42 BUFFERS
EXPERIMENT

PURPOSE

To investigate the capacity of buffered solutions to withstand addition of acid and base without undergoing a significant change in pH.

BACKGROUND

Your blood must be maintained at pH 7.35–7.45 for you to stay healthy. However, chemical reactions taking place in your body are continuously pumping a stream of hydrogen ions into your blood. Your body maintains the proper blood pH, in spite of the hydrogen ions, due to blood buffers. *Buffered solutions* maintain a relatively constant pH when limited amounts of acid or base are added to them.

What are buffers? They usually consist of solutions of a weak acid and its salt or of a weak base and its salt. For example, a solution containing ethanoic acid (CH_3COOH) and its salt, sodium ethanoate (CH_3COONa), is a buffer. A solution containing ammonia (NH_3) and its salt, ammonium chloride (NH_4Cl), is also a buffer. Sodium ethanoate is formed by the neutralization of ethanoic acid by sodium hydroxide. Ammonium chloride is formed by the neutralization of ammonia by hydrochloric acid. In other words, a buffer can be created by the partial neutralization of a weak acid by a strong base or by partial neutralization of a weak base by a strong acid.

In this experiment, you will examine the effectiveness of different buffering systems in resisting changes in pH.

MATERIALS (PER PAIR)

safety goggles and apron
7 medium test tubes
1 test-tube rack
paper towels
2 50-mL beakers
2 dropper pipets
1 10-mL graduated cylinder
glass-marking pencil
1*M* hydrochloric acid, HCl [I]
1*M* sodium hydroxide, NaOH [I] [C] [T]
0.1*M* sodium carbonate, Na_2CO_3
0.1*M* sodium hydrogen carbonate, $NaHCO_3$
0.1*M* disodium hydrogen phosphate, Na_2HPO_4 [I]
0.1*M* sodium dihydrogen phosphate, NaH_2PO_4 [I]
boiled distilled water
wide-range indicator solution (pH 1–14) or wide-range pH paper (pH 1–14)

SAFETY FIRST!

In this lab, observe all precautions, especially the ones listed below. If you see a safety icon beside a step in the procedure, refer to the list below for its meaning.

Caution: Wear your safety goggles. (All steps.)

Caution: Hydrochloric acid and aqueous sodium hydroxide are irritants at the concentrations used in this experiment. They are corrosive and can cause severe burns. (Steps 6 and 7.)

Caution: Never pick up a dropper bottle by its cap. Always hold a dropper with the lip lower than the rubber bulb so that the liquid does not run into the bulb. (Steps 5–8.)

Note: Return or dispose of all materials according to the instructions of your teacher. (Step 9.)

PROCEDURE

As you perform the experiment, record your results in Data Table 1.

1. Label seven medium test tubes with the numbers 1–7.
2. Mix 5 mL of 0.1*M* Na_2CO_3 and 5 mL of 0.1*M* $NaHCO_3$ in a 50-mL beaker. This is a carbonate/hydrogen carbonate (CO_3^{2-}/HCO_3^-) buffer. Divide this buffer solution equally between test tubes 1 and 2.
3. In another 50-mL beaker, mix 5 mL of 0.1*M* Na_2HPO_4 and 5 mL of 0.1*M* NaH_2PO_4. This is a monohydrogen phosphate/dihydrogen phosphate ($HPO_4^{2-}/H_2PO_4^-$) buffer. Divide this buffer solution equally between test tubes 3 and 4.
4. Put 5 mL of 0.1*M* $NaHCO_3$ in test tube 5, 5 mL of 0.1*M* Na_2HPO_4 in test tube 6, and 5 mL of cool, previously boiled distilled water in test tube 7.
5. Use a dropper to add 3 drops of wide-range indicator to each test tube. Estimate the pH of each solution by comparing your results with those in the color chart supplied with the indicator. Record the results in Data Table 1.

6. Use a dropper to add 1 drop of 1*M* HCl to tubes 1, 3, 5, 6, and 7. Flick the test tubes to mix, note the color changes, and record the results.

7. Use a dropper to add 2 drops of 1*M* NaOH to tubes 1, 3, 5, 6, and 7—the tubes that received the HCl solution. Flick the test tubes to mix and note the color changes. Estimate and record the pH.
8. (Optional) Add hydrochloric acid, drop by drop, to tubes 2 and 4. Flick the test tubes to mix until the pH drops to about 2. Record the number of drops required for this to occur.

9. Follow your teacher's instructions for proper disposal of the materials.

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OBSERVATIONS

DATA TABLE 1: EFFECTS OF ACID AND BASE ON BUFFERED AND UNBUFFERED SOLUTIONS

Tube	Contents of Tube	Initial pH	pH After Adding 1 Drop HCl	pH After Adding 2 Drops NaOH	Number of Drops HCl Added (Optional)
1	CO_3^{2-}/HCO_3^-				—
2	CO_3^{2-}/HCO_3^-		—	—	
3	$HPO_4^{2-}/H_2PO_4^-$				—
4	$HPO_4^{2-}/H_2PO_4^-$		—	—	
5	0.1*M* $NaHCO_3$				—
6	0.1*M* NaH_2PO_4				—
7	Boiled distilled water				—

ANALYSES AND CONCLUSIONS

1. Based upon your experimental evidence, how effective are the CO_3^{2-}/HCO_3^- and $HPO_4^{2-}/H_2PO_4^-$ buffer systems? Explain your answer.

2. Do 0.1*M* $NaHCO_3$ and 0.1*M* NaH_2PO_4 solutions buffer as effectively as the CO_3^{2-}/HCO_3^- and $HPO_4^{2-}/H_2PO_4^-$ systems? Explain your answer.

Name _____ Class _____ Date _____

3. Write equations for the reaction of the $HPO_4^{2-}/H_2PO_4^-$ buffer system with an acid and a base.

4. Write equations for the reaction of the CO_3^{2-}/HCO_3^- buffer system with an acid and a base.

5. Do all buffers maintain the pH in the same range? In a chemistry handbook, look up the pH range of buffers in the list that follows. Prepare and measure the pH of each buffer solution. How do your experimental results compare to the published values? Which of these buffer systems would be effective at pH 5.0?

Buffer System	pH Range
monohydrogen phosphate/dihydrogen phosphate	**6.1–7.4**
ethanoate/ethanoic acid	**3.7–5.6**
carbonate/hydrogen carbonate	**9.2–11.0**
phosphate/monohydrogen phosphate	**11.0–12.0**

GOING FURTHER

Develop a Hypothesis

The carbonate buffer system plays an important role in maintaining proper blood pH. However, under certain conditions the buffering capacity of blood may be overwhelmed. For example, pH can be affected by irregular breathing patterns that alter the balance of gases, such as CO_2, in the blood. Inhaled air contains 0.04% CO_2; exhaled air contains 4% CO_2. Based on the results of this lab, develop a hypothesis about how the concentration of dissolved CO_2 in an aqueous solution affects the pH of the solution.

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