January 30, 2021
Chemical Bond Acts Like a Mash-Up
In this Guide, based on the online *Science News* “This weird chemical bond acts like a mash-up of hydrogen and covalent bonds,” students will learn about recent research findings that challenge long-held ideas about chemical bonding and discuss how to incorporate exceptions to general chemistry concepts into their learning.

**This Guide includes:**

**Article-based Comprehension Q&A** — Students will answer questions about the online *Science News* article “This weird chemical bond acts like a mash-up of hydrogen and covalent bonds,” which explores new research that suggests chemical bonds exist on a continuum. A version of the story, “Chemical bond acts like a mash-up,” can be found in the January 30, 2021 issue of *Science News*. Related standards include NGSS-DCI: HS-PS1; HS-PS2; HS-PS3.

  **Student Comprehension Worksheet** — These questions are formatted so it’s easy to print them out as a worksheet.

**Cross-curricular Discussion Q&A** — Students will discuss the classical definitions of chemical bonds and determine how to adjust those definitions based on new research. Then, students will talk about the best strategies for assessing general chemistry concepts and exceptions to those generalizations. Related standards include NGSS-DCI: HS-PS1; HS-PS2; HS-PS3.

  **Student Discussion Worksheet** — These questions are formatted so it’s easy to print them out as a worksheet.
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Article-based Comprehension, Q&A

Directions for teachers: Ask your students to read the online Science News article “This weird chemical bond acts like a mash-up of hydrogen and covalent bonds,” which explores a new type of chemical bond, and answer the following questions. A version of the story, “Chemical bond acts like a mash-up,” can be found in the January 30, 2021 issue of Science News.

1. Define hydrogen bonds and covalent bonds based on the information provided in the Science News article. Of the two types of bonds, which is not considered a “true chemical bond?”

Hydrogen bonds result from weak attractions between atoms in one molecule to oppositely charged atoms in a neighboring molecule. Covalent bonds result from electrons being shared among atoms, typically within a molecule. Unlike the covalent bond, the hydrogen bond is not considered a true chemical bond.

2. What is the new type of bond that scientists discovered? What makes it special?

Researchers discovered what’s called a hydrogen-mediated chemical bond. At first it was thought to be an unusually strong variety of hydrogen bond. But experiments revealed that the bond is a hybrid of a hydrogen bond and a covalent bond, as it involves shared electrons—a characteristic of covalent bonds.

3. Where was the new bond found? Name and describe the molecule that contains the new bond.

The new bond was found in bifluoride ions in water. A bifluoride ion consists of a hydrogen atom sandwiched between two fluorine atoms.

4. According to the rules of chemistry, how should the molecule have been bound together? How was the molecule actually bound together?

According to the rules of chemistry, the hydrogen atom in one bifluoride molecule should be loosely bound to one fluorine atom via hydrogen bonding and closely bound to the other fluorine atom via covalent bonding. Instead, the hydrogen atom was shared equally between the fluorine atoms.

5. What did computer simulations reveal about the new bond’s behavior?

As the fluorine atoms moved closer together and squeezed the hydrogen atom, the normal hydrogen bond became stronger until all three atoms began sharing electrons as in a covalent bond.

6. What does chemist Bogdan Dereka say about the discovery?

The hydrogen-mediated bond erases the difference between covalent and hydrogen bonds so that the distinction is no longer meaningful.
7. Why is understanding strong hydrogen bonds important?

Strong hydrogen bonds are thought to play a role in transporting hydrogen ions, a process crucial for powering living cells and for technologies such as fuel cells. Better understanding these bonds could shed light on a variety of effects.

8. What are the big-picture implications of the discovery?

The discovery has implications for scientists’ fundamental understanding of what a chemical bond is, as well as what qualifies as a molecule.
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1. Define hydrogen bonds and covalent bonds based on the information provided in the Science News article. Of the two types of bonds, which is not considered a “true chemical bond”?

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Chemical Bond Acts Like a Mash-Up

Cross-curricular Discussion, Q&A

Directions for teachers:
Use the online Science News article “This weird chemical bond acts like a mash-up of hydrogen and covalent bonds” and the prompts below to have students explore classical definitions of chemical bonding and how those definitions should be revised based on new research. A version of the story, “Chemical bond acts like a mash-up,” appears in the January 30, 2021 issue of Science News. As a final exercise, have students discuss how to best learn general chemistry concepts and their exceptions.

Want to make it a virtual lesson? Post the online Science News article “This weird chemical bond acts like a mash-up of hydrogen and covalent bonds,” to your learning management system. Pair up students and allow them to connect via virtual breakout rooms in a video conference, over the phone, in a shared document or using another chat system. Have each pair post its answers to the third set of questions, or conduct a class discussion to allow groups to share out.

Classical definitions

Discuss the following questions with a partner before reading the Science News article. Reference an outside resource if needed, but try to determine examples on your own.

1. What does electrostatic attraction mean? How does this concept apply to atoms and chemical bonding?

Electrostatic attraction is the electric force between two oppositely charged bodies. The force of attraction between positively charged protons and negatively charged electrons within an atom, and the attractive forces between partially or fully charged molecules in a substance, impacts the chemical reactivity of the substance.

2. What is the difference between intermolecular and intramolecular attraction forces? Explain and give an example of each based on your understanding of the concepts.

Intermolecular attraction forces are attractive forces between molecules. Intramolecular attraction forces are the attractive forces between atoms within a molecule. Generally, hydrogen bonds and dipole-dipole interactions are considered intermolecular attraction forces. Covalent bonds, both polar and nonpolar, are typically defined as intramolecular attractions. Ionic bonds are also generally thought of intramolecular forces. They are forces of attraction between charged atoms and/or molecules. Water, or H₂O, can be used as an example of both intra- and intermolecular attraction forces. Hydrogen bonds occur between molecules of H₂O, but within one H₂O molecule, each hydrogen atom forms a polar covalent bond with the lone oxygen atom in the molecule.
3. What type of attraction force is generally thought of as a “true chemical bond?” What does this tell you about the general difference in attractive strength of intermolecular versus intramolecular attraction forces?

Intramolecular attraction forces are generally viewed as true chemical bonds. These forces are very strong, meaning a lot of energy is generally required to separate atoms within molecules. Intermolecular attraction forces are generally less strong, meaning it doesn’t take much energy to separate molecules.

4. Why do we attempt to classify types of chemical bonds and/or attractive forces within a substance or mixture?

To predict the physical and chemical properties of a substance, such as the ability to transport hydrogen ions, as mentioned in the Science News article.

**Modifying definitions**

Read the online Science News article “This weird chemical bond acts like a mash-up of hydrogen and covalent bonds” and answer the following questions individually, before discussing them with a partner.

1. What is a hydrogen-mediated chemical bond and why is it unique?

A hydrogen-mediated chemical bond is a hybrid of a hydrogen bond and a covalent bond. It is stronger than a typical hydrogen bond and involves electron sharing, which is typically characteristic of covalent bonding.

2. Given the information in the article, what chemistry terms need to be redefined? Why?

Molecules and chemical bonds. The newly discovered hydrogen-mediated chemical bond does not fit into the conventional bond categories. It also redefines the conventional knowledge about what constitutes a molecule.

**Exceptions to the rules**

Discuss the following questions with a classmate. Write down your thoughts and be prepared to share your answers with the class.

1. Give an example of an exception to a generalized chemistry concept that you learned about this year and explain why the exception exists. For example, were there exceptions to trends on the periodic table, classifications of properties of certain types of substances (acids/bases, conductors/insulators, etc.), or other theories (kinetic molecular theory, etc.)?
When learning the trends on the periodic table, there are exceptions to trends in ionization energy, or the energy required to remove the outermost electron from an atom. Generally, the ionization energy of elements increases as you move from left to right across a row of the periodic table. However, oxygen has a lower first ionization energy than nitrogen. This exception is explained by the fact that oxygen atoms have a paired electron in its outermost energy level which, based on the repulsive forces of that pairing, makes the outermost electron less stable and more easily removed from oxygen.

2. Based on the new research described in the *Science News* article, write an exception to the generalized concept of chemical bonding.

*Generally speaking, intermolecular attraction forces are weaker than intramolecular attractive forces (also called true chemical bonds). However, the hydrogen-mediated bond is an exception to this rule. This bond is a hybrid of intramolecular and intermolecular attractive forces — it acts as both a covalent bond and a hydrogen bond.*

3. Think about how you would prefer to learn information. Would you rather learn a set of generalized concepts then think through and explain the exceptions to those concepts? Or would you rather assume that there are no generalized concepts and evaluate each phenomenon on a case-by-case basis? Before answering, discuss the benefits and drawbacks of each option, and why you think the way that you do.

*Student answers will vary, but will likely include something about the simplicity and the ease of using generalizations and categories to understand many or most specific examples. Treating each example as an individual case to memorize or look up would require much more time and effort. The downside of making generalizations is that it often causes us to overlook or minimize the exceptions, because they aren’t the norm. Students should also give their opinion about the way that they would prefer to learn the material. They may also say that they would like to go with the generalizations, even though remembering the exceptions to the rule can be a pain.*
Student Discussion Worksheet

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### Classical definitions

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1. What does electrostatic attraction mean? How does this concept apply to atoms and chemical bonding?

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3. What type of attraction force is generally thought of as a “true chemical bond?” What does this tell you about the general difference in attractive strength of intermolecular versus intramolecular attraction forces?

4. Why do we attempt to classify types of chemical bonds and/or attractive forces within a substance or mixture?

### Modifying definitions

Read the online *Science News* article “This weird chemical bond acts like a mash-up of hydrogen and covalent bonds,” and answer the following questions individually, before discussing them with a partner.

1. What is a hydrogen-mediated chemical bond and why is it unique?

2. Given the information in the article, what chemistry terms need to be redefined? Why?
Exceptions to the rules

Discuss the following questions with a classmate. Write down your thoughts and be prepared to share your answers with the class.

1. Give an example of an exception to a generalized chemistry concept that you learned about this year and explain why the exception exists. For example, were there exceptions to trends on the periodic table, classifications of properties of certain types of substances (acids/bases, conductors/insulators, etc.), or other theories (kinetic molecular theory, etc.)?

2. Based on the new research described in the Science News article, write an exception to the generalized concept of chemical bonding.

3. Think about how you would prefer to learn information. Would you rather learn a set of generalized concepts then think through and explain the exceptions to those concepts? Or would you rather assume that there are no generalized concepts and evaluate each phenomenon on a case-by-case basis? Before answering, discuss the benefits and drawbacks of each option, and why you think the way that you do.