADDED} = (m_s \times c_s \times \Delta T_c) + (C_{\text{cal}} \times \Delta T_c)$$

DIVIDE THE HEAT ADDED BY THE MOLES OF Mg OR MgO USED TO GET  $\Delta H$  IN J/MOLE



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## 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.



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## 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



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## **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.**



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## **SOME FATHERly Advice**



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## **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.**



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## THE POST-LAB

ONE CALCULATION OF SPECIFIC HEAT CAPACITY.

TWO CALORIMETRY PROBLEMS.

TWO HESS'S LAW PROBLEMS.

NO PARTIAL CREDIT THIS TIME!

THERE IS A HINT SHEET ON THE [FREEBIES](#) PAGE.

EVERYBODY GET A 10 ON THIS!



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## 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



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