TEACHER'S GUIDE

CHEMISTRY'S RAINBOW

NEUTRALIZE AN ACID AND A BASE

Thanks for the opportunity to work with your students. Our goal is to teach developmentally appropriate chemistry concepts that support your science curriculum. We hope that this experience of doing hands-on activities and learning science from a real scientist will inspire your students to pursue further studies in science.

This lesson is part of the Kids & Chemistry program developed by the American Chemical Society (ACS) to support science professionals who want to share their love and knowledge of science with elementary and middle school students. As a group of volunteers, these science professionals are valuable community partners who serve individual classrooms, schools, museums, science resource centers, and departments of education. Kids & Chemistry volunteers are amazing people!

ACS is a professional organization for chemists. It is the world's largest scientific society and is one of the world's leading sources of authoritative scientific information. The Society publishes numerous scientific journals and databases, convenes major research conferences, and provides educational, science policy, and career programs in chemistry.

ACS also produces resources for elementary and middle school teachers and students. Turn to the last page of this Teacher's Guide or visit *www.acs.org/education* to learn about these excellent resources. You can rely on ACS education resources to provide safe activities and accurate explanations that are just right for you and your students.

We wish you the best as you strive to educate your students. And we hope that our efforts help you and your students enjoy learning science.

Education Division Staff
American Chemical Society

What will happen?

You agreed to have a guest speaker come into your classroom, and you wonder what your visiting scientist will do. Basically, the scientist will conduct an introductory demonstration and then guide students through a series of related hands-on activities. Each student will receive a Student Lab Guide that includes procedures, science information, a place to record data, and questions about the content. The following descriptions of the demonstrations and activities will give you a better idea of what the presentation will be like.

The dazzling demo

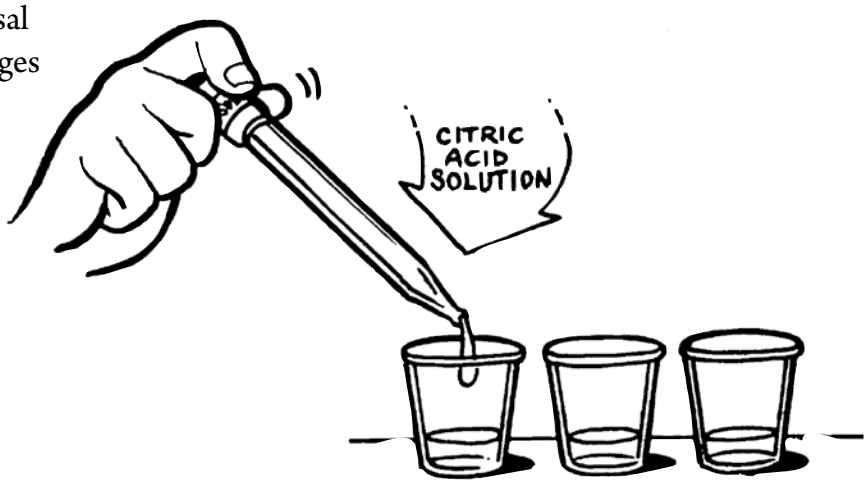
The presenter pours a green liquid into two seemingly empty cups and gets surprising color changes. The liquid turns pink as it enters one cup and purple as it enters the other cup! The presenter admits that the green liquid was universal indicator solution and then helps students solve the mystery of the color changes by showing them how to use the Universal Indicator pH Color Chart.

Get ready for the activity

Students make their own citric acid, sodium carbonate, and universal indicator solutions. They also label their equipment and practice skills needed for the activities.

Test your solutions

Students add single drops of citric acid to universal indicator and observe the progressive color changes as more and more acid is added to the indicator solution. Students then do the same with the sodium carbonate solution to see the full range of colors of universal indicator solution.



Neutralize your solutions

Students add single drops of sodium carbonate solution to the citric acid and universal indicator solution from the previous activity and watch as the color gradually shifts back to green. Then they neutralize the sodium carbonate and indicator solution from the previous activity to learn that acids and bases can neutralize each other.

The grand finale

Students add water and universal indicator to a small zip-closing plastic bag. Then you and the presenter add an Alka-Seltzer tablet to each bag and quickly seal it. Based on students' experiences with acids, bases, universal indicator, and neutralizing solutions, they can interpret the color changes that occur during this chemical reaction. To make things even more exciting, the bag fully inflates!

What will students learn?

The goal of this presentation is to support your science curriculum in a fun and special way. As your students do science with a real chemist, we hope they realize that they can do science, too.

Learning objectives

- Students will be able to categorize a substance as an acid or a base, on the basis of the characteristic color changes of universal indicator solution.
- Students will be able to neutralize an acid and a base using the characteristic color changes of universal indicator solution.
- Students will be able to describe the relative amount of acid or base in a solution during a chemical reaction based on their experiences with the color changes of universal indicator solution.

Vocabulary words

After completing this lesson, students will be very familiar with the meaning of the following terms. You may use this lesson to introduce or reinforce these terms.

- Chemistry
- Indicator
- Acid
- Base
- Control
- Neutralize

Assessment

As students complete each procedure, they will answer questions about the activity in their own Student Lab Guide. You can check to see that students were on task by reviewing these pages. The last page of the Student Lab Guide provides a more summative assessment. Have students answer the 5 questions on this final page after the presenter leaves. This way you can evaluate how well each student understands the concepts presented during the lesson. The questions and answers are provided on the following page.

What did you learn?

What does an indicator do?

An indicator is a substance that changes color when acids and bases are added to it.

If you add a substance to universal indicator and it turns red, what can you say about the substance?

If universal indicator solution turns red, the substance added is an acid.

If you add a substance to universal indicator and it turns purple, what can you say about the substance?

If universal indicator solution turns purple, the substance added is a base.

How can you neutralize an acid?

Add drops of a base. The solution will be neutralized when the indicator turns green.

How can you neutralize a base?

Add drops of an acid. The solution will be neutralized when the indicator turns green.

How can I help?

Please stay involved every step of the way. The presenter needs your help to make this lesson go smoothly and ensure that your students learn as much as possible from this experience.

To ensure a successful lesson, please do the following:

- Place students in groups of 3 or 4 around a shared workspace before the presenter arrives.
- Provide a space where the presenter can set up the demo immediately before the lesson.
- Provide access to water before the presentation. Each student group will need about a half cup of water.
- Provide one sheet of white paper or notebook paper for each group.
- Provide safety goggles for every student and yourself. (If you do not have goggles, contact your visiting scientist.)
- Arrange to have all students wash their hands and desks after the lesson.
- Help with classroom management. You are an expert in this area, and the visiting scientist is not. Use each other's strengths to make this lesson a wonderful experience for everyone.

A final word on safety

The activities the presenter will do with your students have been reviewed for safety by the ACS Committee on Chemical Safety. Because one of the activities uses effervescent antacid and pain relief tablets (Alka-Seltzer), which contain medicine, the committee recommends that you check with your school nurse to make sure that you and the presenter follow your district's policy for handling medications.

The effervescent antacid and pain relief tablets will not be consumed by the students. In fact, only you and the presenter will handle the tablets. Both of you will walk around to each student group and place a tablet in an indicator solution contained within a zip-closing plastic bag. Then you will seal the bag and hand it to the students. Make sure that students do not open the bag during or after the activity.

You and the presenter may safely dispose of the contents of these bags in a sink, or you can place the entire sealed bag in the trash.

What if students ask a chemistry question after the presenter leaves?

You and your students may have some questions about the activities you explored with your visiting chemist. This guide provides a little background to help you confidently answer these questions. Feel free to contact your visiting chemist or the message board at *www.inquiryinaction.org* with other questions. ACS Education Division staff moderate this message board.

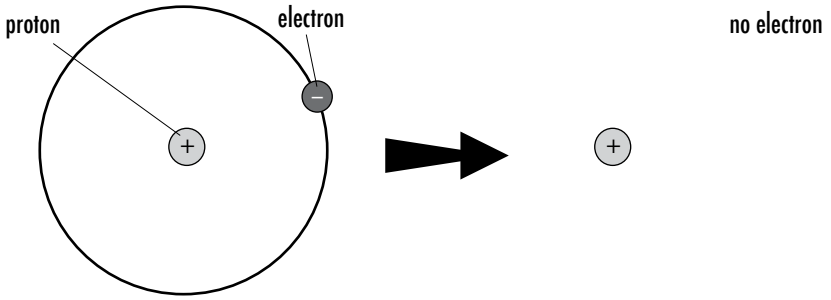
It is important to note that these explanations are written for you, the teacher. They go above and beyond chemistry concepts taught at the elementary and middle school level. We understand that you know better than anyone how to properly convey these ideas to your curious students who want to learn more.

Why did the indicator solution change color when an acid was added?

In chemistry, indicators are complex molecules that have the unique property of changing color in the presence of an acid or base. In the experiments your students performed with the visiting scientist, the indicator solution changed color when citric acid was added to it because the citric acid reacted with the indicator molecule.

More specifically, citric acid donated a proton to the indicator molecule, and this caused the indicator molecule to change color. In chemistry, donating a proton is what being an acid is all about.

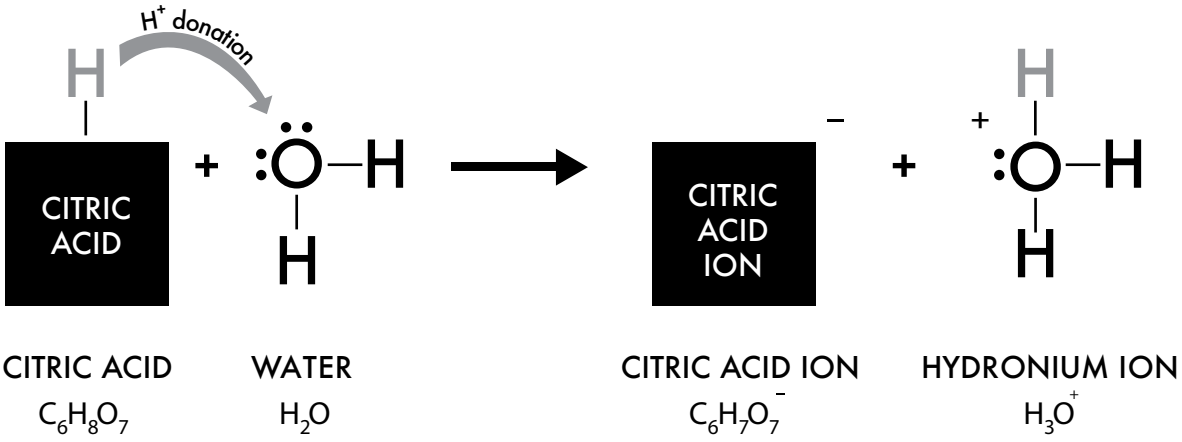
We can think of a proton as a hydrogen atom that has lost its electron. Most hydrogen atoms have one electron (negatively charged), one proton (positively charged), and no neutrons (no charge). When a hydrogen atom loses its sole electron, all that is left is the positively charged proton, which we represent as H^+. The superscripted plus sign symbolizes the presence of only the proton.



So an acid is a molecule that contains at least one hydrogen atom that can be donated in the form of a proton. In the reaction between the citric acid and the indicator molecule, the citric acid acted as the acid by donating a proton to the indicator molecule.

This act of donating a proton seems trivial, but it can cause the indicator molecule to change shape, which in turn causes it to change color.

But what about water? What does water do while the citric acid is reacting with the indicator? Recall that citric acid was added to a solution of water plus a few drops of the indicator. In fact, the citric acid reacts with water as well. And it does so in the same way that it reacts with the indicator: by donating a proton to water molecules. Because the chemical formula for water is H_2O (or HOH), when the citric acid donates a proton to water, it forms H_3O^+ ions, which are called hydronium ions. This process is important because chemists use the amount of H_3O^+ ions to describe how acidic or basic a solution is.



Why did the indicator solution change color when a base was added?

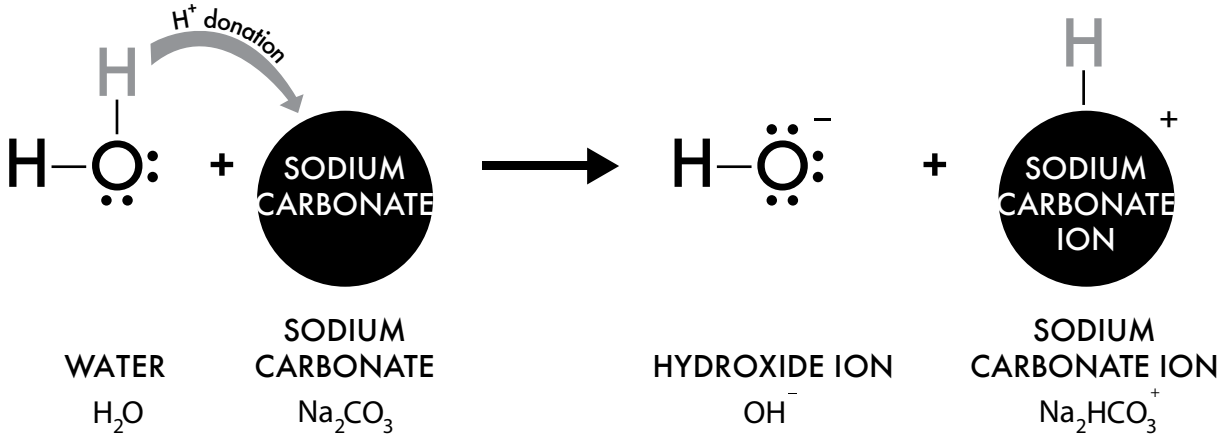
As we discussed in the previous question, an indicator is a molecule that can change color in the presence of an acid or base. The indicator changed color when citric acid was added because the citric acid reacted with the indicator molecule by donating a proton to it.

Similarly, the indicator solution changed color when sodium carbonate was added because the sodium carbonate reacted with the indicator solution.

This time, however, the indicator donated a proton to sodium carbonate. When the indicator molecule donates a proton, it causes the indicator molecule to change color. Keep in mind that indicator molecules are special because they change color with subtle modifications like accepting or donating a proton. Most molecules do not change color under these circumstances.

In this case, sodium carbonate accepts a proton from the indicator. In chemistry, accepting a proton is what being a base is all about. So, when sodium carbonate was added to the indicator solution, it acted as a base and accepted a proton from the indicator. This is what causes the indicator solution to change color.

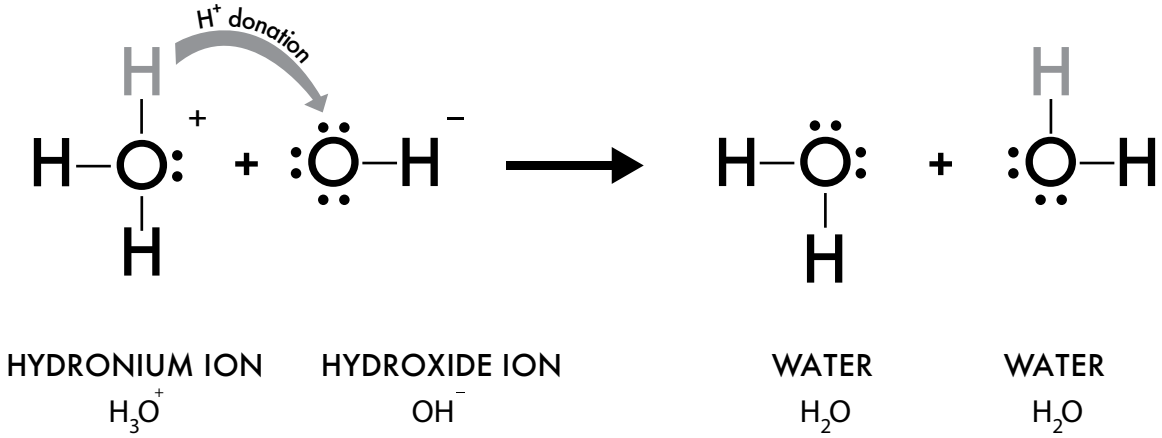
But what about water? Just as the citric acid did when it was added to the indicator solution, sodium carbonate also reacts with water. This time, however, it is the water that donates a proton to sodium carbonate. Because the chemical formula for water is H_2O (or HOH), when the water donates a proton to sodium carbonate, it causes the formation of OH^- ions, which are called hydroxide ions.



Why do citric acid and sodium carbonate neutralize each other?

As we have discussed, citric acid and sodium carbonate act in corresponding but opposite ways when they react with water. Citric acid, acting as an acid, donates a proton to water, which causes the formation of hydronium ions, which we write as H_3O^+. Conversely, sodium carbonate accepts a proton from water, and this leads to the formation of hydroxide ions, which we write as OH^-.

So, when you combine a solution of citric acid to a solution of sodium carbonate, you are adding a solution that contains an excess of hydronium ions to a solution that contains an excess of hydroxide ions. When the two are combined, the hydronium ions (H_3O^+) react with the hydroxide ions (OH^-) to form water.



Because water is electrically neutral, it makes sense to describe this process of putting together water molecules as neutralization.

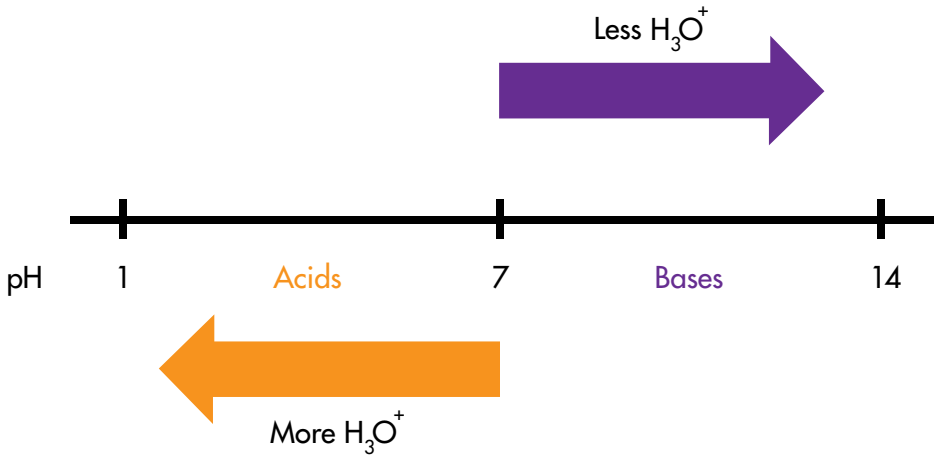
Looking at it another way, because we know that the amount of H_3O^+ ions in a solution is used to measure how acidic or basic that solution is, the process of using H_3O^+ ions to make water makes the solution neutral.

What does the pH scale measure?

The pH scale measures how acidic or basic an aqueous solution is. Solutions with a pH lower than 7 are acids, while solutions with a pH greater than 7 are bases.

The pH of a solution is calculated using the concentration of H_3O^+ ions in solution. The greater the concentration of H_3O^+ ions, the more acidic the solution is said to be, and the lower the pH. Solutions with sufficiently low concentrations of H_3O^+ ions have pH values above 7 and are bases.

Each step down on the pH scale corresponds to a tenfold *increase* in the concentration of H_3O^+ ions in solution. Each step up the pH scale corresponds to a tenfold *decrease* in the H_3O^+ concentration.

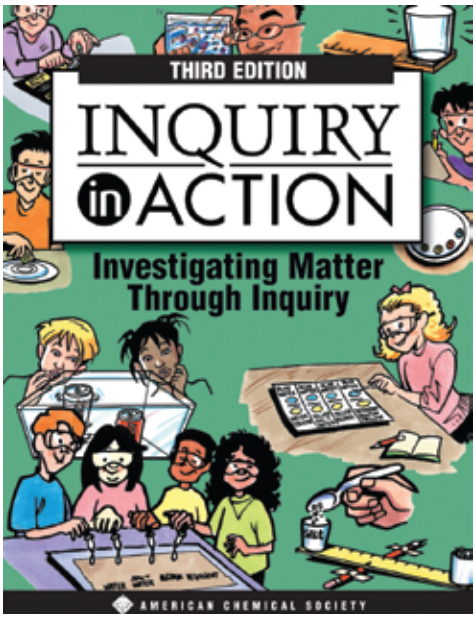


Does ACS produce materials for teachers?

The American Chemical Society produces resources specifically for teachers. Check out *www.acs.org/education* or e-mail us at *kids@acs.org* to find out more.

Science for Kids
This collection of hands-on activities, at *www.acs.org/kids*, uses common household materials and is organized by science topic to help you easily find activities that supplement your curriculum.

Inquiry in Action
Inquiry in Action is a book filled with hands-on activities, demonstrations, student activity sheets, and assessments. The activities use inexpensive household materials and address both physical science and inquiry content. The entire 480-page book can be downloaded at *www.inquiryinaction.org*. The website also includes explanations of the chemistry content along with helpful molecular model animations and a message board.



Books for Pre-K to 2
The book *Apples, Bubbles, and Crystals* features a poem and a science activity for each letter of the alphabet. *Sunlight, Skyscrapers, and Soda Pop* shows students that science is all around them as they spend a day with two cute characters and do hands-on activities with them.

The Best of WonderScience
Help your students better understand science concepts with this comprehensive collection of over 600 activities using household materials.

Kids & Chemistry
This program provides resources for chemists who volunteer to work with elementary and middle school students. But you certainly can do the activities the presenter did with your class with next year's students. Download the instructions from *www.acs.org/education*. Follow the Kids & Chemistry link to find the free pdf files for this and other Kids & Chemistry kits.

Thank you for participating in the Kids & Chemistry program!