



# **EXPERIMENT 8**

# **THERMOCHEMISTRY**

**CH 204 FALL 2008**

**DR. BRIAN ANDERSON**

**LAST WEEK**

**DILUTIONS - BACKWARD AND FORWARD**

**BEER'S LAW:  $A = \epsilon c l$**

**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,  $\Delta H_{\text{RXN}}$ .



# **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:  $Q_{\text{Added}} = Q_{\text{WATER}} + Q_{\text{CALORIMETER}}$

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:  $Q_{\text{WATER}} = m_{\text{W}} \times c_{\text{W}} \times \Delta T_{\text{C}}$

THE AMOUNT OF HEAT ABSORBED BY THE CALORIMETER IS EQUAL TO ITS HEAT CAPACITY TIMES THE CHANGE IN TEMPERATURE:  $Q_{\text{CAL}} = C_{\text{CAL}} \times \Delta T_{\text{C}}$



# Specific HEAT CAPACITY

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

UNITS ARE J/gK

$c_{\text{subscript}}$



# 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!

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

$$Q_{\text{Added}} = (m_{\text{C}} \times c_{\text{s}} \times \Delta T_{\text{C}}) + (C_{\text{CAL}} \times \Delta T_{\text{C}})$$

$$\text{HEAT Added} = -(m_{\text{H}} \times c_{\text{H}} \times \Delta T_{\text{H}})$$

COMBINE 'EM ALL IN ONE EQUATION

AND YOU GET...



# ...A VERY USEFUL EQUATION

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

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

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

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

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



# **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**



**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**

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

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



# 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:**

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

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



# 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



Calculate the standard molar enthalpy of formation for  $\text{CS}_2 (\text{l})$ .



# 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?**

