Experiment E2

The Properties of Buffers

Name: [Xiao Luyan]

Date: [3 March 2023]

Student ID: 522370910178
Section #: 11
Group #: 5
Group Members: Xiao Luyan Wang Zhiyuan Su Jinfu Wang Yiyang

Telephone #: 17302121018
Email Address: Xiao_1125@sjtu.edu.cn

This is for TAs ONLY. DO NOT write in this table.

Grades				Grader/s
Post-lab (100+10 pts)	Observation (30 pts)			
	Data Analysis (30 pts)			
	Discussion (30+10 pts)			
	Data Sheet (10 pts)			
	Total			

University of Michigan – Shanghai Jiao Tong University Joint Institute (UM-SJTU JI)

POST-LAB

*Please finish (hand-written or typed) this memo during and/or after the lab and submit it through canvas (pdf file name convention: LASTNAME+last four digits of your student ID) before due time, typically 10 min before the next experiment. This memo consists of OBSERVATION, DATA ANALYSIS, DISCUSSION, and DATA SHEET, and are worth a total of 100 points, counted as **6%** of the total course grade. This is an individual assignment and your own work is expected. The sample DATA SHEET is for recording of raw data **during** your lab work and shall be submitted as it is (the very original copy you filled in during lab). Calculations and data analysis shall use the original data you obtained in the lab. Any alteration to raw data is a serious violation of **HONOR CODE** and you will receive '0' point for Post-Lab Memo.*

***Note:** This memo first describes experimental observations, then analyzes data, finally discusses the results. Although a frame is provided with useful tips, you are **encouraged** to conduct critical thinking on your own and try to write a coherent and complete memo by yourself (passive piecing together tips is not considered to be a complete memo). Bonus is available for outstanding points as mentioned in detail below.*

OBSERVATION

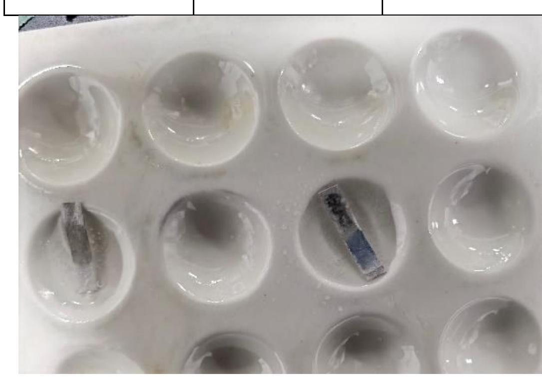
Part A. pH of Strong and Weak Acids

- *Explain your observation in Part A.1 by filling in the blanks in the following paragraph.*

With the same concentration, the pH of HCl is much lower *(higher or lower) than that of HAc. This phenomenon shows that the* molarity of H+ *in strong acid is higher than in weak acid. And from the fact that the pH of the unknown concentration HAc solution is* higher *(higher or lower) than that of the 0.5M HAc, we can conclude that its concentration is* lower *(higher or lower) than 0.5M.*

- *Include photos you took during Part A.2 to show the difference.*
- *Shortly describe your observation when adding the 5-10 drops of HCl/HAc to the Mg strips at the same time.*

	Part A.1			Part A.2	
pH meter calibration	0.5 M HCl	0.5M HAc	? M HAc	Mg with 0.5M HCl	Mg with 0.5M HAc
pH0 & Temp.	pH1	pH2	pH3	observation	observation
4.00 10℃	0.41	2.52	2.71	quick	moderate



(1) left is with HCl, right is with HAc

When adding the 5-10 drops of HCl/Hac to the Mg strips at the same time, both Mg strips dissolve and bubbles up. However, the Mg strip with HCl has more bubbles than the one with HAc, which means the reaction with HCl is more intense than with HAc.

Part C. Properties of a Buffer

After performing this part, did the buffer "do its job"? Is there any difference between the buffer and the DI–water when the strong acid/base was added? Explain your observation qualitatively.

After performing this part, the buffer did its job. When the strong acid/base was added, the pH of buffer changed slightly but the pH of the DI-water changed greatly, much more fiercely than buffer.

Part D. Determination of Buffer Capacity

- *What is the signal of reaching buffer capacity?*
- *Please attach a photo of the pH meter reading at the end of the test.*

Theoretically, the signal of reaching buffer capacity is that the pH of a buffer solution increases or decreases by 1 when strong base or acid is added. However, in the experiment, the signal is that the pH of the solution reaches 2.00

DATA ANALYSIS

Part B. Design of buffer solutions

- *Which is your assigned buffer? Show your calculation for the volume of acid and base needed (x and y).*
- *Closely examine the data from Part B, looking at all four buffer solutions, do you see a relationship between the pKa value of the acid, the desired or target pH of the buffer, and the [base]/[acid] ratio? Explain.*

buffer	Design pH	cb/ca	x mL (5.00 M CH3COOH)	y mL (2.00M CH3COONa)
#1	4.15	0.251	1.60	1.00
#2	4.57	0.661	1.20	2.00
#3	4.75	1.000	1.00	2.50
#4	5.35	3.981	0.40	4.00

pH = 4.15

$C_b / C_a = 10^{pH-pKa} = 10^{4.15-4.75} = 0.251$

$C_a + C_b = 0.1$ M

$C_a = 0.080$ M $\quad C_b = 0.020$ M

$V_a = 1.6$ ml $\quad V_b = 1$ ml

pH = 4.57

$C_b / C_a = 10^{pH-pKa} = 10^{4.57-4.75} = 0.661$

$C_b / C_a = 0.661$

$C_a = 0.060$ M $\quad C_b = 0.040$ M

$V_a = 1.2$ ml $\quad V_b = 2$ ml

pH = 4.75

$C_b / C_a = 10^{pH-pKa} = 10^{4.75-4.75} = 1$

$C_a + C_b = 0.1$ M

$C_a = 0.050$ M

$C_b = 0.050$ M

$V_a = 1$ ml

$V_b = 2.5$ ml

pH = 5.35

$C_b / C_a = 10^{pH-pKa} = 10^{5.35-4.75} = 3.981$

$C_a + C_b = 0.1$ M

$C_a = 0.020$ M

$C_b = 0.080$ M

$V_a = 0.4$ ml

$V_b = 4$ ml

The relationship between the pKa value of the acid, the desired or target pH of the buffer, and the [base]/[acid] ratio is pH = pKa + log$\frac{[base]}{[acid]}$. Because when the designed pH is smaller than pKa, the acid needed to make the buffer is more than the base needed. When the designed pH is larger than pKa, the base needed to make the buffer is more than the acid needed.

Part C. Properties of a Buffer

- *Show the difference between the buffer and the DI-water when the strong acid/base was added quantitatively*
- *From the data obtained in this part, what conclusion can you draw?*
- *Which theory in the background is verified? Explain how the theory is verified.*

H_2O	initial	+5mL H_2O	+5 drops NaOH	+5 drops HCl
	pH4	pH5	pH6	pH7
	7.81	7.64	11.12	2.71
Buffer	initial	+5mL H_2O	+5 drops NaOH	+5 drops HCl
	pH8	pH9	pH10	pH11
#1	4.14	4.06	4.25	3.88
#2	4.48	4.46	4.63	4.27
#3	4.61	4.60	4.66	4.48
#4	5.17	5.17	5.36	4.97

According to the data sheet, when the strong acid/base was added, the pH of the buffer changed between 0.05 and 0.26. The smallest change of pH is the buffer of initial pH of 4.61 with 5 drops NaOH. The largest change of pH is the buffer of initial pH of 4.14 with 5 drops HCl. But the pH of the DI-water changed much more fiercely than the one of buffer. It changed 3.31 with 5 drops of NaOH and changed 5.1 with 5 drops of HCl.
From the data obtained in this part, I can draw the conclusion that buffer can resist the pH change when small amounts of strong acids or bases are added.
The theory common-ion effect in the background is verified. The common-ion effect is the solubility of a sparingly soluble salt is reduced by the addition of another soluble salt that has an ion in common with the salt. In this experiment, the buffer is made with CH3COOH and CH3COONa, so it has a higher concentration of Na+ and H+. NaOH and HCl in solution will form Na+, OH-, H+, Cl-, so when NaOH or HCl is added to the buffer, their solubility will be reduced by the existing Na+ and H+. Therefore, the pH of the buffer won't change much. This is the common-ion effect.

Part D. Determination of Buffer Capacity

- *How will the amount of HCl needed change if the [base]/[acid] ratio is higher?*
- *How does the total moles of NaOH needed to reach buffer capacity relate to the number of moles of acid in the buffer? Explain.*

The amount of HCl needed will increase if the [base]/[acid] ratio is higher. Since based on the Henderson–Hasselbalch equation 10^(pH-pKa)=[base]/[acid], with the same pKa, the higher [base]/[acid] ratio is, the larger the pH is. Therefore, more HCl will be needed.

Since based on the Henderson–Hasselbalch equation 10^(pH-pKa)=[base]/[acid], with the same pKa, the larger the number of moles of acid in the buffer, the more total moles of NaOH will be needed to reach buffer capacity. The total moles of NaOH needed to reach buffer capacity is the same as the number of moles of acid in the buffer.

<u>DISCUSSION*</u>

This part is very important. The basic requirement is that you cover the outcome of the whole experiment. (You may choose to divide the section into several parts in accordance with the experiment.) Bonus can be earned by including the following aspects or showing creative ideas. (1page limit for the discussion part)

[Bonus]

1. Is there any relatively huge error to the results? What are the possible main causes of these errors?
2. What will the phenomenon and the condition be if we use NaOH solution to titrate the buffer instead of HCl? Describe the process and what we need pay attention to.
3. Why is a buffer said to be the most efficient when its pH = pKa?
4. Recommendations for the improvement of the experiments if you have any.
5. Crucial experimental procedures during the experiment (Can other procedures work? Why or Why not?)
6. Any other discussion point/s you'd like to explore.

Part A. pH of Strong and Weak Acids

In this experiment, we test the pH and temperature of 0.5M HCl, 0.5M HAc and HAc with unknown concentration. The temperature is 10℃, and their pH respectively are 0.41, 2.52, 2.71. In the next part Mg reacts with 0.5M HCl quickly but reacts with 0.5M HAc moderately. The test of temperature is necessary because the temperature will affect the equilibrium equation for ionization. It is important to calibrate a digital pH Meter before testing buffers because it makes sure the pH meter can work.

Part B. Design of buffer solutions

In this experiment, we design 4 buffers with different pH and document the [base]/[acid] ratio, needed volumes of CH_3COOH and CH_3COONa. We find that the buffer with maximum capacity is the one with pH closest to pKa, this conforms to Henderson–Hasselbalch equation.

Part C. Properties of a Buffer

In this experiment, a control group with H_2O is set up, and we respectively test how much the pH changes with 5mL H_2O, 5 drops of NaOH, and 5 drops of HCl. It turns out that the pH of buffers changes much more slightly than the pH of H_2O. However, we find that every buffer's initial pH is a bit smaller than the designed ones in Part B. This may because the CO_2 in the air will dissolve slowly into buffers in beakers and affects their pH. A buffer is said to be the most efficient when its pH = pKa is because according to Henderson–Hasselbalch equation $\mathrm{pH} = \mathrm{pKa} + \log\frac{[base]}{[acid]}$, when pH = pKa, [base] = [acid], the capacity of the buffer is the best.

Part D. Determination of Buffer Capacity

In this experiment, we choose #1 buffer as the sample and measure the total volume of HCl needed to decrease the pH of the buffer from 4.12 to 2.05 is 4.6mL. We should pay attention that the end of buffer pH is near 2.00 and if the $\frac{[base]}{[acid]}$ is higher, more HCl will be needed.

REFERENCE

- List any source of reference.

CHEM2110J-VC211 SP23 E2 Manual
CHEM2110J-VC211 Lecture E2

DATA SHEET

Name: Xiao Luyan　　Section: 11

E2-A

Part A	Part A.1			Part A.2	
pH meter calibration	0.5 M HCl	0.5M HAc	? M HAc	Mg with 0.5M HCl	Mg with 0.5M HAc
pH0 & Temp.	pH1	pH2	pH3	observation	observation
4.00 10℃	0.41	2.52	2.71	quick	moderate

E2-B(show it to your section TA before starting part C&D)

buffer	Design pH (pKa1)	c_b/c_a	x mL (5.00 M CH_3COOH)	y mL (2.00M CH_3COONa)
#1	4.15	0.251	1.60	1.00
#2	4.57	0.661	1.20	2.00
#3	4.75	1.000	1.00	2.50
#4	5.35	3.981	0.40	4.00

E2-C

H_2O	initial	+5mL H_2O	+5 drops NaOH	+5 drops HCl
	pH4	pH5	pH6	pH7
	7.81	7.64	11.12	2.71
Buffer	initial	+5mL H_2O	+5 drops NaOH	+5 drops HCl
	pH8	pH9	pH10	pH11
#1	4.14	4.06	4.25	3.88
#2	4.48	4.46	4.63	4.27
#3	4.61	4.60	4.66	4.48
#4	5.17	5.17	5.36	4.97

E2-D

Buffer	initial	+5mL H_2O	+5 drops NaOH	+5 drops HCl	End	Total HCl
	pH8	pH9	pH10	pH11	pH12	V(mL)
#1	4.12				2.05	4.6