**Lesson 5 - Dissolving Liquids and Gases**

**Storyline Summary:**

Students now know why water is a good dissolver of ionic and polar solids. An important factor in ocean acidification is water’s ability to dissolve a gas - carbon dioxide.

Remind students that they know what happens when a solid like salt or sugar interacts with water. Ask students if they think it is important to know how water interacts with carbon dioxide. Ask students if they think that water can dissolve substances that are not solids, such as a liquids or a gases.

At the end of the lesson, students will relate the dissolved carbon dioxide from the experiment to the dissolved carbon dioxide in the ocean and begin a new level of understanding of ocean acidification.

**Note:** This lesson includes two parts. Depending on the length of time you spend on each component, this lesson will probably take at least two class periods.

**What Students Do**

**Part 1** - Students investigate whether different liquids dissolve in water and then explore on the molecular level why some do and others do not.

**Part 2** – Students explore carbon dioxide that has been dissolved in water (club soda). Students then analyze carbon dioxide on the molecular level to see why it dissolves in water.

**What Students Learn**

* Water can dissolve polar liquids but cannot dissolve non-polar liquids.
* Water can dissolve carbon dioxide gas.

**Materials & Preparation**

**Part 1 – Can Liquids Dissolve in Water?**

***Materials for the Demonstrations***

* + Clear plastic cup
  + Water
  + Food coloring
  + Straw or popsicle stick
  + Isopropyl alcohol (70% or higher)
  + 2 identical 100-mL graduated cylinders

***Materials for Each Group***

* + Water
  + Mineral oil
  + Isopropyl alcohol (70% or higher)
  + Corn syrup
  + 3 clear plastic cups
  + 5 small cups
  + Permanent marker or masking tape and a pen for labeling cups
  + 3 straws or popsicle sticks (for stirring)
  + Laminated index card or card covered with wax paper
  + Blue water
  + Yellow isopropyl alcohol (70% or higher)
  + 2 droppers
  + Toothpick or popsicle stick

**Part 2 – Can Gases Dissolve in Water?**

***Materials for the Demonstration***

Unopened 1-liter bottle of club soda, which will also be used in the activity.

***Materials for each group***

* Club soda
* 3 clear plastic cups
* 1 M&M
* Pipe cleaner

**Part 1—Can Liquids Dissolve in Water?**

(From Middle School Chemistry – Chapter 5, Lesson 7)

***Key Concepts***

* Liquids have characteristic properties based on the molecules they are made of.
* The properties of liquids depend on the attractions the molecules of the liquid have for each other and for other substances.
* Liquids can dissolve certain other liquids, depending on the attractions between the molecules of both liquids.
* Polar liquids, like water, dissolve other liquids which are polar or somewhat polar.
* Polar liquids, like water, do not dissolve nonpolar liquids like oil.

***Summary***

Students will place isopropyl alcohol, mineral oil, and corn syrup in water to see if any of these liquids dissolve in water. Students will extend their understanding and definition of “dissolving” and see that certain, but not all, liquids can dissolve in water.

***Objective***

Students will identify and control variables to help design a solubility test for different liquids in water. Students will be able to explain, on the molecular level, why certain liquids, but not all, will dissolve in water. They will also be able to explain that the solubility of a liquid is a characteristic property of that liquid.

***Evaluation***

The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

***Safety***

Be sure you and the students wear properly fitting goggles. Isopropyl alcohol is flammable. Keep it away from flames or spark sources. Read and follow all warnings on the label. Isopropyl alcohol and mineral oil should be disposed of according to local regulations. Have students wash hands after the activity.

***Materials for the Demonstrations***

* + Clear plastic cup
  + Water
  + Food coloring
  + Straw or popsicle stick
  + Isopropyl alcohol (70% or higher)
  + 2 identical 100-mL graduated cylinders

***Materials for Each Group***

* + Water
  + Mineral oil
  + Isopropyl alcohol (70% or higher)
  + Corn syrup
  + 3 clear plastic cups
  + 5 small cups
  + Permanent marker or masking tape and a pen for labeling cups
  + 3 straws or popsicle sticks (for stirring)
  + Laminated index card or card covered with wax paper
  + Blue water
  + Yellow isopropyl alcohol (70% or higher)
  + 2 droppers
  + Toothpick or popsicle stick

**ENGAGE**

Have a class discussion about what makes the water molecule such a good dissolver of ionic and polar solids. Let students know that the next two lessons will explore whether liquids and gases can dissolve in water and what this might have to do with ocean acidification.

1. **Do a demonstration to introduce the idea that solids aren’t the only substances that can dissolve—liquids can also dissolve in liquids.**

Ask students to make a prediction:

* + **Solids, like salt or sugar, can dissolve in water. Do you think that liquids can dissolve in water?**

**Question to Investigate**

Does liquid food coloring dissolve in water?

**Materials for the Demonstration**

* Clear plastic cup
* Water
* Food coloring
* Straw or popsicle stick

**A cartoon of a person pouring liquid into a glass

Description automatically generatedProcedure**

1. Hold up a clear plastic cup or other clear container of room temperature water. Add 1 or 2 drops of food coloring and allow the coloring to drift and spread in the water a bit.
2. Stir with a straw or popsicle stick.

**Expected results**

The food coloring will drift and slowly mix throughout the water. When stirred, the water will be evenly colored throughout.

Ask students:

* + **Does food coloring dissolve in water?**

Yes.

* + **How do you know when a solute, like food coloring, has dissolved in a solvent, like water?**

As part of the answer to this question, review the definition of dissolving using the food coloring and water as an example. The solute (food coloring) is dissolved in the solvent (water) when the molecules of the solute are so thoroughly intermixed within the molecules of the solvent that they do not settle out or separate.

* + **This demonstration showed that food coloring can dissolve in water. Describe an experiment you could do to compare how isopropyl alcohol, mineral oil, and corn syrup dissolve in water.**

Students should agree that they will need three cups filled with the same amount of water. They should also realize that it’s important that the same temperature water is used in each cup and that the temperature of each of the three liquids being tested is the same, too.

**Give each student an activity sheet for Part 1.**

Students will describe their experimental design, record their observations, and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

**EXPLORE**

1. **Have students conduct an activity to see how well isopropyl alcohol, mineral oil, and corn syrup dissolve in water.**

**Question to Investigate**

Do isopropyl alcohol, mineral oil, and corn syrup dissolve in water?

**Teacher Preparation for Each Group**

* + Label 3 small cups Alcohol, Oil, and Syrup for each group.
  + Pour about 1 tablespoon of isopropyl alcohol, mineral oil, and corn syrup into their labeled cups.

**Materials for Each Group**

* + Water
  + Isopropyl alcohol (70% or higher) in small, labeled cup
  + Mineral oil in small, labeled cup
  + Corn syrup in small, labeled cup
  + 3 clear plastic cups
  + Permanent marker or masking tape and a pen for labeling cups
  + 3 straws or popsicle sticks for stirring

**Procedure**

1. A diagram of different types of alcohol

   Description automatically generatedLabel 3 clear plastic cups *Alcohol*, *Oil*, and *Syrup*.
2. Pour water into all three labeled cups until each is about half-full.
3. While looking at the water from the side, slowly pour the alcohol into its labeled cup.
4. Without stirring, watch to see if the alcohol dissolves in the water on its own. Record your observations in the chart.
5. After waiting about 10 seconds, stir to see if the alcohol dissolves. Record your observations.
6. Repeat Steps 2–5 for oil and corn syrup.

**Expected Results**

* The alcohol looks kind of gray and swirly as it goes into the water. The alcohol tends to stay on the surface of the water because it is less dense than water. It does not seem to dissolve immediately but dissolves when stirred.
* The oil stays on the surface of the water because it is less dense than water, but it does not appear to mix much at all with the water. When stirred, the oil breaks apart a bit and then forms a layer again on the surface of the water. The oil does not dissolve.
* The corn syrup sinks in the water because it is more dense than water. It seems to stay there without much initial dissolving. After stirring, the corn syrup dissolves into the water and the solution turns clear.

1. **Discuss student observations.**

Have students describe what the alcohol, oil, and corn syrup looked like in the water and whether or not they dissolved.

Ask students:

* + **Can a liquid dissolve another liquid?**

Students should realize that some liquids, but not all, can dissolve in water.

* + **Based on your observations of the way isopropyl alcohol, mineral oil, and corn syrup dissolve in water, would you say that solubility is a characteristic property of a liquid? Why?**

Yes. Solubility is a characteristic property because each liquid interacted with the water differently.

**EXPLAIN**

1. **Discuss how the molecular structure of isopropyl alcohol, mineral oil, and glucose (in corn syrup) determines whether or not each liquid will dissolve in water.**

**Project the image *Isopropyl Alcohol*.**

[www.acs.org/middleschoolchemistry/simulations/chapter5/lesson7.html](http://www.acs.org/middleschoolchemistry/simulations/chapter5/lesson7.html)

Point out the bond between oxygen and hydrogen in one area of the alcohol molecule.

A molecule model with a red ball

Description automatically generatedAsk students:

* + **What do you already know about the O–H bond?**

It is polar. The oxygen has a slight negative charge, and the hydrogen has a slight positive charge.

* + **How do you think this polar part of the molecule affects the solubility of alcohol?**

Even though alcohol has one polar area (O–H bond) and a larger nonpolar area (C–H bonds), polar water molecules and the polar area on alcohol molecules are attracted to each other, causing alcohol to dissolve in water.

**Project the image *Mineral Oil*.**

[www.acs.org/middleschoolchemistry/simulations/chapter5/lesson7.html](http://www.acs.org/middleschoolchemistry/simulations/chapter5/lesson7.html)

Remind students that the carbon (darker gray) and hydrogen atoms share electrons rather evenly. This means that the bonds in mineral oil are nonpolar, so water molecules and mineral oil molecules are not attracted to each other.

A molecule model of a molecule

Description automatically generated with medium confidence

* + **Why do you think the oil does not dissolve in water?**

The mineral oil molecule is made of carbon atoms bonded to hydrogen atoms. The bond between these atoms creates very little polarity. Water is not very attracted to the oil and so does not dissolve it.

* + **In some salad dressings a layer of oil, like canola or olive oil, floats on top of a layer of vinegar, which is mostly water. If you shake a bottle of this kind of salad dressing, the liquids will temporarily combine. But the oil and vinegar do not dissolve in one another because eventually the two liquids will separate out again. Knowing what you do about molecules and dissolving, why doesn’t the oil in these salad dressings dissolve in vinegar?**

Oil is nonpolar and is not attracted to the water in vinegar, so it will not dissolve.

***Note****: Students should understand that polar molecules, like water, attract other polar molecules but they do not attract nonpolar molecules, like oil. At the middle school level, this understanding is sufficient but could lead to the impression that nonpolar molecules have no attractions at all. This is not true.*

**Project the image *Glucose*.**

A close-up of a molecule

Description automatically generated[www.acs.org/middleschoolchemistry/simulations/chapter5/lesson7.html](http://www.acs.org/middleschoolchemistry/simulations/chapter5/lesson7.html)

Explain to students that corn syrup is mostly glucose but also

contains a similar sugar, fructose. Show students the glucose

molecule and point out the bonds between oxygen and

hydrogen.

***Note****: Students may have heard of “high fructose corn syrup” used in carbonated beverages and some prepared foods. This type of corn syrup contains a higher percentage of fructose than the corn syrup commonly sold in the baking aisle at grocery stores.*

Ask students:

* + **Why do you think glucose molecules dissolve well in water?**

Glucose has many areas where oxygen is bonded to hydrogen. These O–H bonds are polar. Polar water molecules and the polar areas of glucose molecules are attracted to each other, causing the corn syrup to dissolve.

* + **Some people with diabetes may accidentally let their sugar level get too low. There are glucose tablets to help them with this problem. When a person eats one, do you think it will act quickly to increase his/her blood sugar level? Why or why not?**

Yes. The tablet will act quickly because the water in a person’s saliva and stomach will easily dissolve the glucose.

**EXTEND**

1. **Look more closely at the way water and alcohol mix.**

Water and alcohol do some pretty interesting things when they mix. Tell students that you colored water blue and isopropyl alcohol yellow so that they can see the mixing better.

**Materials for Each Group**

* Water (colored blue)
* Isopropyl alcohol (70% or higher and colored yellow)
* Laminated index card or card covered with wax paper
* 2 droppers
* Toothpick or popsicle stick

**Procedure**

1. A cartoon of a child drawing on a piece of paper

   Description automatically generatedUse a dropper to place about 5 drops of blue water together to make 1 large drop on your index card.
2. Use another dropper to make a similar large drop of yellow alcohol close to, but not touching, the blue drop.
3. Use a toothpick to drag the blue water toward the yellow alcohol until they touch. As soon as the drops touch, lift the toothpick away and do not stir.
4. Watch closely as the alcohol and water mix.

**Expected Results**

The alcohol and water will kind of “shake” or “jiggle” right at the area where they are mixing.

1. **Discuss student observations.**

Ask students:

* + **What do you observe when the drop of alcohol and drop of water combine?**

Students will notice that the alcohol and water seem to shake at the area where they are mixing. As the liquids mix, the yellow and blue colors combine to make green.

Tell students that the mixing of alcohol and water is not completely understood on the molecular level. One reason for the shaky appearance might be that alcohol is less dense than water so as it mixes with water, the density of the overall liquid changes. Alcohol (which alone floats on water) sinks as it mixes. Maybe lots of little “sinkings” make the mixing look shaky. It could be that the changing density causes light to refract differently to cause the shaky look. Maybe the alcohol interferes with water’s surface tension and causes a shaky look on the surface. It is also true that when water and alcohol are mixed, the solution gets warmer. Maybe the heat increases molecular motion at the surface, which somehow contributes to the shaky look.

1. **Do a demonstration to show that when water and alcohol combine, the volume of the resulting solution is less than expected.**

Tell students that the characteristic way water and alcohol interact with each other causes another interesting phenomenon.

**A person pouring liquid into a cylinder

Description automatically generatedMaterials for the Demonstration**

* Isopropyl alcohol (90% or higher)
* Water
* 2 identical 100-mL graduated cylinders

**Procedure**

1. Measure 50 mL of isopropyl alcohol and pour it into a 100-mL graduated cylinder.
2. Measure 50 mL of water and add it to the alcohol in the 100-mL graduated cylinder.

**Expected Results**

The total volume of the liquid will be about 97 or 98 mL. This is surprising because 50 mL of water + 50 mL of water equals 100 mL.

Explain to students that when the water and alcohol molecules interact, they rearrange and actually take up less room than if you add up their individual volumes.

***Note****: You may have heard the explanation that the water molecules are in the spaces between the alcohol molecules, or the alcohol molecules are in the spaces between the water molecules. This is too passive an explanation. It’s not like marbles falling in the spaces between golf balls. There is an active rearranging of molecules that are attracted to one another that results in the final volume. In fact, adding any two liquids that can dissolve in one another will result in a volume that’s different from the sum of the separate liquid volumes. Alcohol and water are often used as an example of this phenomenon because they are easy to get and show a particularly big difference.*

**Part 2—Can Gases Dissolve in Water?**

(From Middle School Chemistry – Chapter 5, Lesson 8)

***Key Concepts***

* Gases can dissolve in water.
* The dissolving of a gas in water depends on the interaction between the molecules of the gas and the water molecules.

***Summary***

Students will observe the dissolved carbon dioxide (CO2) in a bottle of club soda. They will help design an experiment to compare the amount of CO2 that stays in cold club soda compared to warmer club soda.

***Objective***

Students will be able to explain, on the molecular level, how a gas dissolves in water. They will also be able to explain why the gas comes out of solution faster in warm water than in cold water.

***Evaluation***

The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

***Safety***

Be sure you and the students wear properly fitting goggles. Warn students not to eat the M&M. Use caution when handling hot water.

***Materials for the Demonstration***

Unopened 1-liter bottle of club soda, which will also be used in the activity.

***Materials for each group***

* Club soda
* 3 clear plastic cups
* 1 M&M
* Pipe cleaner

# ENGAGE

## Show students the bubbles that appear when a new bottle of soda is opened.

Ask students:

## Do you think that gases can dissolve in water?

The idea of a gas dissolving may seem strange to students, but this demonstration will help them realize that gases can dissolve in water.

## Materials

Unopened 1-liter bottle of club soda

## Teacher Preparation

Remove the label from a 1-liter bottle of carbonated water.

Ask students:

## How is a bottle of carbonated water different from a bottle of regular water?

Students will probably say that carbonated water has bubbles.

## A hand opening a bottle of water Description automatically generatedDo you see any bubbles in the carbonated water?

They shouldn’t see any, yet.

## Procedure

1. Very slowly unscrew the bottle cap.
2. Wait a few seconds to allow students to observe the bubbles.
3. Tighten the cap on the bottle.

## Expected Results

When the cap is loosened, many bubbles will appear throughout the soda and rise through the water to the surface, where they pop. When the cap is tightened, fewer bubbles will form.

Ask students:

* + **What did you observe when I opened and then closed the bottle of soda?**

Bubbles appeared only when the bottle was opened. The bubbles stopped forming when the bottle cap was tightened.

## What is the gas that makes these bubbles?

Carbon dioxide (CO2)

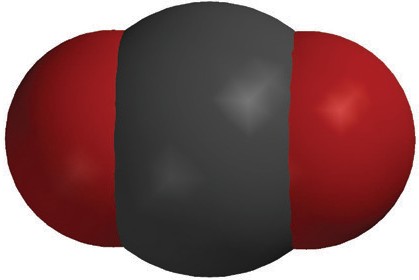
## Where was the CO2 before the bottle was opened?

The carbon dioxide was dissolved in the water.

## Explain that carbonated water is made of carbon dioxide gas dissolved in water.

Tell students that at a soda factory, carbon dioxide gas is added to cold water under high pressure to make carbonated water. The pressure forces more gas to dissolve than ordinarily would.

**Project the image *CO2 Molecule*.** [www.acs.org/middleschoolchemistry/simulations/chapter5/lesson8.html](http://www.acs.org/middleschoolchemistry/simulations/chapter5/lesson8.html)



**+**

**\_**

**\_**

**+**

Point out that a molecule of carbon dioxide has a slight negative charge near the oxygen and a slight positive charge near the carbon. CO2 is soluble because water molecules are attracted to these polar areas. The bond between carbon and oxygen is not as polar as the bond between hydrogen and oxygen, but it is polar enough that carbon dioxide can dissolve in water.

**Project the image *CO2 Dissolved in Water*.**

[www.acs.org/middleschoolchemistry/simulations/chapter5/lesson8.html](http://www.acs.org/middleschoolchemistry/simulations/chapter5/lesson8.html)

A group of red and white spheres

Description automatically generatedExplain that in carbonated water, molecules of carbon dioxide are thoroughly mixed and dissolved in water. This is similar to molecules of sucrose, sodium and chloride ions from salt, or the molecules of isopropyl alcohol, which students dissolved in water in previous activities in this chapter. Point out that when dissolved, the molecules of CO2 are not like tiny little bubbles of gas mixed in the water. Instead, single molecules of CO2 are surrounded by water molecules.

Let students know that although the CO2 dissolves, the molecules are not attracted as strongly by the water molecules as substances like salt or sugar. Due to these weaker attractions, the molecules of CO2 come out of solution relatively easily. This is why soda becomes flat if it is left uncapped for too long.

## Give each student an activity sheet for Part 2.

Students will describe their experimental design, record their observations, and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

# EXPLORE

## Have students add objects to carbonated water to see if they can get carbon dioxide gas to come out of solution.

Ask students:

## Aside from shaking soda, or leaving it uncovered, are there other ways to make carbon dioxide gas come out of carbonated water?

Tell students that objects can be placed in the soda that can cause the carbon dioxide to bubble out of the soda.

## Question to Investigate

How can you make carbon dioxide gas come out of solution?

## Materials for Each Group

* Club soda in clear plastic cup
* 2 clear plastic cups
* M&M
* Pipe cleaner

## Teacher Preparation

A close-up of a logo

Description automatically generatedImmediately before the activity, use the bottle of carbonated water from the demonstration to pour about ¾ cup of carbonated water into a clear plastic cup for each group.

## Procedure

1. Evenly divide the club soda among the 3 clear plastic cups. Push two of these cups aside to use later.
2. Place a pipe cleaner in the soda and observe.
3. Place an M&M in the soda and observe.

## Expected Results

Bubbles form on the pipe cleaner. Bubbles also form on the M&M and rise to the surface.

Ask students:

## Where did the gas bubbles that you observed come from?

There were molecules of carbon dioxide dissolved in the water.

## Where did the carbon dioxide gas that was dissolved in the water go?

The carbon dioxide bubbles rose to the surface and popped, releasing carbon dioxide into the air.

Explain that the objects placed in the soda had tiny bumpy areas where the carbon dioxide molecules collected. When enough of the molecules were together in a certain area, they became a bubble. When this bubble, which is less dense than the water around it, became big enough, it floated to the surface and popped, releasing carbon dioxide gas into the air.

Ask students:

## While drinking soda pop with a straw, you may have noticed that bubbles form on the outside of the straw. Now that you have done this activity, why do you think these bubbles form on the straw?

Even though the straw looks smooth, it also has tiny bumpy areas, where molecules of carbon dioxide collect. When enough of them collect in an area, they become a bubble of carbon dioxide gas.

# EXTEND

## Have students observe and explain what happens when Mentos candies are dropped in a bottle of Diet Coke.

Ask students:

## Has anyone ever seen the Diet Coke and Mentos demonstration?

If students have seen it, ask them to describe the activity. An entire packet of Mentos mints is dropped into a 2-liter bottle of carbonated beverage, usually Diet Coke. The soda pop shoots out of the bottle with a lot of force and goes high into the air.

**Project the video *Mentos and Diet Coke Demo*.**

[www.acs.org/middleschoolchemistry/simulations/chapter5/lesson8.html](http://www.acs.org/middleschoolchemistry/simulations/chapter5/lesson8.html)

If you are willing to do this demonstration, it must be done outside.

Remind students that the pipe cleaner and the M&M they added to carbonated water caused CO2 to escape from the solution. Mentos and Diet Coke work in the same way. On the microscopic level, the surface of the mint is rough with many tiny bumps and pits. When the candy is added to the soda pop, carbon dioxide molecules adhere to these tiny spots called *nucleation points*. More carbon dioxide molecules collect in these areas, forming bubbles. The bubbles of carbon dioxide form quickly and grow in all directions but can only escape from the top of the bottle. Because many bubbles are forming and rising to the surface all at once, they bring a large amount of the soda pop with them as they come out of the soda, creating a “fountain” of soda.

1. **Lead a discussion about how the work students have done so far relates to the understanding of ocean acidification.**

Remind students of the demonstrations and activities they did back in Lesson 1 at the beginning of the unit. Have them look back at their notes and ask them what they have learned so far that relates to understanding the process of how carbon dioxide might be involved in the process of ocean acidification.

At this point, students should agree that because of the characteristics of the water molecule and the carbon dioxide molecule, carbon dioxide gas can dissolve in water. Students do not yet have enough information to know how the dissolved carbon dioxide and water interact to make water more acidic.

But even before the class gets to that, let students know that there’s something about dissolving that they still need to explore: The question of whether the temperature of water has an effect on the amount of substance that will dissolve.