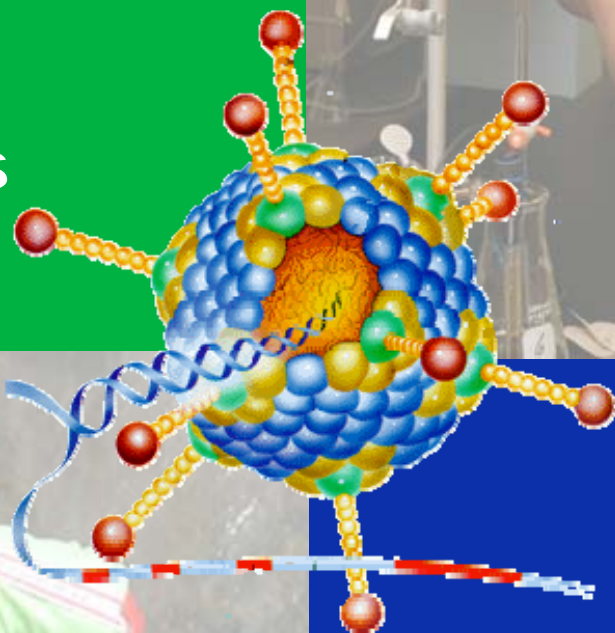


# Changes in Conductivity and pH

## Teacher's Guide



*The waterCAMPWS*  
Center for Advanced Materials  
for Purification of Water with Systems



**Curriculum Connection:** Chemistry or Environmental Sciences

**Bloom's Taxonomy:**

**Grade Level:** 10-12 AP

**Topic:** Titration, pH, Conductivity

**Lesson Duration:** 120 minutes

### Purpose

Controlling the amount of acid or base, referred to as pH, of our water is a very important task for civil engineers. For example, water with a pH of 5.0 or below will be corrosive and destroy pipes in your home. Water with a high pH of 8.0 or more will form a scale and start to clog pipes and form scale on sinks and tubs. Materials, such as activated granular charcoal is used to control water's pH as well as remove harmful substances from the water. This lab demonstrates the change in the pH curve when granular activated carbon is added during the acid base titration. The primary objective of this laboratory experiment is to observe changes in conductivity and pH with the addition of a strong base (aqueous) to a strong acid solution, in the presence of activated carbon.

### Learning Goals and Objectives

1. Students will develop an understanding of the equilibrium reactions taking place
2. Students will predict titration curves
3. Students will understand how pH is related to charge (concentration of ions).
4. Students will relate pH to conductivity.
5. Students will determine the concentration of a base by titrating an acid with a known concentration.

### Benchmarks and Standards

#### Illinois State Learning Standards:

- 11.A.5c Conduct systematic controlled experiments to test the selected hypotheses.
- 11.A.5e Report, display and defend the results of investigations to audiences that may include professionals and technical experts.
- 11.B.5f Using available technology, prepare and present findings of the tested design solution to an audience that may include professional and technical experts.
- 13.A.5a Design procedures and policies to eliminate or reduce risk in potentially hazardous science activities.
- 13.A.5c Explain the strengths, weaknesses and uses of research methodologies including observational studies, controlled laboratory experiments, computer modeling and statistical studies.

#### NSES Standards: In grades 9-12, students will learn:

- *Content A* Abilities necessary to do scientific inquiry & understandings about scientific inquiry.
- *Content B* Structure and properties of matter, motions and forces, and interactions of energy and matter
- *Content E* Abilities of technical design and understandings about science and technology
- *Content F* Personal and Community health, population growth, natural resources, environmental quality, natural and human induced hazards, and science and technology in local, national and global challenges
- *Content G* Science as a human endeavor, nature of scientific knowledge
- *Teaching A* Plan an inquiry-based science program for their students
- *Teaching B* Guide and facilitate learning
- *Teaching D* Design and manage learning environments that provide students with the time, space and resources need for learning science.
- *Teaching E* Develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.

## Materials and Equipment

Materials required for this lesson are (for each group of students):

- Reagents: 0.002 M CuCl<sub>2</sub>
  - 0.1 M HCl
  - 0.1 M NaOH
- granular activated carbon or AC (presoaked overnight in distilled water)
- 100 mL graduated cylinder
- 400 mL beaker
- Titration setup
- magnetic mixers and magnetic stir bars
- pH probe
- Hand pipettes or burettes
- Scale

## Introduction

### Acids and Bases

An acid is generally defined as any substance that dissociates in aqueous solution to produce hydrogen cations in solution. The strength of the acidity of the substance is determined by the extent to which the acid dissociates in water. In other words, a strong acid will have an equilibrium that favors the products from the dissociation. The equilibrium reaction for an aqueous acid is shown below:



The equilibrium constant ( $K_a$ ) for the reaction, gives us a quantitative measurement for the substance's acidity and tells us the extent to which it dissociates in water. For strong acids and strong bases, virtually all molecules exist as dissociated ions, so they have very high equilibrium constants.

$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} \quad (\text{at equilibrium})$$

Bases are defined as substances that produce hydroxide anions when dissolved in water. The greater the number of hydroxide molecules, the stronger the base. The equilibrium reaction for a base is as follows:



The equilibrium constant ( $K_b$ ) for a base is represented by

$$K_b = \frac{[\text{B}^+][\text{OH}^-]}{[\text{BOH}]}$$

### pH

The pH scale ranges from 0-14. These are standardized values used to measure the acidity or alkalinity (how basic) a particular substance is. A pH of seven indicates that the substance/solution is neutral. Any pH reading below 7 denotes the solution is acidic, while readings above 7 denote the solution is basic. Essentially, pH is a measurement of the concentration of hydronium ions ( $\text{H}^+$ ) present and is given by the equation:

$$\text{pH} = -\log [\text{H}^+]$$

## Activated Carbon

Activated carbon is useful in a number of different systems because of its ability to absorb different particles and organic materials. Absorption of activated carbon generally occurs in a simple process in which substances pass through the exterior of the carbon surface and enter carbon pores. Once this has occurred, the substance is absorbed by carbon's interior walls. This makes activated carbon ideal for water filtration methods. It is important to note that after all absorption sites are filled, the activated carbon can no longer be used as an effective means of particle/substance removal.

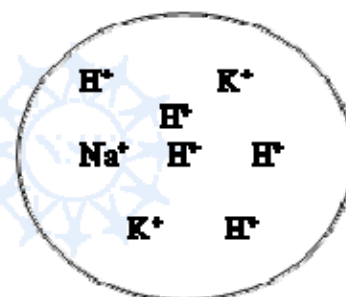
For this particular experiment, the pH of the solution will determine what ions are being absorbed by the activated carbon. In acidic solutions (pH below 7.0), protonated (positively charged) ions (namely  $\text{Cu}^{2+}$ ) are absorbed by carbon. At pHs above 7, activated carbon absorbs  $\text{Cl}^-$  anions (negatively charged).

## Conductivity

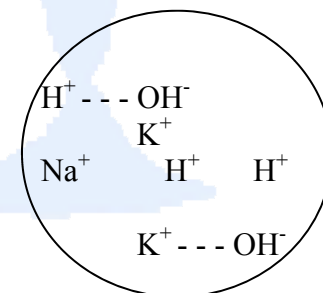
The electrical conductivity of a solution is the measurement of all ions present. A high concentration of ions will correspond to high conductivity (assuming there is no reaction between the ions present). If ions react/bind to form compounds or molecules, conductivity will decrease. If greater dissociation occurs as a result of the presence of certain ions, conductivity will increase. The two drawings below illustrate this concept. While they both have the same number of ions, the presence of the hydroxide anion in Solution B decreases the conductivity of the solution because of its ability to form compounds with other ions.

The density and mobility of the ions, as well as the viscosity of the solution (ability to flow) will also affect the conductivity. More mobile ions will have higher conductivity, but a highly viscous solution will make it more difficult for the ions to move (lowering the conductivity).

In this laboratory experiment, the concentration of ions present, their reactions with each other, and their binding to the activated carbon will affect the conductivity of the solution.



**Solution A**



**Solution B**

Conductivity decreases due to ability to form compounds

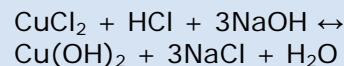
## Activities

1. Before beginning this lab, prepare several liters of the reagents and soak the activated carbon in distilled water overnight before class.
2. Present the introduction to this lab or another appropriate introduction to pH, conductivity, ionic charge, etc.
3. Divide students into groups. Have someone from each group collect the supplies they will need.
4. Students will perform two titrations. For the first titration:
  - a. Have students take a 0.002M solution of copper chloride ( $\text{CuCl}_2$ ).
  - b. Have them (or do so yourself) add three mL of 0.1M hydrochloric acid (HCl).
  - c. Have students titrate the acidic solution using sodium hydroxide (NaOH) and record the pH after each addition in their lab book.
5. For the second titration:
  - a. Have students take a 0.002M solution of copper chloride ( $\text{CuCl}_2$ ).
  - b. Have them (or do so yourself) add three mL of 0.1M hydrochloric acid (HCl).
  - c. Have the students add approximately 2.0 grams of activated carbon to the solution before beginning the titration.
  - d. Have students titrate the acidic solution using sodium hydroxide (NaOH) and record the pH after each addition in their lab book. Include any other observations, color change, etc.
6. Have students complete the comprehension and analysis questions in their lab books.
7. Conclude the lab with a discussion of their results.

The equivalence point (stoichiometric point) is the point in the titration in which the number of moles of base is equal to the number of moles of acid. Therefore, if the concentration of HCl is known (0.1 M), the concentration of NaOH can be determined by calculating the amount of NaOH needed to reach the equivalence point. The concentration of HCl times the volumes of HCl is equal to the concentration of NaOH times the volume of NaOH.

Be sure to use the values from the titration completed without the use of AC (activated charcoal) to determine the concentration of AC.

The equilibrium reaction that takes place as NaOH is added to solution can be expressed as follows:



## Conclusion

Have the students clean up the lab. With remaining time, have some of the groups share their results. Collect the lab books at the end.

## Assessment

The lab book should provide an assessment tool for this lesson.