

VC211 FALL 2020 Chemistry Lab Report

Experiment E2

The Properties of Buffers

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There are main sections in each report, Pre-lab Exercises and Post-lab Report. Please finish the **Pre-lab** exercises before your scheduled lab time, which is **due at the beginning of each lab**. You need to submit a **hard copy** (double-sided printing) of your finished Pre-lab exercises (hand-written or typed) to your section TA when meet in the chemistry building. Please print out '**DATA SHEET**' to fill in raw data during the lab. Submit the hard copy of completed report (double-side printing) to your section TA when meet for the next experiment in the lab.

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

THIS IS FOR THE GRADER DO NOT WRITE IN THIS TABLE

Grades				Grader/s
Pre-lab (100 pts)				
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 report during and/or after the lab and submit it (double-sided printing) to your section TA when meeting for the next experiment. This report 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. The 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, not a photocopy, not a scan, neither of photo of it). Calculations and data analysis shall use the original data you obtained in the lab. Any alteration to raw data is a serious violation to HONOR CODE and you will receive '0' point for Post-Lab Report.

OBSERVATION

A. pH of Strong and Weak Acids

With the same concentration, the pH of HCl is much lower than that of HAC. This phenomenon shows that the amount 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 than that of the 0.5M HAC, we can conclude that its concentration is lower than 0.5M.

After cleaning the surface of the Mg strips with a piece of abrasive paper, we put them into the porcelain dropper plate. Shortly describe the phenomenon when adding the 5-10 drops of HCl/HAC to the Mg strips at the same time. From Figure 4 we can see that the Mg strip acts quickly with HCl, as there exist bubbles soon after HCl is added. However, the reaction between Mg and HAC is very slow and has only few bubbles.

Figure 1 Mg reacts with HCl and HAC with equal concentration and amount.



B. Design of buffer solutions

C. Properties of a Buffer

After performing this part, did you notice a difference between the buffer and the DI-water when the strong acid/base was added? Did the buffer “do its job”?

From the data we can know that compared to pure de-ionized water, the pH change is very small in buffer solution when strong acid or base is added. So, the buffer did its job.

D. Determination of Buffer Capacity

We also tested the buffer capacity by adding HCl to it until the limit is reached. The signal for us to determine the limit of buffering action is the pH is smaller than 2 when adding HCl. We expected that the bigger the [base]/ [acid] ratio is, the more HCl is needed to reach buffer capacity.



Figure 2 Figure at limit

DATA ANALYSIS

B. Designing a Buffer Solution

Using the Henderson-Hasselbalch equation, we can get $\frac{C_a}{C_b} = 10^{pH-pK_a}$.

Suppose $V_a=x(\text{mL})$ and $V_b=y(\text{mL})$

We can get the system: $0.005x+0.002y=0.1\text{M}\times 0.1\text{L}=0.01(\text{mol})$

$$\frac{2y}{5x} = \frac{C_b}{C_a} = 10^{pH-pK_a}$$

We solve the equation set for each buffer and get 4 sets of values listed in Table3:

Buffer	Design pH	cb/ca	x mL (5.00M CH ₃ COOH)	y mL (2.00M CH ₃ COONa)
1	4.15	0.251	1.6	1.00
2	4.57	0.661	1.2	1.99
3	4.75	1	1.0	2.50
4	5.35	3.981	0.4	4.00

Table 3 Results of Calculation

The relationship between the pK_a value of the acid, the desired or target pH of the buffer, and the [base]/[acid] ratio is $\frac{C_a}{C_b} = 10^{pH-pK_a}$. Because the original Henderson-Hasselbalch equation said $pH=pK_a+\log\frac{[base]}{[acid]}$.

C. Properties of a Buffer

From the data obtained in this part, what conclusion can you draw? Which theory in the background is verified? Explain.

We took 20mL of buffer solution each time. Another 20mL deionized water was experimented on through the same procedure as a control experiment. The deionized water used in the experiment has an average pH of 5.04 I individually tested Buffer 4. The rest of the data is from my other group members.

	Buffer 1	Buffer 2	Buffer 3	Buffer 4	De-ionized water
Initial pH	4.08	4.45	4.63	5.15	5.01
pH after adding 5mL water	4.09	4.45	4.61	5.13	5.15
pH after adding 5 drops of NaOH	4.22	4.55	4.74	5.25	11.36
pH after adding 5 drops of HCl	3.81	4.30	4.49	5.02	2.28

Table 4 Experiment data for Part C

We then calculate the change of pH and get the following table.

	Buffer 1	Buffer 2	Buffer 3	Buffer 4	De-ionized water
Error of Initial pH	-1.7%	-2.6%	-2.5%	-3.7%	/
Change of pH after adding	0.01	± 0	-0.02	-0.02	+0.14

5mL water					
Change of pH after adding 5 drops of NaOH	+0.14	+0.13	+0.11	+0.10	+6.35
Change of pH after adding 5 drops of HCl	-0.28	-0.15	-0.11	-0.10	-2.73

Table 5 Data analyzation for Part C

From the data we can know that compared to pure de-ionized water, the pH change is very small in buffer solution when strong acid or base is added.

Theoretically, when 5mL de-ionized water is added, the pH of each buffer should become higher. However, the experimental data shows the opposite.

Also, from buffer 1 to 4, the concentration of acid grows smaller and the concentration of conjugate base grows bigger. Therefore, from buffer 1 to 4, the pH change should become bigger when a strong acid is added and become smaller when a strong base is added. From the analyzation of experiment data, buffer 1, 2,3,4 show the right tendency.

D. Determination of Buffer Capacity

How does the total moles of NaOH needed to reach buffer capacity relate to the number of moles of acid in the buffer? Explain.

Buffer	Total consumption of HCl(mL)	pH at end point
4	4.1	1.98

Table 6 Experiment data for Part D

Then we analyze the data:

Buffer	Initial pH	Moles of base in buffer(mol)	Consumption of HCl(mol)	Δ pH
4	5.15	8×10^{-3}	2×10^{-3}	-3.17

Table7 Data analyzation for Part D

When we use HCl, it reacts with the acid part of the buffer, while the NaOH react with the base part of the buffer. According to the equation: $\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$. The number of moles will change, but we cannot ensure whether it is larger or smaller without the certain value.

DISCUSSION

1. After designing and making the buffer, did you notice that the designed pH value is different than the measured pH of a buffer? Explain factors that may cause difference.

All the pH of designed buffer is lower than theoretical values. The possible causes are as follows:

1. The actual environment temperature is 18°C, which is lower than the standard room temperature (25°C). This causes the pKa of HAC to be smaller than 4.75, resulting in a smaller pH.
2. When pipetting NaAC, there is some solution staying in the pipet.

3. There is previous (more acidic) solution left on the electrode when measuring the pH of the next buffer.
2. In the last part, we used HCl solution to titrate the buffer, but didn't try the other direction. Think about how to use NaOH solution to test the buffer capacity; describe the process and what we need pay attention to.

Do the same as we use HCl to test, just remember to stop as soon as the pH become more than 12. Take down the volume of NaOH we used to get the limit. And then observe the consumption of NaOH(mol). Be careful to operate and reduce waste through transferring.

3. Why is a buffer said to be the most efficient when its $\text{pH} = \text{pK}_a$

A buffer is most effective when the concentrations of acid and conjugate base (or base and conjugate acid) are approximately equal—in other words, when the $\log [\text{base}]/[\text{acid}]$ equals 0 and the pH equals the pK_a . This is due to the change that occurs when another acid or base is added to the buffer. The change is minimized (refer to the mathematical figure of log function) if the concentrations of acid and conjugate base are equal. The more the ratio needs to differ to achieve the desired pH, the less effective the buffer.

4. Is there any inconformity between your results and the theoretical values? What are the possible factors that could have led to them?

In Part A, the pH of 0.5M HCl measured is much higher than theoretical value, while the pH of 0.5M HAc measured is lower than theoretical value. The possible reasons are as follows:

1. There is stock buffer of pH4.0 left on the electrode when measuring the pH of HCl.
2. There is 0.5M HCl left on the electrode when measuring the pH of HAC.

In Part D, because buffer 4 has the most moles of base, it needs more HCl to reach its end point. The data is in line with the theoretical values. However, we achieved the volume of added HCl by reading the changed volume of volumetric cylinder and it's inaccurate. The right way is to directly read the initial and final readings of the pipet.

In Part A, we've learned that strong acid has a lower pH than weak acid with the same concentration. Strong acid also acts with Mg much faster than weak acid.

In Part B, we've learned how to prepare a buffer solution with desired pH.

In Part C, we experimented with buffers of different pH and tested their properties when strong acid or base is added.

In Part D, we've collected data and compared the capacity of buffers with different pH.

We strongly recommend you to divide labor properly during the experiment so that your work will be more efficient. Also, we recommend you to read the readings carefully and patiently to increase the accuracy of the data.

REFERENCE

- 1. Peter Atkins, *Chemical Principles The Quest for Insight Seventh Edition*, Macmillan education, 2016.
- 2. VC211 Laboratory Manual, UM-SJTU JI & SJTU Chemistry Department, 2019-2020.