2.3) BUFFERING CAPACITY

Objective: Following this laboratory exercise, you will be able to distinguish between high pH and acid buffering capacity.

Introduction: "Alkalinity" is the ability of a water sample to absorb hydrogen ions with little or no change in overall pH. The effectiveness of the carbonate and bicarbonate ions as a buffering agent is evident in the following two reactions: $\boxed{CO_3^{2-} + 2H^+ \rightarrow H_2CO_3 \quad \text{and} \quad HCO_3^- + H^+ \rightarrow H_2CO_3}$
These reactions convert strong acid (such as hydrochloric, sulfuric, or nitric acids) into the milder carbonic acid (responsible for the bubbles in carbonated beverages).

Based on the chemical equation, one mole of carbonate can react with two moles of hydrogen ions to reach the "equivalence point." The equivalence point is when there is just enough buffer to react with all of the hydrogen ions that are present. This comes out to about 100 grams of limestone per 2 liters of 1M HCl solution. The main advantage of applying weak bases such as gardening lime is that excess amounts can be added with no risk of causing pH levels to go dangerously high. This is why limestone-rich bodies of water are more resistant to ravages of acid rain.

Part A: Buffering Capacity at 1X Concentration

1) Put on your goggles. You will be using a mild HCl solution that can still cause injury. If you make skin contact with the acid, flush with water immediately.
2) Add 10 mL of the following to four test tubes;
    a. non-sparkling spring water
    b. sample from a local river, creek, or pond
    c. salt water from an ocean or aquarium
    d. buffer: saturated sodium carbonate or bicarbonate solution
    e. 0.001 M NaOH solution
3) Add 1-3 drops pH indicator solution to each (Fig. 1) and enter the initial pH in Table 1 and final pH in Table 2.
4) *Carefully* add one drop at a time of 0.1 M HCl to each test tube and stop when the color becomes orange or red (as in the case of the test tube on the right in Fig. 2). Count drops and record. If drops needed exceed 50, stop adding drops and record your value as ">50" drops.

Fig. 1

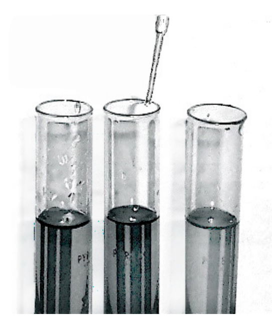


Fig. 2

Table 1: 1X Buffering

10 mL Sample	Initial pH	Drops 0.1M HCl
Spring		
Creek		
SW		
Buffer		
NaOH		

Part B: Buffering Capacity at 0.1X Concentration

1) Dilute by a factor of 10 any solution that was not acidified at 50 drops.
2) Repeat steps 3-4 to test these 0.1X solution concentration.
3) Organize data into a 2nd table (right).
4) If 50 drops still fails to acidify your sample, repeat this procedure at 0.01X and prepare a 3rd table to record this data.

0.1X Buffering

10 mL Sample	Initial pH	Drops 0.1M HCl

5) If 50 drops fails to acidify your 0.01X sample, add the HCl by the dropperful until acidified, then pour it into a graduate cylinder to determine total mL added.
6) Use the conversion factors below to determine how many drops HCl would have needed to be added to acidify the original undiluted (1X) sample concentration:

   a. 1 mL = 20 drops
   b. If your solution is 0.1X, 1 drop = 10 drops at 1X, and 1 mL = 200 drops
   c. If your solution is 0.01X, 1 drop = 100 drops at 1X, and 1 mL = 2000 drops

7) Use calculations based on these conversion factors to out the complete information in Table A-2.

Table 2: Buffering (comprehensive data set)

10 mL Sample	Initial pH at 1X concentr.	Initial pH at 0.1X concentr.	Initial pH at 0.01X concentr.	Final pH	Drops 0.1M HCl needed to acidify 1X concentr.
Spring		N/A*	N/A*		
Creek		N/A*	N/A*		
SW		N/A*	N/A*		
Buffer					
NaOH					

*These spaces will be unused because these samples are easily acidified at 1X concentration.

Questions:

1. Which natural water sample has the lowest buffering capacity?

2. Which natural water sample has the highest buffering capacity?

3. Which prepared solution has the highest buffering capacity?

4. Which natural water started with the highest pH?

5. Which prepared solution started with the highest pH?

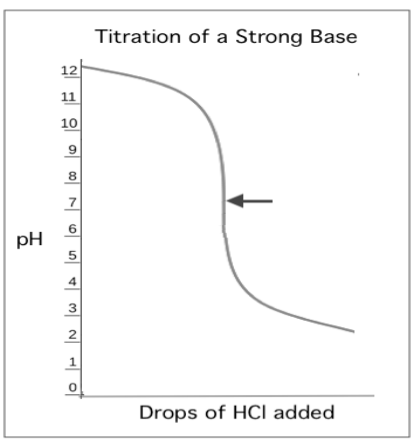
6. Based on this information, does higher pH always indicate stronger buffering against HCl? Explain:

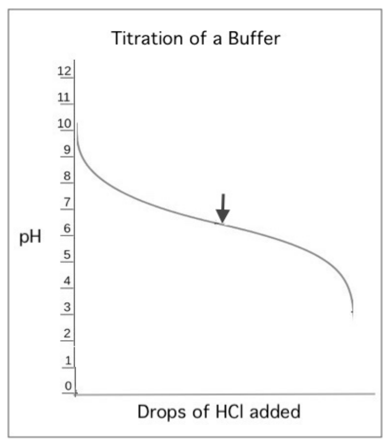
7. Which solution pH changed the most as the result of 0.01X dilution?

8. The graphs below indicate how pH is affected when you add HCl to two different kinds of solutions. The arrows in each graph represent the "equivalence point." This is when the acidifying agent is equal the base or buffering agent in the container. Use this information to answer the following questions:
    a. Which graph below starts at the highest pH?

    b. In which graph below does pH drop more *gradually* to the right of the equivalence point?

    c. Which prepared solution used in lab most resembles the graph on the right?





9. Quicklime (calcium oxide) and garden lime (a crude mixture of calcium carbonate and magnesium carbonate) are often added to earthen ponds to enrich them with calcium and increase pH. Since quicklime is very corrosive, it is sometimes applied to the mud puddles in order to kill unwanted species. Which of these two pond additives is a buffering agent? Explain why:

Assignment Checklist:
1. Did you completely answer all the questions?
2. Did you enter the values in Tables A and B (0.1X and 0.01X).
3. Did you calculate total drops HCl needed at 1X and re-enter values in Table A?