TEACHER'S GUIDE

WHAT'S NEW, CO_2?

GET TO KNOW A CHEMICAL REACTION

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 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?

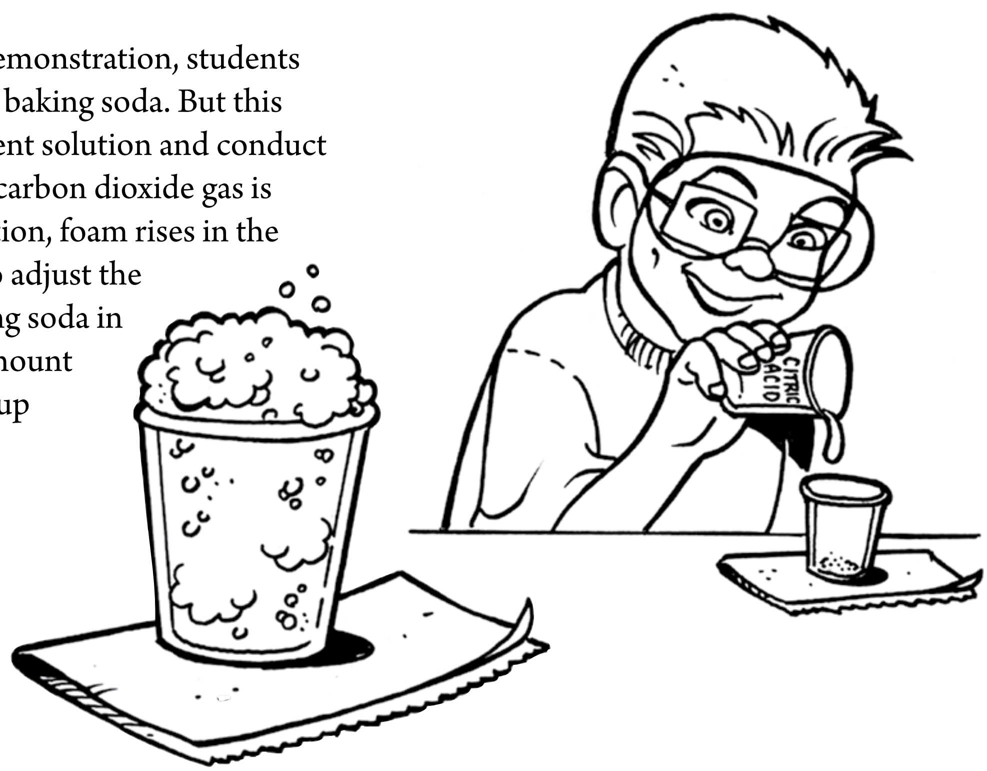
You agreed to have a guest speaker come into your classroom, and you wonder what your visiting scientist will do. Basically, the scientist will conduct an introductory demonstration and then guide students through a series of related hands-on activities. Each student will receive a Student Lab Guide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

Pop the Top

The presenter combines a small amount of water, citric acid, and baking soda in a test tube and seals the opening with a rubber stopper. Surprisingly, the rubber stopper pops out of the test tube.

Foam Dome

Like the presenter did in the demonstration, students combine water, citric acid, and baking soda. But this time they add a drop of detergent solution and conduct the reaction in a small cup. As carbon dioxide gas is produced in the chemical reaction, foam rises in the cup. Students are challenged to adjust the amount of citric acid and baking soda in order to create just the right amount of foam to completely fill the cup without spilling over.



The Invisible Blue Buster

The presenter blows into bromthymol blue indicator solution, causing it to turn green. The presenter then reveals that carbon dioxide gas from his/her breath caused the color change. Students are asked whether carbon dioxide gas from the citric acid and baking soda reaction might do the same. Students prepare an indicator solution in one cup and then combine citric acid and baking soda in another. They use an inverted cup to help trap the carbon dioxide gas that is produced in the chemical reaction. Then, as students swirl their set of cups, the invisible carbon dioxide gas falls into the small cup, turning the blue indicator solution green.

The Grand Finale

Students rupture a small bag of liquid inside both decorated and see-through self-inflating balloons. Based on their experience with the activities in this lesson, students are able to explain that carbon dioxide gas produced in the chemical reaction between citric acid and baking soda causes these balloons to inflate.

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 scientist, we hope they realize that they can do science, too.

Learning objectives

- Students will be able to explain that increasing the amount of reactants increases the amount of products in a chemical reaction.
- Students will use a beaker to measure milliliters.
- Students will recognize that carbon dioxide gas has characteristic properties.
- Students will be able to explain that in chemical reactions molecules break apart, rearrange, and join together to form different substances.

Vocabulary words

This lesson can be used to introduce or reinforce these words.

- Chemistry
- Chemical reaction
- Carbon dioxide gas
- Property

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 five 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?

Carbon dioxide gas is invisible. Name three ways you observed it in the activities you did with the presenter.

We trapped the gas inside soap bubbles, saw a blue liquid turn green when carbon dioxide gas dissolved in it, and we watched sealed balloons fill with carbon dioxide gas.

You can make carbon dioxide gas at home by combining vinegar and baking soda. What color would you expect bromthymol blue indicator to turn if you did the Invisible Blue Buster activity with vinegar and baking soda?

The bromthymol blue indicator solution will turn green or yellow.

What would you mix together if you wanted to fill a sandwich-sized zip-closing plastic bag with carbon dioxide gas?

I would mix a few scoops of baking soda, citric acid, and water (or baking soda and vinegar).

What is CO_2 an abbreviation for?

CO_2 is short for carbon dioxide gas.

What is a chemical reaction?

A chemical reaction is when chemicals break apart into their smallest parts and then rearrange themselves to become different chemicals.

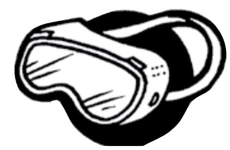
How can I help?

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.
- Provide a space where the presenter can set up the demo immediately before the presentation.
- Provide access to water. Each group of 4 students will need about half a cup of water.
- Provide safety goggles for each 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.

Are the activities safe?



The activities the presenter will do with your students have been reviewed for safety by the ACS Committee on Chemical Safety. Students must wear goggles to protect their eyes during the activities and also take care to use the chemicals only as directed by the presenter.

Citric acid and baking soda are both common household chemicals. Citric acid occurs naturally in lemons and other fruits and is added to foods like candy to give them a sour taste. Baking soda is used in cleaning, deodorizing, and baking. When citric acid and baking soda react with one another, they change chemically and form sodium ions, citric acid ions, carbon dioxide gas, and water. Carbon dioxide gas is a normal component in our air. It also makes up the bubbles in carbonated drinks and is a gas we naturally exhale. Carbon dioxide gas is safe in the quantities produced in the activities.

Students should take care with bromthymol blue indicator. Like all materials used in science activities, it should not be ingested. You will find that it is stored in a dropper bottle and is diluted with water in the activity.

The presenter has the Material Safety Data Sheets for each chemical used in this activity. These explain how to properly store and dispose of the chemicals and what to do if students ingest them.

All liquids used in this activity may be safely washed down the drain of a regular classroom or household sink. Cups may be rinsed and reused. However, they should never be used with food or drinks. They may also be placed with the regular trash.

When handled as outlined in the procedures, these activities are safe for you and your students.

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

You and your students may have some questions about the activities and the chemical reaction 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 ACS Education Division Staff at *kids@acs.org*.

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.

What is the chemical equation that describes the reaction between citric acid and baking soda?

$$3NaHCO_3 + C_6H_8O_7 \longrightarrow 3Na^{+} + C_6H_5O_7^{3-} + 3H_2O + 3CO_2$$

SODIUM BICARBONATE	CITRIC ACID	SODIUM ION	CITRIC ACID ION	WATER	CARBON DIOXIDE

In this chemical reaction, baking soda (also known to chemists as sodium bicarbonate) and citric acid are combined. In the process, several products are formed, including ions—which are atoms or molecules that have lost or gained one or more electrons, thus making them positively or negatively charged. In all the activities your students performed with the visiting scientist, the production of carbon dioxide was emphasized, but notice that water is formed also, along with the ions.

Everything on the left side of the reaction arrow is referred to as a "reactant", while everything on the right side of the arrow is called a "product". In a chemical reaction, the products are always chemically different than the reactants.

It's important to remember, however, that while the products are different than the reactants in any chemical change, nothing appears on the right side of a chemical equation that isn't on the left. The reactants are rearranged to form the products. All the same atoms are present (and in the same amounts!) on both sides of the equation. The difference is in the way the atoms in the products are connected to each other. They are rearranged to make new molecules and ions, which are unlike those in the reactants.

This is what distinguishes a chemical change from a physical change. In a physical change, there is no change in chemical composition. Consider, for example, ice melting.

$$H_2O_{(solid)} \longrightarrow H_2O_{(liquid)}$$

Notice that the same molecule (water) is present on both sides of the equation. Because nothing chemically new is formed, we can confirm that this process is a physical change.

How do I know I have the same number and kind of atoms on both sides of the equation?

$$3NaHCO_3 + C_6H_8O_7 \longrightarrow 3Na^+ + C_6H_5O_7^{3-} + 3H_2O + 3CO_2$$

SODIUM BICARBONATE	CITRIC ACID	SODIUM ION	CITRIC ACID ION	WATER	CARBON DIOXIDE

In chemistry, there is a rule called the Law of Conservation of Matter, which states that matter cannot be created or destroyed. This means that atoms in the reactants of a chemical equation must always be represented in the products of a chemical equation. The atoms that make up the reactants (or "matter") cannot be "destroyed"; they can only be rearranged into other things. Likewise, atoms or molecules can't appear in the products if they are not represented in the reactants. So, matter can't be "created" or appear out of nowhere. The atoms and molecules represented in the products must always come from somewhere, and that somewhere is the reactants.

So, how can you be sure you have the same number and type of atom in both the reactants and the products? You can do this in 5 easy steps:

STEP 1: Ignoring numbers for a moment, confirm that you have the same kind of atoms on both sides of the equation.

Knowing chemical symbols is helpful, but actually not necessary. If you see "Na" (which is the chemical symbol for sodium) on the left side of the equation, simply make sure you see "Na" on the other side as well. Repeat this for all the different kinds of atoms (or different abbreviations) you see. For this step, don't worry about numbers.

STEP 2: Begin making a count of how many atoms of a particular element you have on both sides of the equation. Look at each molecule or ion, and if it has a subscripted number following it, then count the atom that many times. If an atom has no subscripts, count it once.

For example, in citric acid (which has the chemical formula $C_6H_8O_7$) we would record 6 C (or carbon atoms) 8 H (or hydrogen atoms) and 7 O (or oxygen atoms).

STEP 3: If a molecule or ion has a number in front of it (called a chemical coefficient), then multiply that number by the number of atoms you counted in Step 2.

If you were considering $3NaHCO_3$ (which is sodium bicarbonate), then in Step 2 you would have counted 1 Na, 1 H, 1 C, and 3 O to take into account the subscripts. In this step, however, we need to multiply each of those values by 3 to incorporate the chemical coefficient. For sodium bicarbonate, this would give us a final count of 3 Na atoms, 3 H atoms, 3 C atoms, and 9 O atoms.

STEP 4: Starting with the reactants, add together the numbers you've tallied for the same kinds of atoms. Make a separate tally for the products, adding together the numbers you've calculated for the same kind of atom.

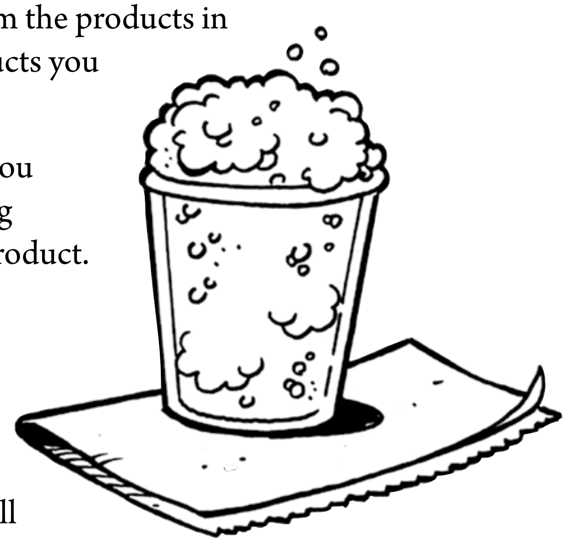
STEP 5: Confirm that you have the same number of atoms on both sides of the equation.

If you follow this process, you'll find that you can confirm that there are the same number and kinds of atoms on both sides of any correctly expressed chemical equation. This is what is meant if you've ever heard anyone refer to a "balanced equation". After each molecule or ion has been written correctly, the chemical coefficients must be adjusted so that the chemical equation shows that there are equal amounts of the same kind of atoms on both sides of the equation.

If you add more reactants, will you always get more products?

In general, yes. Because the reactants are always rearranged to form the products in any chemical change, the more reactants you add, the more products you will get.

If, however, you add one reactant but none of the other(s), then you might not get more products. Consider, for example, the following chemical equation where A and B are the reactants and C is the product.



$$A + B \longrightarrow C$$

Assuming that you have just enough A to react with all the B, once you have used up both of the reactants, adding only one of the reactants will not generate any more products because it will have nothing to react with.

But what if the reactants are not exactly equivalent to one another and one reactant is used up before the other? Chemists would call the reactant that is used up a limiting reactant.

Let's return to our previous example to see how this works:

$$A + B \longrightarrow C$$

If A were the limiting reactant, then it would dictate the amount of products that were formed. After all of A was used up, you wouldn't get any more products no matter how much B you added. You would have to add more A to get more products. This is what is meant by a limiting reactant, the reactant that dictates the amount of product(s) that can be formed.

A reactant may be limiting based on the characteristic way that the molecules interact in a given chemical reaction. Before chemists run a reaction, they study the equation carefully, and decide how much of each reactant will be needed to form the amount of products they want.

Why does bromthymol blue indicator change color?

In chemistry, indicators are complex molecules that have the unique property of changing color in the presence of certain chemicals classified as acids or bases.

In the activity *The Invisible Blue Buster*, carbon dioxide gas is produced when citric acid and baking soda react with one another. As students swirl the stack of cups, CO_2 gas dissolves in the solution containing the indicator.

When carbon dioxide dissolves in water, it forms an acid called carbonic acid. It is the carbonic acid that reacts with the indicator molecule (bromthymol blue) and causes the indicator to become an ion, which in turn causes it to change color. In this case, the indicator solution turned green when it reacted with the carbonic acid.

Later in the activity, however, the indicator solution returned to its blue color. How did that happen?

Students may have noticed the color return to blue. This is because the carbon dioxide gas that dissolved in the water is not very soluble. So when the cups are left alone and no more carbon dioxide is being formed in the baking soda-citric acid reaction, the carbon dioxide gas comes out of the solution and returns to the air. You may notice this if you leave a carbonated drink out for a few hours. The drink becomes flat because carbon dioxide gas leaves the solution. The green indicator solution returns to blue when enough of the carbon dioxide gas that was dissolved in it comes out of the solution and reduces the amount of carbonic acid in the solution.

What is in the self-inflating balloon?

The self-inflating balloon takes advantage of the same chemical change we discussed earlier—the reaction of citric acid with baking soda to produce carbon dioxide gas and other products.

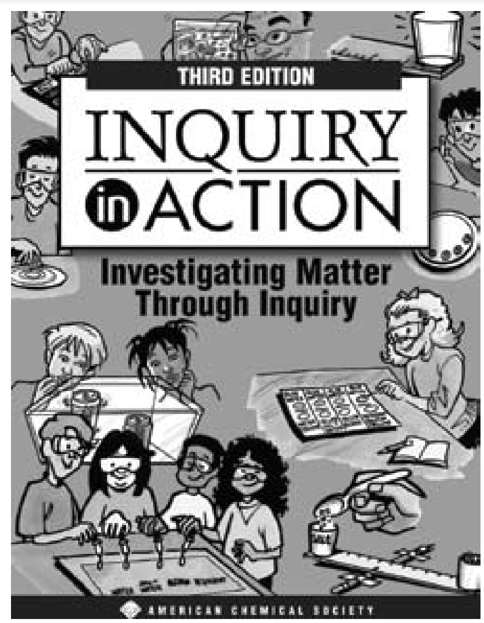
Before the chemical reaction takes place, you have baking soda (which is a solid) and a small amount of citric acid solution (which is a liquid). After the citric acid solution and baking soda react, carbon dioxide gas is formed, along with other products. Because the molecules in a gas are much further apart than they are in a solid or a liquid, the gas takes up much more space than the reactants did. The balloon inflates as carbon dioxide gas is produced.

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 scientists 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!