**Lesson 3 - Covalent and Ionic Bonding**

**Storyline**

Now that students have a basic understanding of protons, neutrons, electrons, and the energy levels in atoms, it is time to look at how atoms combine to make substances like water (H2O) and salt (NaCl) – the two main components of ocean water.

Have a class discussion about how water and salt are the two main ingredients in ocean water and how a better understanding of how these substances are formed may help to better understand their characteristics. Let students know that a deeper understanding of the characteristics of water in particular will be helpful to see how water and carbon dioxide interact.

**Note:** This lesson has two parts: Depending on the amount of time you spend on class discussion, the lesson should take about two to three class periods.

**What Students Do**

**Part 1** –Students learn how the covalent bonds form in the water molecule and do an experiment to produce oxygen and hydrogen gas from a sample of water.

**Part 2** - Students look closely at the cubic shape of salt granules and relate the ionic bonding between sodium and chloride ions to the cubic structure.

**What Students Learn**

* The number of electrons on the outer energy level affects covalent bonding between atoms and how a water molecule is formed.
* The number of electrons on the outer energy level affects how ions are formed and the ionic bonding of a salt crystal.

**Materials & Preparation**

**Part 1 - Energy Levels, Electrons, and Covalent Bonding**

**Materials for Each Group**

* 9-volt battery
* 2 wires with alligator clips on both ends
* 2 pencils sharpened at both ends
* Water
* Clear plastic cup
* Epsom Salt (magnesium sulfate)
* Tape

**Part 2 - Energy Levels, Electrons, and Ionic Bonding**

**Materials for Each Group**

* Black paper
* Salt
* Cup with salt from evaporated saltwater
* Magnifier
* Permanent marker

**Part 1: Energy Levels, Electrons, and Covalent Bonding**

(From Middle School Chemistry - Chapter 4, Lesson 4)

***Key Concepts***

* The electrons on the outermost energy level of the atom are called valence electrons.
* The valence electrons are involved in bonding one atom to another.
* The attraction of each atom’s nucleus for the valence electrons of the other atom pulls the atoms together.
* As the attractions bring the atoms together, electrons from each atom are attracted to the nucleus of both atoms, which “share” the electrons.
* The sharing of electrons between atoms is called a covalent bond, which holds the atoms together as a molecule.
* A covalent bond happens if the attractions are strong enough in both atoms and if each atom has room for an electron in its outer energy level.
* Atoms will covalently bond until their outer energy level is full.
* Atoms covalently bonded as a molecule are more stable than as separate atoms.

***Summary***

Students will look at animations and refer to the energy level models they have been using to make drawings of the process of covalent bonding. Students will consider why atoms bond to form molecules like H2 (hydrogen), H2O (water), O2 (oxygen), CH4 (methane), and CO2 (carbon dioxide).

***Objective***

Students will be able to explain that attraction between the protons and electrons of two atoms cause them to bond. Students will be able to draw a model of the covalent bonds between the atoms in H2 (hydrogen), H2O (water), O2 (oxygen), CH4 (methane), and CO2 (carbon dioxide).

***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.

***Safety***

Be sure you and the students wear properly fitting goggles.

***About this Lesson***

This lesson will probably take more than one class period.

***Materials for Each Group***

* 9-volt battery
* 2 wires with alligator clips on both ends
* 2 pencils sharpened at both ends
* Water
* Clear plastic cup
* Epsom Salt (magnesium sulfate)
* Tape

**ENGAGE**

1. **Show an animation to introduce the process of covalent bonding.**

Introduce the question students will investigate in this lesson:

* + If atoms have an equal number of protons and electrons, why do atoms bond to other atoms? Why don’t they just stay separate?

Begin to answer this question by using hydrogen as an example.

**Project the animation *Covalent bond in hydrogen*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)

Make sure students see that each hydrogen atom has 1 proton and 1 electron. Remind students that the electron and its own proton are attracted to each other. Explain that if the atoms get close enough to each other, the electron from each hydrogen atom feels the attraction from the proton of the other hydrogen atom (shown by the double-headed arrow).

Read more about bonding in *Teacher Background.*

Point out to students that the attractions are not strong enough to pull the electron completely away from its own proton. But the attractions are strong enough to pull the two atoms close enough together so that the electrons feel the attraction from both protons and are shared by both atoms.

At the end of the animation, explain that the individual hydrogen atoms have now bonded to become the molecule H2. This type of bond is called a *covalent* bond. In a covalent bond, electrons from each atom are attracted or “shared” by both atoms.

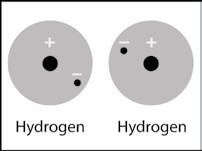
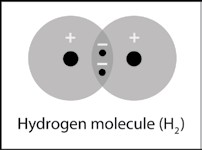
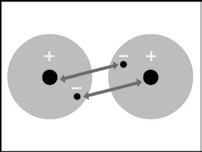
**EXPLAIN**

1. **Discuss the conditions needed for covalent bonding and the stable molecule that is formed.**

**Project the image *Covalent bond in hydrogen.***

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)

***Note****: This model of covalent bonding for the hydrogen molecule (H2) starts with 2 individual hydrogen atoms. In reality, hydrogen atoms are never separate to start with. They are always bonded with something else. To simplify the process, this model does not show the hydrogen atoms breaking their bonds from other atoms. It only focuses on the process of forming covalent bonds between two hydrogen atoms.*



Two hydrogen atoms are near each other.

When two hydrogen atoms get close enough to each other, their electrons are attracted to the protons in the other atom.

Tell students that there are two main reasons why two hydrogen atoms bond together to make one hydrogen molecule:

Because there is both a strong enough attraction between atoms and room in the outer energy level of both atoms, the atoms share electrons. This is a covalent bond.

* There needs to be a strong enough attraction between the electrons of each atom for the protons of the other atom.
* There needs to be room in the outer energy level of both atoms.

Once bonded, the hydrogen molecule is more stable than the individual hydrogen atoms. Explain to students that by being part of a covalent bond, the electron from each hydrogen atom gets to be near two protons instead of only the one proton it started with. Since the electrons are closer to more protons, the molecule of two bonded hydrogen atoms is more stable than the two individual unbonded hydrogen atoms.

This is why it is very rare to find a hydrogen atom that is not bonded to other atoms. Hydrogen atoms bond with other hydrogen atoms to make hydrogen gas (H2). Or they can bond with other atoms like oxygen to make water (H2O) or carbon to make methane (CH4) or many other atoms.

**3. Show students that when two hydrogen atoms bond together, the outer energy level becomes full.**

Have students look at their *Periodic table of energy levels for elements 1–20* distributed in lesson 2.

Explain that the two electrons in the hydrogen molecule (H2) can be thought of as

“belonging” to each atom. This means that each hydrogen atom now has two electrons in its first energy level. The first energy level in the outer energy level for hydrogen and can only accommodate or “hold” two electrons. Atoms will continue to covalently bond until their outer energy levels are full. At this point, additional atoms will not covalently bond to the atoms in the H2 molecule.

**4. Have students describe covalent bonding in a hydrogen molecule on their activity sheet and then review their answers.**

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

Have students write a short caption under each picture to describe the process of covalent bonding and answer the first three questions. The rest of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions.

Ask students:

* + **What did you write for the second and third pictures of covalent bonding?**

Center drawing: When two hydrogen atoms come close enough, their electrons are attracted to the proton of the other atom.

Last drawing: This brings the atoms close enough together that they share electrons.

* + **What are two conditions atoms must have in order to form covalent bonds with one another?**

There is a strong enough attraction between atoms and there is room for electrons in the outer energy level of both atoms.

* + **Why is a hydrogen molecule (H2) more stable than two individual hydrogen atoms?**

In the hydrogen molecule, the electrons from each atom are able to be near two protons instead of only the one proton it started with. Whenever negative electrons are near additional positive protons, the arrangement is more stable.

* + **Why doesn’t a third hydrogen atom join the H2 molecule to make H3?**

When two hydrogen atoms share their electrons with each other, their outer energy levels are full.

You could explain to students that when the outer energy levels are full, sharing electrons with another atom would not happen for two main reasons:

1. An electron from a new atom would have to join an atom in the H2 molecule on the next energy level, further from the nucleus where it would not feel a strong enough attraction.
2. An electron from an atom already in the H2 molecule and close to the nucleus would need to move further away to share with the new atom.

Both possibilities would make the molecule less stable and therefore would not happen.

1. **Discuss the process of covalent bonding in a water molecule.**

**Project the animation *Covalent bond in water*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)

Before hitting the “play” button, point out the oxygen atom and the two hydrogen atoms.

Ask students:

* + **Is there anything that might attract these atoms to one another?**

Students should suggest that the electrons from each atom are attracted to the protons of the other atoms.

Play the animation to show the attraction between the protons of oxygen for the electron from each of the hydrogen atoms, the attraction of the proton from the hydrogen atoms for the electrons of oxygen, and the atoms coming together.

Explain that the electrons are shared by the oxygen and hydrogen atoms forming a covalent bond. These bonds hold the oxygen and hydrogen atoms together and form the H2O molecule. The reason why the atoms are able to bond is that the attractions are strong enough in both directions and there is room for the electrons on the outer energy level of the atoms.

The electron from each hydrogen atom and the electrons from the oxygen atom get to be near more protons when the atoms are bonded together as a molecule than when they are separated as individual atoms. This makes the molecule of bonded oxygen and hydrogen atoms more stable than the individual separated atoms.

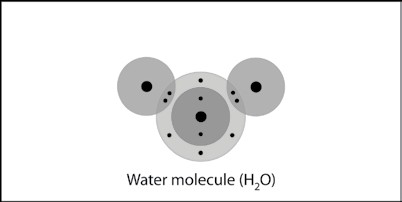
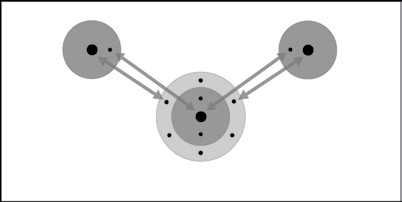
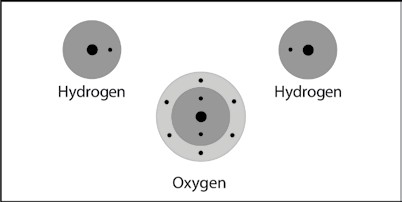
Explain to students that the two electrons in the bond between the hydrogen atom and the oxygen atom can be thought of as “belonging” to each atom. This gives each hydrogen atom two electrons in its outer energy level, which is full. It also gives oxygen 8 electrons in its outer energy level, which is also full.

**Project the image *Covalent bond in water*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)

1. **Have students describe covalent bonding in a water molecule.**

Have students write a short caption beside each picture to describe the process of covalent bonding in the water molecule.



Two hydrogen atoms and one oxygen atom are near each other.

Because there is both a strong enough attraction between atoms and room for electrons in the outer level of the atoms, they share electrons. This forms a covalent bond.

When two hydrogen atoms come close enough to an oxygen atom, their electrons are attracted to the proton of the other atom.

***Note****: This model of covalent bonding for a water molecule starts with 2 individual hydrogen atoms and 1 oxygen atom. In reality, these atoms are never separate to start with. They are always bonded with something else. To simplify the process, this model does not show the hydrogen and oxygen atoms breaking their bonds from other atoms. It only focuses on the process of forming covalent bonds to make water.*

Ask students:

* **Why can’t a third hydrogen atom join the water molecule (H2O) to make H3O?**

Once the outer energy levels are full, sharing electrons with another atom would not happen for two main reasons: An electron from a new atom would have to join an atom in the H2O molecule on the next energy level, further from the nucleus where it would not feel a strong enough attraction. An electron from an atom already in the H2O molecule and close to the nucleus would need to move further away to share with the new atom. Both of these possibilities would make the molecule less stable and would not happen.

**EXPLORE**

1. **Have students use electricity to form oxygen and hydrogen gas from water.**

Tell students that electrical energy causes electrons and atoms from water molecules to rearrange and produce hydrogen atoms and oxygen atoms. Two hydrogen atoms bond to form hydrogen gas (H2) and two oxygen atoms bond to form oxygen gas (O2).

**Note**: It is true that in the electrolysis of water, oxygen and hydrogen atoms from water molecules (H2O) eventually become hydrogen gas (H2) and oxygen gas (O2). But this is a multi-step process and not a simple breaking of the covalent bonds in water and immediately reforming new bonds to make the gases. There are several intermediate steps.

You may choose to do this activity as a demonstration or show the video *Electrolysis*.

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)

**Question to investigate**

What is produced when electricity is put into water?

**Materials for each group**

* 9-volt battery
* 2 wires with alligator clips on both ends
* 2 pencils sharpened at both ends
* Water
* Epsom salt (magnesium sulfate)
* Clear plastic cup
* Tape

**Procedure**

1. Place a battery between 2 pencils. Be sure that the battery is more than half-way up.
2. With the help of a partner, wrap tape around the pencils and battery as shown.
3. Add water to a clear plastic cup until it is about ½-full.
4. A hand holding a cup of pencils

   Description automatically generatedAdd about ½ teaspoon of Epsom salt to the water and stir until the salt dissolves.
5. Connect one alligator clip to one terminal of the battery.
6. Using the other wire, connect one alligator clip to the other terminal of the battery.
7. Connect one end of the pencil lead to the alligator clip at the end of one of the wires.
8. Using the other wire, connect one end of the other pencil lead to the alligator clip at the end of the wire.
9. Place the ends of the pencil into the water as shown.

**Expected results**

Bubbles will form and rise initially from one pencil lead. Soon, bubbles form and rise from the other. Students should be able to see that there is more of one gas than the other. The gas that forms the small bubbles that comes off first is hydrogen. The other gas that forms the larger bubbles and lags behind is oxygen.

***Note****: There will be bubbling when hydrogen and oxygen gas form on the pencil leads. Be sure students do not get the misconception that the bubbles they see mean that the water is boiling. In boiling, the bonds holding the atoms together in water molecules do not come apart. In the process of electrolysis, the bonds holding the atoms together do come apart.*

1. **Discuss student observations.**

Ask students:

* + **What are the bubbles made out of in the activity?**

Hydrogen gas (H2) and oxygen gas (O2)

* + **Why was there more hydrogen gas produced than oxygen gas?**

Each water molecule breaks into 2 hydrogen atoms and 1 oxygen atom. Two hydrogen atoms then bond to form hydrogen gas (H2) and 2 oxygen atoms bond to form oxygen gas (O2).

Each water molecule has all the atoms needed to make 1 molecule of hydrogen gas. But with only 1 oxygen atom, a water molecule only has half of what is needed to make 1 molecule of oxygen gas. So, 2 water molecules will produce 2 molecules of hydrogen gas but only 1 molecule of oxygen gas.

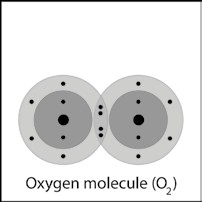
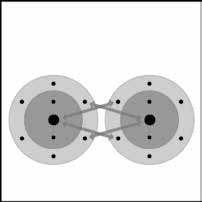
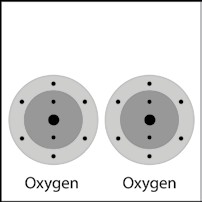
**EXTEND**

1. **Help students understand how atoms combine to form the molecules of oxygen, methane, and carbon dioxide.**

Remind students that in this lesson they looked at the covalent bonds in hydrogen molecules and in water molecules. Tell them that they will look at the covalent bonds in three other common substances.

**Project the animation *Oxygen’s double bond*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)



Each oxygen atom has 6 valence electrons in its outer energy level.

When two oxygen atoms get close to each other, the attractions from the nucleus of both atoms attract the outer electrons.

In this case, *two* electrons from each atoms are shared. This is called a double bond.

Explain to students that the oxygen molecules that are present in our air are made up of 2 oxygen atoms. This animation will show what the covalent bond between 2 oxygen atoms is like.

Narrate the animation by pointing out that:

* Each oxygen atom has 6 valence electrons in its outer energy level.
* When the oxygen atoms get close together, the attractions from the nucleus of both atoms attract the outer electrons from the other atom.
* In this case, 2 electrons from each atom are shared. This is called a double covalent bond.

**Project the image *Oxygen’s double bond II*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)

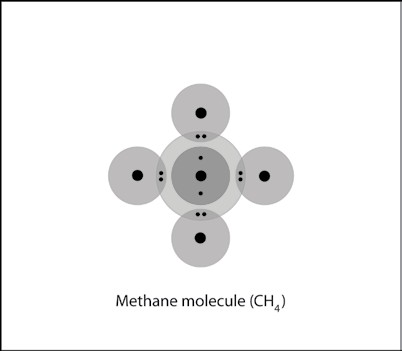
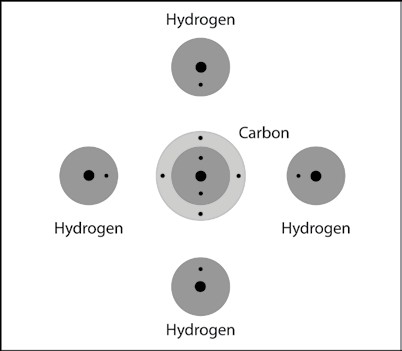
Review with students the process of covalent bonding covered in the animation.

**Project the before and after pictures *Covalent bonding of methane*.** [www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)

Ask students:

* **Describe the process of covalent bonding between the carbon and the four hydrogen atoms to make a methane molecule. Be sure to mention attractions between electrons and protons and the number of electrons in the outer energy level for the atoms in the final molecule.**

Be sure students realize that the protons of each atom attracts the other atoms electrons, which brings the atoms together. Atoms continue to bond with other atoms until their outer energy levels are full.



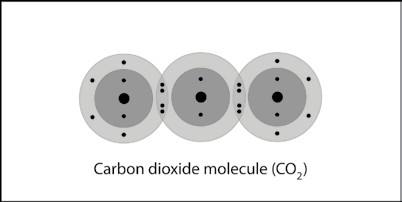
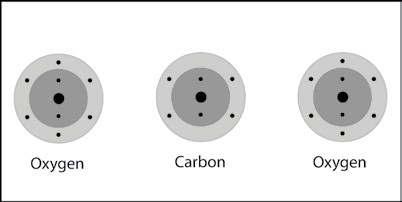
Ask students:

* **Describe the process of covalent bonding between the carbon and the two oxygen atoms to make a carbon dioxide molecule. Be sure to mention attractions between electrons and protons and the number of electrons in the outer energy level for the atoms in the final molecule.**

Be sure students realize that the protons of each atom attracts the other atom’s electrons, which brings the atoms together. Atoms continue to bond with other atoms until their outer energy levels are full.

**Project the before and after pictures *Covalent bonding of carbon dioxide gas*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson4.html)



Ask students:

## Describe the process of covalent bonding between the carbon and the two oxygen atoms to make a carbon dioxide molecule. Be sure to mention attractions between electrons and protons and the number of electrons in the outer energy level for the atoms in the final molecule.

Be sure students realize that the protons of each atom attracts the other atom’s electrons, which brings the atoms together. Atoms continue to bond with other atoms until their outer energy levels are full.

**Part 2: Energy Levels, Electrons, and Ionic Bonding**

(From Middle School Chemistry - Chapter 4, Lesson 5)

***Key Concepts***

* The attractions between the protons and electrons of atoms can cause an electron to move completely from one atom to the other.
* When an atom loses or gains an electron, it is called an ion.
* The atom that loses an electron becomes a positive ion.
* The atom that gains an electron becomes a negative ion.
* A positive and negative ion attract each other and form an ionic bond.

***Summary***

Students will look at animations and make drawings of the ionic bonding of sodium chloride (NaCl). Students will see that both ionic and covalent bonding start with the attractions of protons and electrons between different atoms. But in ionic bonding, electrons are transferred from one atom to the other and not shared like in covalent bonding.

***Objective***

Students will be able to explain the process of the formation of ions and ionic bonds.

***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.

***Materials for Each Group***

* Black paper
* Salt
* Cup with salt from evaporated saltwater
* Magnifier
* Permanent marker

***Note****: In an ionically bonded substance such as NaCl, the smallest ratio of positive and negative ions bonded together is called a “formula unit” rather than a “molecule.” Technically speaking, the term “molecule” refers to two or more atoms that are bonded together covalently, not ionically. For simplicity, you might want to use the term “molecule” for both covalently and ionically bonded substances.*

**ENGAGE**

Review with students that covalent bonding is the sharing of electrons between atoms to form molecules like water, and let students know that the next type of bonding they learn about will be different. Understanding both types of bonding will help understand some of the processes of ocean acidification.

1. **Show a video of sodium metal reacting with chlorine gas.**

**Project the video *Sodium and chlorine react*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html)

Before starting the video, tell students that chlorine is a greenish poisonous gas and sodium is a shiny, soft, and very reactive metal. But when they react, they form sodium chloride (table salt). Tell students that in the video, the drop of water helps expose the atoms at the surface of the sodium so that they can react with the chlorine. The formation of the salt crystals releases a lot of energy.

***Note****: If students ask if the salt they eat is made this way in salt factories, the answer is no. The salt on Earth was produced billions of years ago but probably not from pure chlorine gas and sodium metal. These days, we get salt from mining it from a mineral called halite or from evaporating sea water.*

**EXPLAIN**

1. **Show an animation to introduce the process of ionic bonding.**

**Project the animation *Ionic bond in sodium chloride*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html)

Remind students that in covalent bonding, atoms share electrons. But there is another type of bonding where atoms don’t share, but instead either take or give up electrons. This is called ionic bonding. This animation shows a very simplified model of how sodium and chloride ions are formed.

***Note****: In order to simplify the model of ionic bonding, a single atom of sodium and chlorine are shown. In reality, the chlorine atom would be bonded to another chlorine atom as part of the gas Cl2. The sodium atom would be one of billions of trillions of sodium atoms bonded together as a solid. The combination of these substances is a complex reaction between the atoms of the two substances. The animation shows single separated atoms to illustrate the idea of how ions and ionic bonds are formed.*

**Explain what happens during the animation.**

Tell students that the attraction of the protons in the sodium and chlorine for the other atom’s electrons brings the atoms closer together. Chlorine has a stronger attraction for electrons than sodium (shown by the thicker arrow). At some point during this process, an electron from the sodium is transferred to the chlorine. The sodium loses an electron and the chlorine gains an electron.

Tell students that when an atom gains or loses an electron, it becomes an *ion*.

* Sodium loses an electron, leaving it with 11 protons, but only 10 electrons. Since it has 1 more proton than electrons, sodium has a charge of +1, making it a positive ion.
* Chlorine gains an electron, leaving it with 17 protons and 18 electrons. Since it has 1 more electron than protons, chlorine has a charge of –1, making it a negative ion.
* When ions form, atoms gain or lose electrons until their outer energy level is full.

For example, when sodium loses its one outer electron from the third energy level, the second level becomes the new outer energy level and is full. Since these electrons are closer to the nucleus, they are more tightly held and will not leave.

* + When chlorine gains an electron, its third energy level becomes full. An additional electron cannot join, because it would need to come in at the fourth energy level. This far from the nucleus, the electron would not feel enough attraction from the protons to be stable.
  + Then the positive sodium ion and negative chloride ion attract each other and form an ionic bond. The ions are more stable when they are bonded than they were as individual atoms.

1. **Have students describe the process of ionic bonding in sodium chloride on their activity sheet.**

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

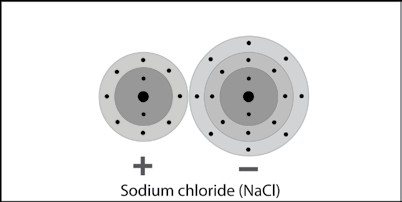
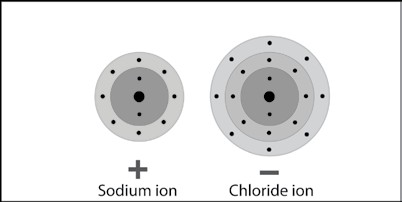
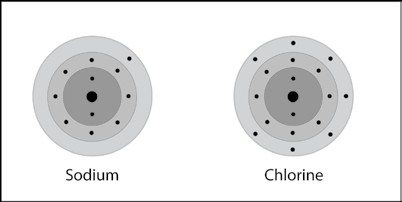
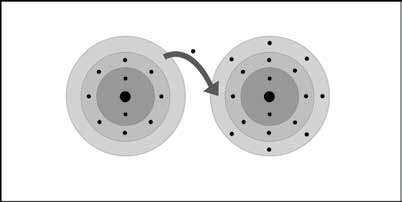
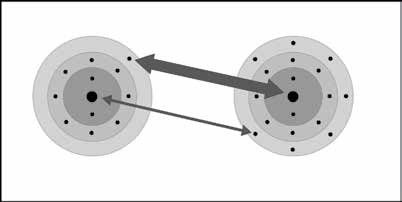
Have students write a short caption under each picture to describe the process of covalent bonding and answer the first three questions. The rest of the activity sheet will either be completed as a class, in groups, or individually depending on your instructions.

**Project the image *Ionic bond in sodium chloride*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html)

Review with students the process of ionic bonding covered in the animation.

Help students write a short caption beside each picture to describe the process of ionic bonding in sodium and chloride ions.



Sodium and chlorine atoms are near each other.

The protons of the two atoms attract the electrons of the other atom. The thicker arrow shows that chlorine has a stronger attraction for electrons than sodium has.

During the interactions between the atoms, the electron in sodium’s outer energy level is transferred to the outer energy level of the chlorine atom.

Since sodium *lost* an electron, it has 11 protons, but only 10 electrons. This makes sodium a *positive* ion with a charge of +1.

Since chlorine *gained* an electron it has 17 protons and 18 electrons. This makes chloride a *negative* ion with a charge of –1.

The positive sodium ion and negative chloride ion attract one another. They make an ionic bond and form the ionic compound NaCl.

**4. Show students a model of a sodium chloride crystal and have them identify the ions.**

**Project the image *Sodium chloride crystal*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html)

Review with students the process of ionic bonding covered in the animation so that students will understand why the sodium ions are positive and the chloride ions are negative. Remind students that the scale of any model of atoms, ions, or molecules is enormous compared to the actual size. In a single grain of salt there are billions of trillions of sodium and chloride ions.

Ask students:

* + **What ion is the larger ball with the negative charge?**

The chlorine ion.

* + **What made it negative?**

It gained an electron.

* + **What is the ion with the positive charge?**

The sodium ion.

* + **What made it positive?**

It lost an electron.

**EXPLORE**

**5. Have students observe actual sodium chloride crystals and relate their shape to the molecular model.**

This two-part activity will help students see the relationship between the arrangement of ions in a model of a sodium chloride crystal and the cubic shape of real sodium chloride crystals.

**Question to investigate:**

Why are salt crystals cube-shaped?

**Teacher preparation**

The day before the lesson, dissolve about 10 grams of salt in 50 ml of water. Use Petri dishes or use scissors to cut down 5 or 6 clear plastic cups to make shallow plastic dishes. Pour enough saltwater to just cover the bottom of each dish (1 for each group). Leave the dishes overnight to evaporate so that new salt crystals will be produced.

**Materials for each group**

* + Black paper
  + Salt
  + Cup with salt from evaporated saltwater
  + Magnifier
  + Permanent marker

**Procedure, Part 1**

*Observe sodium chloride crystals.*

1. Place a few grains of salt on a piece of black paper. Use your magnifier to look closely at the salt.
2. Use your magnifier to look at the salt crystals in the cup.

**Project the image *Cubic sodium chloride*.**

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html)

The image shows both a magnified view of ordinary table salt and a model of the sodium and chloride ions that make up a salt crystal.

A green and white cube

Description automatically generatedA pile of small cubes

Description automatically generated

**Project the animation *Sodium chloride.***

[www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html](http://www.acs.org/middleschoolchemistry/simulations/chapter4/lesson5.html)

The green spheres represent negatively charged chloride ions and the gray spheres represent positively charged sodium ions.

Ask students:

* + **What do the photograph, molecular model, and your observations of real salt crystals tell you about the structure of salt?**

In each case, the salt seems to be shaped like a cube.

**EXTEND**

**6. Review with students what they know about bonding between atoms.**

Students have seen covalent bonding to form molecules of water, and hydrogen, oxygen, and carbon dioxide gas. They have also seen ionic bonding to form a sodium chloride crystal.

Remind students that in the first lesson they saw that carbon dioxide from different sources could enter water to make that water acidic. These were models of the process of ocean acidification.

Lead a discussion to see if students can come up with questions to investigate to begin to understand more about the process of ocean acidification. You can add these questions to the Driving Question Board.

Some questions could be:

* How does the carbon dioxide get into the water?
* What is it about the water and carbon dioxide molecules that allows the carbon dioxide to stay in the water?
* Does the carbon dioxide dissolve into the water like the carbon dioxide in club soda?

If students ask about the reaction between water and carbon dioxide to form carbonic acid, let them know that will come later, but you can record it on the DQB. For now, the question is what are the characteristics of water that allow the carbon dioxide to dissolve into it in the first place.

Let students know that they will explore the water molecule more closely to see how its characteristics contribute to ocean acidification.