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*Photocopy the Student Guide as needed for use in your classroom.

The materials and activities in this kit meet the guidelines and academic standards of the Advanced Placement (AP) Program and have been prepared by Carolina Biological Supply Company, which bears sole responsibility for kit contents.

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Carolina Investigations™ for AP Chemistry

Preparation of a Buffered Solution

Overview

Students investigate buffers as they work in teams of 3 to prepare buffered solutions with a designated pH and investigate the effect of concentration on buffering capacity. This manual includes two alternative approaches to the lab: a guided approach and a more inquiry-centered approach.

In the guided approach, students first prepare stock solutions from which they will produce their buffers. Then, on the basis of their own calculations, they prepare buffers of targeted pH values. Finally, they analyze how their buffers of different pH and concentration are affected by the addition of acid or base.

Students taking the inquiry approach plan and execute experiments that include the creation and use of a buffering solution that meets their stated requirement(s). The kit includes materials for a class of 30 working in groups of 3 and lists those materials that are needed but not supplied. If you choose the inquiry approach, you may need to supply additional items called for in the students’ experimental plans.

Objectives

Students will

- prepare solutions of a given volume and concentration.
- determine the proportion of each chemical needed to produce the targeted buffering capacity.
- evaluate their prepared buffer solution.

Content Standards

This kit is appropriate for Advanced Placement high school students and addresses the following AP Chemistry concepts:

**Big Idea #6: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic completion, sensitive to initial conditions and external perturbations.**

- Essential Knowledge 6.C.2: The pH is an important characteristic of aqueous solutions that can be controlled with buffers. Comparing pH to $pK_a$ allows one to determine the protonation state of a molecule with a labile proton.
  - Learning Objective 6.18. The students can design a buffer solution with a target pH and buffer capacity by selecting an appropriate conjugate acid-base pair and estimating the concentrations needed to achieve the desired capacity.
NOTES

- Essential Knowledge 2.A.3.j: Understanding how to prepare solutions of specified molarity through direct mixing of the components, through use of volumetric glassware, and by dilution of a solution of known molarity with additional solvent, is important for performing laboratory work in chemistry.

### Time Requirements

<table>
<thead>
<tr>
<th>Guided Activity</th>
<th>OR</th>
<th>Inquiry Activity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation</td>
<td>10 minutes</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Part 1</td>
<td>45 minutes</td>
<td>90 minutes</td>
</tr>
<tr>
<td>Part 2</td>
<td>45 minutes</td>
<td>90 minutes</td>
</tr>
<tr>
<td>Presentations</td>
<td>~30 minutes</td>
<td>~30 minutes</td>
</tr>
</tbody>
</table>

This lab is designed to be conducted as either a guided or an inquiry activity. Follow the procedure that better fits your needs.

If time is limited for the Guided Activity, you might split the class in half, with some groups completing Part 1 while others complete Part 2. Then, they can share data.

*If the lab is conducted as an inquiry activity, the time estimates provided may vary according to students’ experimental procedures. Remember to allow students time to prepare their materials. Decide how best to schedule students’ planning for their presentations.

### Materials

**Included in the kit:**

- 30 mL Bogen universal indicator
- 60 mL 6 M acetic acid (CH₃COOH)
- 30 g sodium acetate (CH₃COONa)
- 240 mL 0.1 M sodium hydroxide (NaOH)
- 240 mL 0.1 M hydrochloric acid (HCl)
- 100 g sodium bicarbonate (NaHCO₃)
- 100 g sodium carbonate (Na₂CO₃)
- disposable pipets
- 10 Bogen universal indicator color charts
- Teacher’s Manual and reproducible Student Guide

**Needed, but not supplied:**

- 10 24-well plates
- 20 100-mL volumetric flasks*
- 10 125-mL Erlenmeyer flasks (or larger)
- 50 25-mL Erlenmeyer flasks (or larger)
- 10 10-mL graduated cylinders
- 10 sheets of plain white paper
- pH meters (optional)
balance (to 0.01g)
chemical scoop
distilled water
10 marking pens or wax pencils

*Note: if you do not have enough 100-mL volumetric flasks for each group to have two, see the Helpful Hints section for alternative suggestions.

Items needed but not supplied for the Inquiry Activity may vary according to your students’ planned activities.

**Safety**

Ensure that students understand and adhere to safe laboratory practices when performing any activity in the classroom or lab. Demonstrate the protocol for correctly using the instruments and materials necessary to complete the activities, and emphasize the importance of proper usage. Use personal protective equipment such as chemical splash-resistant goggles, gloves, and aprons when appropriate. Model proper laboratory safety practices for your students and require them to adhere to all laboratory safety rules. Store all chemicals in accordance with their chemical compatibilities in approved storage areas. Upon completion of the lab, properly dispose of chemicals according to federal and local regulations.

The Bogen universal indicator solution may stain skin and clothing. It also contains ethanol, a flammable solvent; keep flames and sources of ignition away from this solution. The 6 M acetic acid is caustic; avoid direct contact. Avoid contact with the dilute solutions of acids and sodium hydroxide as they might irritate the skin.

**Teaching Inquiry**

Since the National Research Council published the National Science Education Standards in 1996, the inquiry approach to science education has become recognized as a method that actively engages students in a learning process that results in a greater mastery of scientific concepts. The findings of the National Research Council support the evidence that an inquiry approach to education helps students gain an in-depth understanding of science by building upon previous knowledge (Inquiry and the National Science Education Standards 2000). Students become empowered, taking responsibility for their learning by conducting inquiry investigations and communicating their discoveries.

Inquiry activities encourage students to explore questions in a scientific way. In structured inquiry, the question is supplied to the student. A systematic procedure for exploring the question and reaching a conclusion may also be provided. In open inquiry, the student directs the entire scientific investigation, determining the question to explore, the materials to use, the procedure to follow, and the methods used to analyze data. Current models of inquiry in science instruction derive from the work of several researchers, including Schwab (1962), Herron (1971), and Rezba, Auldridge, and Rhea (1999).
Carolina’s Approach

Carolina Investigations™ for AP Chemistry offer an inquiry approach to scientific instruction. Teachers may choose to perform a lab as either a Guided Activity, in which students investigate a pre-determined question using an established procedure, or as an Inquiry Activity, using student-directed investigations and presentations. Both approaches are described in each kit manual. With each kit, teachers decide which approach better suits their situation and the needs of their students and fulfills the requirements of the AP Chemistry curriculum. In the inquiry approach, student teams choose a question to investigate and design a procedure to answer the question. After they secure teacher approval, students proceed with their experiment. Teachers assist by providing any extra materials needed, ensuring safe laboratory practice, and asking questions that encourage critical thought about the teams’ progress and findings.

Pre-laboratory questions in the Guided Activity test students’ prior knowledge. Big Idea Assessments administered after the activities provide practice for the AP Chemistry exam’s free-response questions and help students internalize and effectively communicate the scientific concepts addressed by the laboratory activities.

Background Information

See the Student Guide for additional science content information about buffers and their preparation. Note the Prior Knowledge section below. If need be, perform a run-through so that you will be able to troubleshoot.

A buffered solution is one that resists pH changes when either H⁺ or OH⁻ ions are added. Typically, buffered solutions are composed of a weak acid and its conjugate base or a weak base and its conjugate acid. Buffers can also be prepared from a weak acid with a small amount of a strong base, a weak base with a small amount of a strong acid, or from an amphoteric substance.

Most buffers perform best at a pH near the pKₐ of the acid or base used for their preparation. When designing a buffer the chemicals used should be selected which have a pKₐ that is close to the targeted pH.

The pH of a buffered solution is calculated using the Henderson–Hasselbalch equation:

\[
pH = pK_a + \log \frac{[\text{Base}]}{[\text{Acid}]}
\]

When protons or hydroxide ions are added to the solution, the stoichiometry and equilibrium calculations must be performed prior to calculation of the pH.

The same equation can be used to design a buffer of a certain target pH. If the target pH is inserted for the pH in the equation, and the pKₐ of the acid (or base) is inserted into the equation, then the ratio of the acid (or base) to its salt can be calculated.

The buffering capacity of a solution indicates the amount of H⁺ or OH⁻ ions the buffer is able to absorb without causing a significant change in pH. The buffering capacity of a buffered solution is determined by the magnitude of [HA] and [A⁻];...