Buffer Solutions

Topic

A buffer is a substance that resists change in pH.

Introduction

The addition of an acid or base to a solution can change the pH of the solution dramatically. Adding acid to a solution swells the concentration of hydronium ions (H_3O^+), and adding base increases the amount of hydroxide ions (OH^-). An alteration in the concentration of H_3O^+ or OH^- affects the way that solution behaves in a chemical reaction.

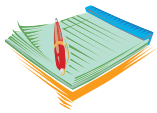
The tissues of living things must maintain a steady pH for their enzymes to function. To avoid pH fluctuations, many organisms rely on *buffers.* An acid buffer, generally composed of a weak acid and its *conjugate base* (or salt), resists pH change by supplying some H_3O^+ to the solution. If a base is added to an acid buffered solution, these H_3O^+ take up the additional OH^- ions. Similarly, a basic buffer, made up of a weak base and its *conjugate acid*, resists changes in pH because it supplies OH^- to neutralize added acids. Buffers maintain equilibrium between the acid (HA) and base (A^-) as represented by the following equation:

$$HA + H_2O \rightarrow H_3O^+ + A^-$$

Chemical reactions with buffers restore the pH to its original level because the excess H_3O^+ and OH^- are used up. In this experiment, you will observe the effectiveness of a boric acid buffer in resisting pH change as hydrochloric acid is added to a solution.

Time Required

30 minutes



Materials

- boric acid (about 1 gram [g])
- borax (about 5 g)
- 0.1 M hydrochloric acid solution
- 0.01 M hydrochloric acid solution
- 250-milliliter (ml) volumetric flask
- four 100-ml beakers
- distilled water (about 200 ml)
- pH paper (wide range)
- dropper
- stirring rod
- electronic scale or triple-beam balance
- weighing boat
- labels or masking tape
- marking pen
- science notebook

Safety Note **Wear safety goggles and tie back long hair. Please review and follow the safety guidelines.**

Procedure

1. Use the electronic scale or triple-beam balance to measure 4.75 g of borax and 0.75 g of boric acid.
2. Add the borax and boric acid to a 250-ml volumetric flask; fill with distilled water until the volume is 250 ml. Swirl to dissolve the solids.
3. Label each of the four beakers as A, B, C, and D.

4. Fill each of the four beakers as follows:
   Beaker A—50 ml distilled water
   Beaker B—50 ml buffer solution
   Beaker C—50 ml distilled water
   Beaker D—50 ml buffer solution
5. Test the pH of each beaker by placing a drop of the solution onto pH paper. Record the initial pH on the data table.
6. Add 5 drops of 0.01 M HCl to beakers A and B. Stir and check the pH with pH paper. Record the pH on the data table.
7. Add 5 drops of 0.1 M HCl to beakers C and D. Stir and check the pH with pH paper. Record the pH on the data table.
8. Calculate the percentage change in each beaker using the following equation:

$$\text{Percentage change} = \text{initial pH} - \frac{\text{final pH}}{\text{initial pH}}$$

   Record the percent change in the data table.

Data Table 1

Beaker	Initial pH	Final pH	Percentage change
A			
B			
C			
D			

Analysis

1. What was the pH of the buffer solution?
2. How did the pH of the distilled water change when 0.01M HCl was added (in beaker A)? 0.1M HCl (in beaker C)?
3. Was the percentage change greater in beaker A or beaker C? Why is this?
4. Did the pH change in beakers B and D when HCl was added?

What's Going On?

Boric acid is a weak acid and borax (sodium tetraborate decahydrate) is its conjugate base. As buffer solutions, these chemicals help maintain a stable pH, even if acid or base is added to a system. A boric acid buffer solution will maintain a pH range of 8 to 10. Buffers continue to work until the concentration of acid produces more H_3O^+ than can be neutralized, or used up, by the conjugate base.

Buffer solutions vary in pH, depending on their components. In the lab, scientists select buffer solutions by the pH range that they are able to maintain. Within the human body, many different buffers are naturally present that help maintain our stable internal conditions. One example is the buffer solution that is present in the plasma of human blood. It is made up of carbonic acid and bicarbonate and helps to maintain blood pH within a range of 7.35 to 7.45.

Want to Know More?

See Our Findings.

OUR FINDINGS

BUFFER SOLUTIONS

Suggestion for class discussion: Review the basics of acid rain, then ask students why some bodies of water undergo more dramatic decreases in pH than others. After students offer some suggestions, explain that many natural bodies of water contain limestone, a mineral that acts as a buffer to help neutralize acid rain. Crushed limestone can be added to bodies of water or aquaria to serve the same purpose.

Analysis

1. Answers may vary slightly, but the pH should be around 9.2.
2. The pH in beaker A was lower than the initial pH; the pH in beaker C was much lower than the initial pH.
3. Percentage change was greater in beaker C because the acid was more concentrated and had more H_3O^+.
4. The pH may have changed slightly, but should have remained between 8.5 and 9.5.

SAFETY PRECAUTIONS

Review Before Starting Any Experiment

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read and remain mindful of the General Safety Precautions that follow this note. Experimental science can be dangerous, and good laboratory procedure always includes following basic safety rules. Things can happen very quickly while you are performing an experiment. Materials can spill, break, or even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. For one reason, we want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical.

Read the safety precautions here and at the beginning of each experiment before performing each lab activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the book does not say “Be careful with hot liquids” or “Don’t cut yourself with a knife” does not mean that you can be careless when boiling water or using knives. Notes in the text are special precautions to which you must pay special attention.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking an unnecessary risk can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the individual experiments in this book for additional safety regulations and adult supervision requirements. Anytime you are working with an electrical current, it becomes possible to shock yourself on exposed wires. If you will be working in a lab, do not work alone. When

you are working off-site, keep in groups with a minimum of three students per group, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

PREPARING

- Clear all surfaces before beginning experiments.
- Read the instructions before you start.
- Know the hazards of the experiments and anticipate dangers.

PROTECTING YOURSELF

- Follow the directions step by step.
- Do only one experiment at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not horseplay.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up by yourself; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult.

USING EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives or other sharp, pointed instruments with care.
- Pull plugs, not cards, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Let your teacher know about broken glassware immediately.
- Do no use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

USING CHEMICALS

- Never taste or inhale chemicals
- Label all bottles and apparatus containing chemicals
- Read labels carefully.
- Avoid chemical contact with skin and eyes (wear safety glasses, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING SUBSTANCES

- Wear safety glasses, apron, and gloves when boiling water.
- Keep your face away from test tubes and beakers.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heat-proof workbenches, put your Bunsen burner on a heat-proof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed, and use a Bunsen burner lighter rather than wooden matches.
- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues and put in proper containers for disposal.
- Dispose of all chemicals according to all local, state, and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES!