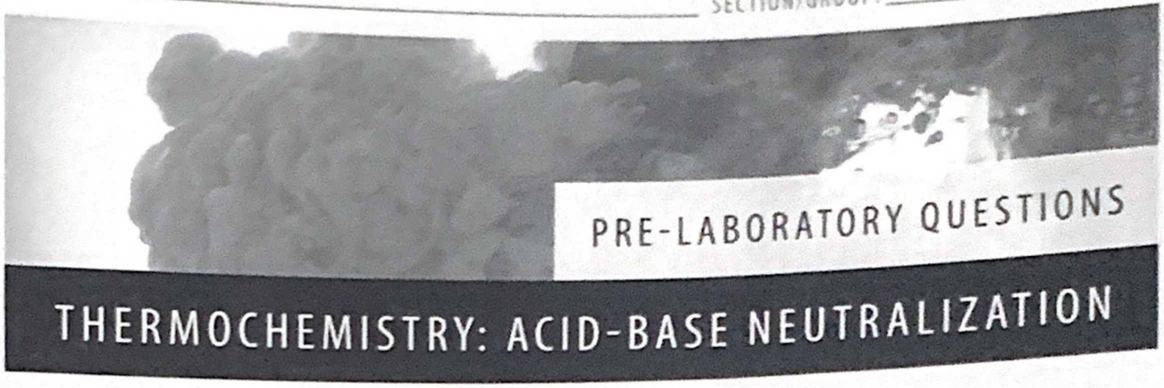
NAME: Amber Lucas

INSTRUCTOR:

DATE:

SECTION/GROUP:



PRE-LABORATORY QUESTIONS

THERMOCHEMISTRY: ACID-BASE NEUTRALIZATION

1. Consider this coffee cup calorimetry experiment:
   a. 100 mL of water at 86.0°C was poured into 100 mL of water at 23.5°C in a coffee cup calorimeter, and the temperature of the contents of the calorimeter equilibrated to 53.5°C before beginning to fall to room temperature. Calculate the heat capacity of the calorimeter. (The density and specific heat of water or any aqueous solution can be assumed to be 1.00 g/mL and 4.184 J/g•°C, respectively)

q_{lost}:

[(100g)(4.184J/g·°C)(86.0°C-53.5°C)]-[(100g)(4.184J/g·°C)(53.5°C-23.5°C)]= 1046J

C_{cup}:

1046J/(53.5°C-23.5°C)= 34.9 J/°C

   b. 100 mL of 2.00M acetic acid was added to 100 mL of 2.00M NaOH at 23.5°C and the temperature of the solution equilibrated to 36.3°C. Calculate an enthalpy of neutralization for acetic acid, using the calculated heat capacity of the coffee cup.

(-56.1 kJ/mol is the accepted value)

q_{surr}

[(200g)(4.184 J/g·°C)(36.3°C-23.5°C)]+[(34.9J/°C)(36.3°C-23.5°C)] = 11157.76J

ΔH

(0.100L)(2.00mol/L) = 0.200mol acetic acid

-11157.76J/0.200 mol = -55788.8J/mol = -55.8 kJ/mol

2. Calculate the enthalpy of formation of acetylene using Hess's Law:

$2C(s) + H_2(g) \longrightarrow C_2H_2(g)$

Given:

$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l)$ –2599 kJ/mol

$C(s) + O_2(g) \longrightarrow CO_2(g)$ –393.5 kJ/mol

$2H_2 + O_2 \longrightarrow 2H_2O$ –285.8 kJ/mol

$\cancel{2H_2O_{(l)}} + 4CO_{2(g)} \rightarrow 2C_2H_{2(g)} + \cancel{5O_{2(g)}}$ + 2599 kJ/mol

$2C_{(s)} + \cancel{2O_{2(g)}} \rightarrow \cancel{2CO_{2(g)}}$ 2(-393.5 kJ/mol)

$2H_{2(g)} + \cancel{O_{2(g)}} \longrightarrow \cancel{2H_2O_{(l)}}$ - 285.8 kJ/mol

$2C_{(s)} + \cancel{2O_{2(g)}} \rightarrow 2CO_{2(g)}$ 2(-393.5 kJ/mol)

$4C_{(s)} + 2H_{2(g)} \rightarrow 2C_2H_2$ 739.2 KJ/mol

$2C_{(s)} + H_{2(g)} \rightarrow C_2H_2$ 739.2/2 = 369.6 kJ/mol

3. Give balanced chemical equations for the following:

a. Dissolving ammonia (NH_3 gas) in water to make **aqueous ammonia (also known as ammonium hydroxide)**:

$NH_{3(g)} + H_2O_{(l)} \rightarrow NH_4OH_{(aq)}$

b. Neutralization of aqueous sodium hydroxide with aqueous hydrochloric acid

$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

c. Neutralization of **aqueous ammonia (also known as ammonium hydroxide)** with aqueous hydrochloric acid

$NH_4OH_{(aq)} + HCl_{(aq)} \rightarrow NH_4Cl_{(aq)} + H_2O_{(l)}$

d. Neutralization of aqueous ammonium chloride with aqueous sodium hydroxide

$NH_4Cl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + NH_4OH_{(aq)}$

You will need the chemical equations from pre-lab question 3 for post-lab question 1. Fill them in on post-lab question 1 before you turn in your pre-lab questions.

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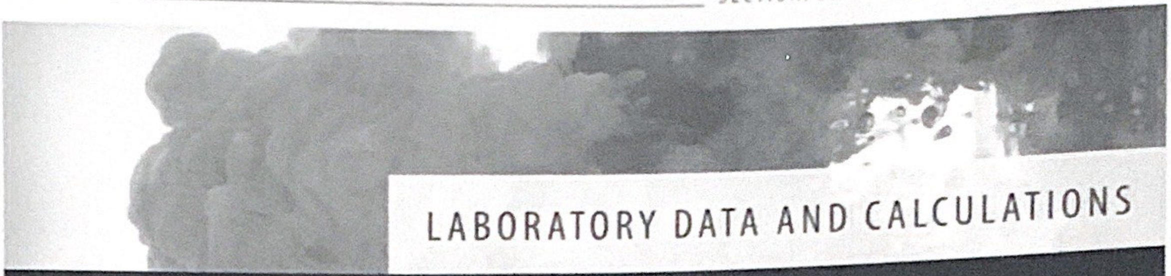

LABORATORY DATA AND CALCULATIONS

THERMOCHEMISTRY: ACID-BASE NEUTRALIZATION

Given: The density of water or an aqueous solution can be approximated as 1.00 g/mL
Given: The specific heat of water or an aqueous solution can be approximated as 4.184 J/g•°C

Table 7.1. Finding the heat capacity of the coffee cup.

	Trial 1	Trial 2
mass of room temp water	50	
mass of hot water	50	
temperature of room temp water	22.9°c	
temperature of hot water water	73.5°C	
final temperature	45.0°c	

Trial 1 Time (sec)	Temperature	Trial 2 Time (sec)	Temperature
After mixing	°C	After mixing	
30	45.9	30	
60	45.9	60	
90	45.2	90	
120	45.0	120	
150	45.0	150	
180	45.0	180	
210		210	
240		240	
270		270	
300		300	

Calculate the heat capacity of the coffee cup calorimeter.

Table 7.2. Neutralization of NaOH(aq) with HCl(aq)

Concentration of HCl 2M
Volume of HCl 50 mL
Moles of HCl 0.1
Total mass of the solution 100g

Concentration of NaOH 2M
Volume of NaOH 50ml
Moles of NaOH 0.1

Trial 1 Time (sec)	Temperature	Trial 2 Time (sec)	Temperature
Initial temperature before mixing	22.4°C	Initial temperature before mixing	
After mixing		After mixing	
30	37.3°C	30	
60	37.3°C	60	
90	37.2°C	90	
120	37.2°C	120	
150	37.2°C	150	
180		180	
210		210	
240		240	
270		270	
300		300	
Final temperature	37.3	Final temperature	

Calculate the enthalpy of this reaction ($\Delta H_{HCl\text{-}NaOH}$)

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

$q = 100g \times 4.18\ J\ \cancel{g^{-1}} \cdot \cancel{°C^{-1}} \times 14.9°C$

$q = 6228.2J$

$\Delta H = \frac{-1 \times q}{n(H_2O)}$

$= \frac{-1 \times 6228.2J}{0.1mol}$

$= -62.282\ kJ\ mol^{-1}$

Table 7.3. Neutralization of NH_3(aq) with HCl(aq)

Concentration of HCl 2M
Volume of HCl 50ml
Moles of HCl 0,1
Total mass of the solution 100g

Concentration of NH_3(aq) 2M
Volume of NH_3 (aq) 50 mL
Moles of NH_3 (aq) 0.1

Trial 1 Time (sec)	Temperature	Trial 2 Time (sec)	Temperature
Initial temperature before mixing	22.4 °C	Initial temperature before mixing	
After mixing		After mixing	
30	35.8 °C	30	
60	35.8 °C	60	
90	35.7 °C	90	
120	35.7 °C	120	
150	35.6 °C	150	
180	35.6 °C	180	
210	35.6 °C	210	
240	35.6 °C	240	
270		270	
300		300	
Final temperature	35.8	Final temperature	

Calculate the enthalpy of this reaction ($\Delta H_{HCl\text{-}NH_3\,(aq)}$)

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

$q = 100g \times 4.18\ J\ \cancel{g^{-1}} \cdot \cancel{°C^{-1}} \times 13.4 \cancel{°C}$

$q = 5601.2J$

$\Delta H = \frac{-q}{n(NH_4Cl)}$

$= \frac{-5601.2J}{1\ mol}$

$= 56.012\ KJ\ mol^{-1}$

Table 7.4. Neutralization of $NH_4Cl(aq)$ with NaOH(aq)

Concentration of $NH_4Cl(aq)$ 2M

Volume of $NH_4Cl(aq)$ 50 ml

Moles of $NH_4Cl(aq)$ 0.1

Total mass of the solution 100g

Concentration of NaOH 2M

Volume of NaOH 50 ml

Moles of NaOH 0.1

Trial 1 Time (sec)	Temperature	Trial 2 Time (sec)	Temperature
Initial temperature before mixing	23.1 °C	Initial temperature before mixing	
After mixing		After mixing	
30	23.8 °C	30	
60	23.8 °C	60	
90	23.8 °C	90	
120	23.8 °C	120	
150	23.7 °C	150	
180	23.7 °C	180	
210		210	
240		240	
270		270	
300		300	
Final temperature	23.8 °C	Final temperature	

Calculate the enthalpy of this reaction ($\Delta H_{NH_4Cl(aq)\text{-}NaOH}$)

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

$q = 100g \times 4\ 18\ Jg^{-1}{}^{\circ}{}^{-1} \times 0.7^{\circ}C$

$q = 292.6J$

$\Delta H = \dfrac{-q}{n(H_2O)}$

$= \dfrac{-292.6J}{6.1\ mol}$

$= 2.926\ kJ\ mol^{-1}$

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POST-LABORATORY QUESTIONS

THERMOCHEMISTRY: ACID-BASE NEUTRALIZATION

1. Use Hess's Law and the class enthalpy values for the reactions of NaOH-HCl and NH_3-HCl to calculate the enthalpy of neutralization of ammonium chloride and hydrochloric acid. You may need to reverse or multiply the chemical equations from *Table 7.2* and 7.3 to get them to add up correctly:

Experiment	Chemical reaction (Refer to the reactions that you wrote in prelab question 3).	Class enthalpy value (kJ/mol)
② 7.2 :NaOH-HCl	$NaOH + HCl \rightarrow NaCl + H_2O$	ΔH= -66.282 kJ/mol
① 7.3 : NH_4OH-HCl	$NH_4Cl + H_2O \rightarrow NH_4OH + HCl$	ΔH= -56.012 kJ/mol
7.4 : NH_4Cl-NaOH	$NH_4Cl + NaOH \rightarrow NaCl + NH_4OH$	ΔH calculated by Hess's Law

$NH_4Cl + H_2O + NaOH + HCl \rightarrow NH_4OH + HCl + NaCl + H_2O$

$\Delta H = -56.012$
$+ -62,282$
$\boxed{-118.294 \text{ kJ/mol}}$

2. Compare the enthalpy of neutralization of $NH_4Cl(aq)$ that you calculated using the class values for enthalpies of neutralization in question 1, with your experimental value. Explain any differences between the values.

Amber Lucas

Reaction 1:

1. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(aq)} + NaCl_{(aq)}$

$\Delta T = 37.3°C - 22.4°C = 14.9°C$

m= 100g

Heat absorbed by water $Q_1 = 4.18 J/g°C \times 14.9°C \times 100g = 6228.2 J$

Heat of reaction, $\Delta H_1 = -6228.2 J$

0.1 moles HCl produced = 6228.2J

Heat of reaction per mol = -6228.2J/0.1 = -62.282 kJ/mol

Reaction 2:

$NH_4OH_{(aq)} + HCl_{(aq)} \rightarrow NaCl + H_2O$

$\Delta T = 35.8°C - 22.4°C = 13.4°C$

m= 100g

Heat absorbed by water $Q_2 = 4.18 J/g°C \times 13.4°C \times 100g = 5601.2J$

Heat of reaction $\Delta H_2 = -5601.2J$

0.1 moles HCl have produced = 5601.2J

Heat of reaction per mol = -5601.2J/0.1 = -56.012 kJ/mol

Reaction 3:

$H_2O_{(aq)} + NH_4Cl_{(aq)} \rightarrow NH_4OH_{(aq)} + HCl_{(aq)}$

The heat of reaction will be positive, the sign will be changed from - to +

Heat of reaction = +56.012 kJ/mol

$NH_4Cl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + NH_4OH_{(aq)}$

$\Delta H_3 = +56.012$ kJ/mol - 62.282 kJ/mol = -6.27 kJ/mol reaction 1:

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(aq)}$

$-167.4\,\frac{kJ}{mol} \quad -469.4\,\frac{kJ}{mol} \quad -407.1\,\frac{kJ}{mol} \quad -285.8\,\frac{kJ}{mol}$

$\Delta H = 0.1(-407.1 - 285.8 + 167.4 + 469.4) = -5.61\ kJ/mol$

reaction 2:

$NH_4OH_{(aq)} + HCl_{(aq)} \rightarrow H_2O_{(aq)} + NH_4Cl_{(aq)}$

$-362.3\,\frac{kJ}{mol} \quad -167.4\,\frac{kJ}{mol} \quad -285.8\,\frac{kJ}{mol} \quad -299.6\,\frac{kJ}{mol}$

$\Delta H = 0.1(-299.6 - 285.8 + 362.3 + 167.4) = -5.57\ kJ/mol$

reaction 3:

$H_2O_{(aq)} + NH_4Cl_{(aq)} \rightarrow NH_4OH_{(aq)} + HCl_{(aq)}$

$\Delta H = +5.57\ kJ/mol$

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(aq)}$

$\Delta H = -5.67\ kJ/mol$

$\Delta H_{total} = +5.57\ kJ/mol - 5.67\ kJ/mol = -0.04\ kJ/mol$

The difference in class value which is -0.04 kJ/mol and the experimental value = -6.21 kJ/mol. The expenmental value shows that more heat was released because error in measurement of temp. accuray and the enivronment condition.