Chemistry 3A

Introductory General Chemistry

Experiment 7a

Calorimetry

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Introduction

- **Calorimetry** means the measurement of heat. This measurement is of heat energy either given off (exothermic) or absorbed (endothermic) by the system from the surroundings
- Heat is measured by **temperature** changes with a thermometer and utilizes the specific heat capacity equation:

$$q = m \times c \times \Delta T$$

Symbol	**Meaning**	**Units**
$\boldsymbol{q}$	energy as/in the form of heat	J or cal
$\boldsymbol{m}$	mass of the substance in the system	g
$\boldsymbol{c}$	specific heat capacity of substance: this is a physical property determined by scientists doing experiments	J / (g °C)
$\boldsymbol{\Delta T}$	change in temperature in °C: this is the final temperature minus the initial temperature	°C

Background: Part 1

When a solid is dissolved in a liquid (solvent), there can be an energy change related to the molecules of the solid interacting with the molecules of the solvent.

- When heat is released in dissolving, reaction is exothermic
- When heat is absorbed in dissolving, reaction is endothermic

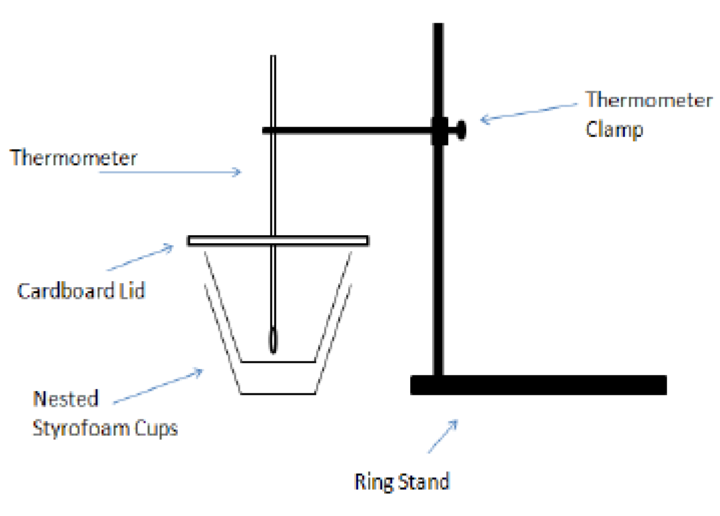


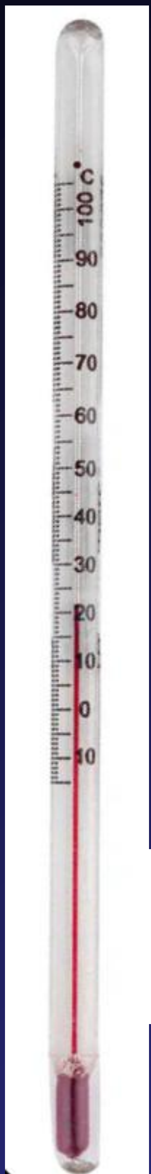
Figure 1: Calorimeter Set-

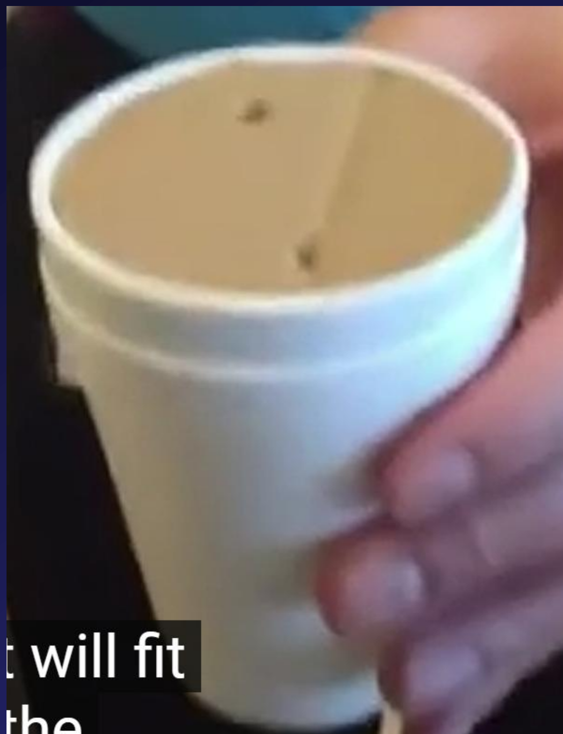
Background: Part 2

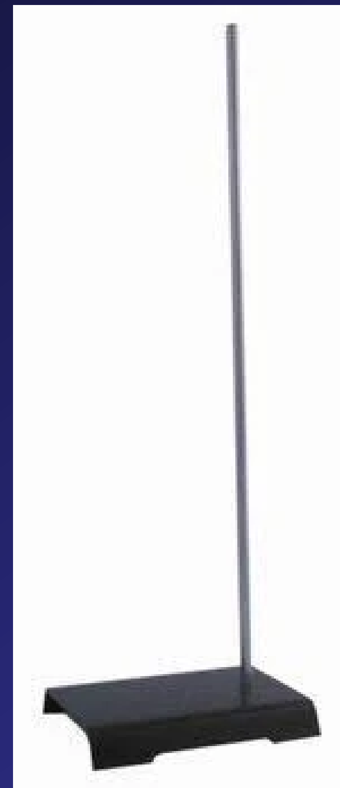
Objects with different temperatures in contact with each other, heat from the warmer object transfers to the cooler object until both reach same temperature.

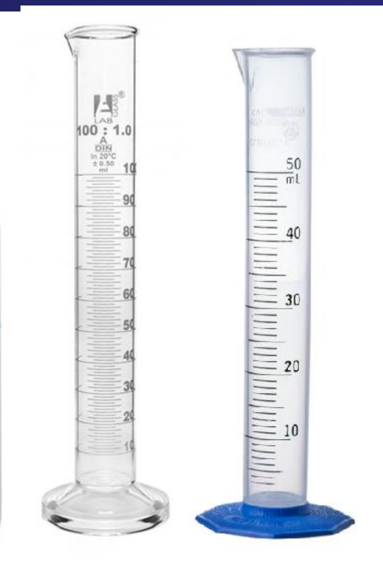
- Since energy is conserved, if H_2O as ice is put in contact with H_2O as water, it should be possible to measure temperature changes in the water as ice melts to see if this law is observed

Equipment You Will Use









Consumables

Procedure: Part 1

1. Construct the calorimetry setup with the foam cups
2. Measure the mass of the cups ONLY
3. Add 45.0 to 55.0 mL DI water to grad cylinder & pour into cups
4. Record temperature to nearest 0.1°C
5. On glassine paper, scoop out 4.8-5.2 g citric acid without causing excessive waste. Tighten the reagent lid after.
6. Add citric acid carefully but quickly to the calorimeter with water and place lid on setup; VERY CAREFULLY with lid closed stir the solution until solid dissolves

Procedure: Part 1

7. Record temperature to nearest 0.1°C after it stabilizes (it might go up or down)
8. Remove the cardboard lid. Record the mass of the calorimeter setup: cups + solution
9. Empty the solution into a beaker (for waste) then rinse and dry the inner cup
10. Switch the inner cup with outer cup
11. Repeat steps 3-8 with sodium carbonate (Na_2CO_3)
12. Pour out the waste into the beaker, discard the solution into the sink

Procedure: Part 2

1. Construct the calorimetry setup with the foam cups and add 45.0-55.0 mL DI water
2. Measure the mass of calorimeter with water without lid
3. Record temperature to nearest 0.1°C
4. Transfer 2-3 cubes ice to calorimeter
5. Place lid and stir carefully with thermometer until ice melts. Record the final temperature
6. Record mass of calorimeter with contents (not lid)

Example Data Analysis

PART 1 – Exothermic and Endothermic Changes

DATA

Mass of calorimeter (empty): 16.4831 g

	$H_3C_6H_5O_7$	Na_2CO_3
Initial Temperature (°C)	22.8°C	22.1°C
Final Temperature (°C)	19.3°C	27.9°C
Mass of calorimeter *and* solution (g)	72.0944 g	68.3891 g

PART 2 – Specific Heat Capacity and Enthalpy of Fusion

DATA

	Data
Mass of calorimeter + water (g)	64.3499 g
Initial Temperature of water (°C)	21.4°C
Final Temperature of water (°C)	15.8°C
Mass of calorimeter + water + ice (g)	67.8851 g

Example Data Analysis

PART 1 – Exothermic and Endothermic Changes

DATA

Mass of calorimeter (empty): 16.4831 g

	$H_3C_6H_5O_7$	Na_2CO_3
Initial Temperature (°C)	22.8°C	22.1°C
Final Temperature (°C)	19.3°C	27.9°C
Mass of calorimeter *and* solution (g)	72.0944 g	68.3891 g

CALCULATIONS – PART 1 – EXOTHERMIC AND ENDOTHERMIC CHANGES

* Show your work, complete with units for $H_3C_6H_5O_7$. I will assume you did Na_2CO_3 the same way

1. ☐ Mass of the solution

How do you calculate?

2. ☐ Change in Temperature of Solution

3. ☐ Heat of Solution ($q_{solution}$)

RESULTS – PART 1 – ENDOTHERMIC AND EXOTHERMIC CHANGES

	$H_3C_6H_5O_7$	Na_2CO_3
Mass of Solution (m)	How do you calculate?	
Specific Heat of Solution (c)	4.184 J/g°C	4.184 J/g°C
Change in Temperature of Solution(ΔT)		
Heat of solution ($q_{solution}$)		
Heat of reaction* ($q_{reaction} + q_{solution} = 0$)		
Reaction is: Exothermic or Endothermic		

* The water in the calorimeter is considered the reaction's surroundings, therefore if heat is released by the reaction, it is absorbed by the water and vice-versa.

Example Data Analysis

PART 2 – Specific Heat Capacity and Enthalpy of Fusion

DATA

	Data
Mass of calorimeter + water (g)	64.3499 g
Initial Temperature of water (°C)	21.4°C
Final Temperature of water (°C)	15.8°C
Mass of calorimeter + water + ice (g)	67.8851 g

CALCULATIONS – PART 2 – SPECIFIC HEAT CAPACITY AND ENTHALPY OF FUSION

* Show your work, complete with units.

1. Mass of H_2O

How do you calculate?

2. Change in Temperature of Water
3. q_{water}

How do you calculate?

4. Mass of Ice
5. Moles of Ice
6. q_{ice}
7. $q_{water} + q_{ice}$

RESULTS

	Results
Mass of H_2O	
Specific Heat of water (c)	4.184 J/g°C
Change in Temperature of water (ΔT) ($\Delta T = T_f - T_i$)	
q_{water} (kJ)	
Mass of Ice	
Moles of Ice (n)	
Enthalpy of Fusion (ΔH_{fus})	6.01 kJ/mol
q_{ice} (kJ)	
$q_{water} + q_{ice}$	

How do you calculate?

Example Data Analysis

PART 1 – Exothermic and Endothermic Changes

DATA

Mass of calorimeter (empty): 16.4831 g

	$H_3C_6H_5O_7$	Na_2CO_3
Initial Temperature (°C)	22.8°C	22.1°C
Final Temperature (°C)	19.3°C	27.9°C
Mass of calorimeter *and* solution (g)	72.0944 g	68.3891 g

CALCULATIONS – PART 1 – EXOTHERMIC AND ENDOTHERMIC CHANGES

* Show your work, complete with units for $H_3C_6H_5O_7$. I will assume you did Na_2CO_3 the same way

1. ☐ Mass of the solution 72.0944-16.4381 = 55.6563 g

2. ☐ Change in Temperature of Solution 19.3 - 22.8 = -3.5°C

3. ☐ Heat of Solution ($q_{solution}$)

4.184 J/g°C x 55.6553 g x (-3.5°C)
= -820 J 2 significant digits

RESULTS – PART 1 – ENDOTHERMIC AND EXOTHERMIC CHANGES

	$H_3C_6H_5O_7$	Na_2CO_3
Mass of Solution (m)	55.6553 g	51.9060 g
Specific Heat of Solution (c)	4.184 J/g°C	4.184 J/g°C
Change in Temperature of Solution(ΔT)	-3.5°C	5.8°C
Heat of solution ($q_{solution}$)	-820 J	1300 J
Heat of reaction* ($q_{reaction} + q_{solution} = 0$)	820 J	-1300 J
Reaction is: Exothermic or Endothermic	endothermic	exothermic

* The water in the calorimeter is considered the reaction's surroundings, therefore if heat is released by the reaction, it is absorbed by the water and vice-versa.

Example Data Analysis

PART 2 – Specific Heat Capacity and Enthalpy of Fusion

DATA

	Data
Mass of calorimeter + water (g)	64.3499 g
Initial Temperature of water (°C)	21.4°C
Final Temperature of water (°C)	15.8°C
Mass of calorimeter + water + ice (g)	67.8851 g

CALCULATIONS – PART 2 – SPECIFIC HEAT CAPACITY AND ENTHALPY OF FUSION

* Show your work, complete with units.

1. Mass of H_2O

   64.3499 - 16.4831 = 47.8668 g

2. Change in Temperature of Water

   15.8 - 21.4 = -5.6°C

3. q_{water}

   47.8668 g x (-5.6°C) x 4.184 J/g°C
   = -1.1 kJ
   =1.1215 kJ (no intermediate round off)

4. Mass of Ice

   67.8851 - 64.3499 = 3.5352 g

5. Moles of Ice

   3.5352 g / 18.02 g/mol
   = 0.1962 mol

6. q_{ice}

   0.1962 mol x 6.01 kJ/mol
   = 1.179 kJ

7. $q_{water} + q_{ice}$

   -1100 + 1179 = 79 J
   -1121.5 + 1179 = 57 J

Example Data Analysis

PART 2 – Specific Heat Capacity and Enthalpy of Fusion

DATA

	Data
Mass of calorimeter + water (g)	64.3499 g
Initial Temperature of water (°C)	21.4°C
Final Temperature of water (°C)	15.8°C
Mass of calorimeter + water + ice (g)	67.8851 g

RESULTS

	Results
Mass of H_2O	47.8668 g
Specific Heat of water (c)	4.184 J/g°C
Change in Temperature of water (ΔT) ($\Delta T = T_f - T_i$)	-5.6°C
q_{water} (kJ)	-1.122 kJ
Mass of Ice	3.5352 g
Moles of Ice (n)	0.1962 mol
Enthalpy of Fusion (ΔH_{fus})	6.01 kJ/mol
q_{ice} (kJ)	1.179 kJ
$q_{water} + q_{ice}$	57 J

Clean Up

- Return equipment cleaned if necessary to its storage areas
- Return cardboard lid to supply bin
- Discard the Styrofoam cups