

**Teacher’s Guide**

**The Chemistry of Convenience**

***December 2020***

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Activate students’ prior knowledge and engage them before they read the article.

[Reading Comprehension Questions](#_Student_Reading_Comprehension) 3

These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[Graphic Organizer 5](#_Graphic_Organizer)

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[Answers 6](#_Answers_to_Reading)

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[Additional Resources 9](#_Additional_Resources_1)

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

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# Anticipation Guide

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. PFAS (polyfluoroalkyl) substances are synthetic. |
|  |  | 1. All synthetic chemicals are harmful. |
|  |  | 1. PFAS contain oxygen, nitrogen, carbon, and fluorine atoms. |
|  |  | 1. The covalent bond formed between carbon and fluorine is one of the strongest single bonds in nature. |
|  |  | 1. The covalent bond between carbon and fluorine is longer than other covalent bonds. |
|  |  | 1. PFAS can cause health problems in several different human body systems. |
|  |  | 1. A huge amount of data must be collected in lab experiments to make predictions about how PFAS move in our bodies |
|  |  | 1. Filtering out PFAS molecules from water is fairly easy with common filtration technology. |
|  |  | 1. An ordinary incinerator can destroy PFAS molecules. |
|  |  | 1. A few specific PFAS can no longer be manufactured in the U.S. |

# Student Reading Comprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: Use the article to answer the questions below.

1. Which two elements are present in every polyfluoroalkyl (PFAS) compound?
2. What are some primary uses of PFAS chemicals?
3. Why do PFAS compounds remain for a long time in the environment? What specific types of bonds cause PFAS compounds to be known as “forever chemicals”?
4. PFAS chemicals are considered to be inert and thus do not react with other chemicals in the body. The effects of PFAS chemicals accumulating in the body are not yet fully understood, but what are some potential health risks associated with PFAS chemicals in the body mentioned in the article?
5. What are some ways scientists are having success removing PFAS chemicals from the environment?
6. PFAS durability, inertness, and water/oil repelling properties have made the compounds extremely popular. Examine the structure of C7H15COOHon page 6 of the article. What characteristics of the structure make C7H15COOH an excellent choice for outerwear clothing?
7. Examine the electronegativity trends on the periodic table on page 6 of the article. Electronegativity tends to decrease as you move down columns on the table and increases as you move across a row. Explain the trends in electronegativity based on your knowledge of periodic trends and the atom.
8. The table on page 7 of the article indicates the bond energy of various binary chemical bonds. The article explains how an increased electronegativity difference results in an electrostatic attraction and a shorter, stronger covalent bond. Why do you suppose the F-F bond energy is significantly lower than the O-O bond energy even though fluorine is smaller than oxygen and can form a shorter bond? (Note: since these bonds are diatomic, the electronegativity difference in each bond is zero.)

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Regulations have been put into place that have helped limit the accumulation of PFAS in the environment. The best method of preventing PFAS compounds from entering the environment is to avoid, if possible, using materials that contain “forever chemicals.” Identify 3 items that you use daily that contain PFAS compounds and attempt to find PFAS free alternatives to these items.
2. Create a public service announcement about the dangers of PFAS compounds accumulating in the environment in hopes convincing individuals to limit their exposure and use of PFAS compounds. You may use a YouTube video, Infographic, TikTok, or Twitter to present your announcement. In the video, inform the public about PFAS compounds and their uses, the dangers of PFAS compounds, and how limit exposure/use of PFAS compounds.

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: As you read, complete the graphic organizer below to describe how the chemistry terms relate to the chemistry of PFAS.

|  |  |
| --- | --- |
| **Chemistry Term** | **Relate to the chemistry of PFAS** |
| **Hydrophilic** |  |
| **Covalent bond** |  |
| **Electronegativity** |  |
| **Bond energy** |  |
| **Inert** |  |
| **Predictions** |  |
| **Reverse osmosis** |  |

**Summary:** Write a one-sentence summary (15 words or less) about the chemistry of PFAS.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. **Which two elements are present in every polyfluoroalkyl (PFAS) compound?**

*Carbon (C) and fluorine (F) are present in every PFAS compound.*

1. **What are some primary uses of PFAS chemicals?**

*Water resistant/repellent clothes, non-stick cookware, and food wrappers.*

1. **Why do PFAS compounds remain for a long time in the environment? What specific types of bonds cause PFAS compounds to be known as “forever chemicals”?**

*The carbon to fluorine bonds are very strong due to the large electronegativity different between carbon and fluorine, which causes a permanent net dipole and strong electrostatic attraction between the two atoms. This strong attraction causes a short, strong bond between the atoms and gives PFAS compounds their durable properties.*

1. **PFAS chemicals are considered to be inert and thus do not react with other chemicals in the body. The effects of PFAS chemicals accumulating in the body are not yet fully understood, but what are some potential health risks associated with PFAS chemicals in the body mentioned in the article?**

*Health concerns associated with PFAS chemicals inside the body include pregnancy complications, kidney and testicular cancer, liver damage, and asthma.*

1. **What are some ways scientists are having success removing PFAS chemicals from the environment?**

*Water chemists have been able to remove PFAS from water sources through filtration methods such as activated carbon and reverse osmosis.*

1. **PFAS durability, inertness, and water/oil repelling properties have made the compounds extremely popular. Examine the structure of C7H15COOHon page 6 of the article. What characteristics of the structure make C7H15COOH an excellent choice for outerwear clothing?**

*C7H15COOH(perfluorooctanoic acid) has a large non-polar or hydrophobic portion of the molecule which will repel water which is a desirable characteristic of outerwear clothing. Polar compounds such as water, like and dissolve in other polar compounds. Non-polar compounds such as oil, like and dissolve in other non-polar compounds.*

1. **Examine the electronegativity trends on the periodic table on page 6 of the article. Electronegativity tends to decrease as you move down columns on the table and increases as you move across a row. Explain the trends in electronegativity based on your knowledge of periodic trends and the atom.**

*Electronegativity decreases as you move down a column on the table because additional energy levels are added to the atom. Additional energy levels cause valence electrons to be further from the nucleus and experience more shielding from inner electrons which limits the atoms ability to attract bonding pairs of electrons. Electronegativity increases across a row due to the fact that valence electrons are at the same distance from the nucleus (same energy level), however additional protons are added to the nucleus you move across a row increasing the effective nuclear charge and increasing the atoms ability to attract electrons in a bond.*

1. **The table on page 7 of the article indicates the bond energy of various binary chemical bonds. The article explains how an increased electronegativity difference results in an electrostatic attraction and a shorter, stronger covalent bond. Why do you suppose the F-F bond energy is significantly lower than the O-O bond energy even though fluorine is smaller than oxygen and can form a shorter bond? (Note: since these bonds are diatomic, the electronegativity difference in each bond is zero.)**

*The fluorine to fluorine bond is a single bond while the oxygen to oxygen bond is a double bond. Double bonds tend to be shorter in length and have higher bond energy compared to single bonds because an extra shared pair of electrons needs to be separated.*

**Questions for Further Learning**

1. **Regulations have been put into place that have helped limit the accumulation of PFAS in the environment. The best method of preventing PFAS compounds from entering the environment is to avoid, if possible, using materials that contain “forever chemicals.” Identify 3 items that you use daily that contain PFAS compounds and attempt to find PFAS free alternatives to these items.**

*Student answers will vary. Example: Using PFAS free take-out containers or Teflon free cookware.*

1. **Create a public service announcement about the dangers of PFAS compounds accumulating in the environment in hopes convincing individuals to limit their exposure and use of PFAS compounds. You may use a YouTube video, Infographic, TikTok, or Twitter to present your announcement. In the video, inform the public about PFAS compounds and their uses, the dangers of PFAS compounds, and how limit exposure/use of PFAS compounds.**

*Student answers will vary.*

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

# Additional Resources

**Labs and demos**

**Periodic Table Trends:** In this lesson, students will investigate trends of the periodic table.

<https://teachchemistry.org/classroom-resources/periodic-table-trends>

**Simulations**

**Periodic Trends: Ionization Energy, Atomic Radius & Ionic Radius:** In this simulation, students can investigate the periodic trends of atomic radius, ionization energy, and ionic radius. By choosing elements from the periodic table, atoms can be selected for a side by side comparison and analysis.   
<https://teachchemistry.org/classroom-resources/periodic-trends-simulation>

**Lessons and lesson plans**

**Making Connections between Electronegativity, Molecular Shape, and Polarity:** In this activity, students will find the electronegativity values of a variety of elements, draw the Lewis structures of select molecules that are made with those elements, and identify the molecular shape of each molecule. <https://teachchemistry.org/classroom-resources/making-connections-between-electronegativity-molecular-shape-and-polarity>

**Bond Polarity Modeling Activity:** Students will kinesthetically demonstrate the use of electronegativity in determining covalent bond types.   
<https://teachchemistry.org/periodical/issues/may-2019/modeling-polarity>

**AACT Chemical Bonding Unit Plan:** The AACT high school classroom resource library has everything you need to put together a unit plan for your classroom: lessons, activities, labs, projects, videos, simulations, and animations. <https://teachchemistry.org/classroom-resources/chemical-bonding-unit-plan>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Molecules & bonding
* Molecular structure
* Intermolecular forces
* Electronegativity

**Correlations to Next Generation Science Standards**

This article relates to the following performance expectations and dimensions of the NGSS:

**HS-PS1-3**

Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**HS-ETS1-3**

Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraint, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

**Disciplinary Core Ideas:**

* PS1.A: Structure and Properties of Matter
* ETS1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Cause and Effect: Mechanism and explanation.
* Structure and Function

**Science and Engineering Practices:**

* Analyzing and interpreting data
* Constructing explanations and designing solutions

**Nature of Science:**

* Science addresses questions about the natural and material world.

**Correlations to Common Core State Standards**

See how *ChemMatters* correlates to the[**Common Core State Standards**](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html)  at www.acs.org/chemmatters.

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Alternative to Anticipation Guide:** Before reading, ask students how innovative products may harm people and the environment. Also, ask them how strong they think the bonds between atoms might be in products that remain in the environment for a long time. As they read, students can find information to confirm or refute their original ideas.
* After they read, ask students what they learned about PFAS and how they will use their new understanding.
* “Open for Discussion: A Balancing Act” in this month’s issue (page 4) has important information about how the benefits and potential risks of products are analyzed.
* In the *The Chemistry of Convenience* article (bottom of page 6), there is a question posed to students relating to electronegativity and bonding: *Which molecule would you expect to have a stronger carbon-halogen bond, methyl chloride (CH3Cl) or methyl iodide (CH3I)?*

*Answer:* Methyl chloride (CH3Cl) will have a stronger carbon-halogen bond because chlorine (Cl) is more electronegative than iodide (I). When chlorine is bonded to carbon, chlorine will pull more on the electrons and create a slight negative charge. Similarly, when iodine is bonded to carbon, iodine will pull more on the electrons and create a slight negative charge. However, since chlorine is more electronegative than iodide, chlorine will pull more on the electrons compared to iodide, creating a bigger difference between charges. This larger difference in charges between carbon and chlorine (which creates a dipole) makes the bond stronger compared to the carbon iodine bond.