ChemMatters®

Demystifying Everyday Chemistry

# Teacher's Guide

## February 2025




www.acs.org/chemmatters

ACS Chemistry for Life®

# February Teacher's Guide Introduction

# Lesson Ideas

This issue contains a good deal of information about biochemistry since most of the articles focus on the uses and importance of plants in everyday life.

For all of the articles, encourage students to think about how science is done, how we know what we know, and how chemistry connects to their lives.

**Teaching Ideas for this issue:**

1. "Chemistry in Pictures" on page 2 describes rose oil. Invite students to determine which article(s) in this issue relates to the photograph, and how. Also ask them what is special about rose oil.
2. "Open for Discussion" on page 4 challenges students to think about the meaning of life, and how we define life. Important concepts reviewed in this article include cells, biomolecules, viruses, RNA, the Gaia hypothesis, and geoscience.
3. "Quick Read: The Amazing Disappearing Purple Glue Sticks" on page 14 examines the chemistry of purple glue sticks. Ask students if they have ever used purple glue sticks and if they work as described. This article reviews acid-base reactions.
4. The "Chemistry in Person" column on page 19 describes how investigating the sense of smells in crayfish got one person interested in studying chemistry. Ask them how our sense of smell is unique among our 5 senses. Consider pairing this article with the article on page 13 in this issue, "Bringing Back the Sense of Smell."
5. Assign a team of students to read each feature article, then present what they learned in a podcast, PowerPoint or similar presentation, poster or brochure, or some other engaging format.
    - Prior to reading the article, give students the Anticipation Guide for the article along with the graphic organizer and links to other information provided.
    - Be sure to ask students to include information providing evidence for the claims made in the article.
6. Alternatively, students can create concept maps about the important chemistry concepts in the article they choose.

**5E Lesson Ideas** for individual articles:

| | |
|---|---|
| **Engage** | Provide the Anticipation Guide or ask a thoughtful question (see the individual Teacher's Guide for each article) to engage students in the reading. Students should record their initial ideas individually, in pen, so they can't be erased or forgotten. Students can then discuss their initial ideas in small groups or as a whole class. |
| **Explore** | Students read the article to discover more about the concepts in the article. During this phase, students will revisit their beginning ideas and record how the information in the article supports or refutes their initial ideas, providing evidence from the article. |
| **Explain** | Students answer questions and/or complete the graphic organizer provided for each article, then discuss their learning with their classmates. Students should recognize the evidence for the claims made in the articles, and how the evidence supports the claims. |
| **Elaborate** | Students can pose questions for further study.<br><br>For some articles, there are related ACS Reactions videos students can watch to learn more about the concepts presented. See the individual Teacher's Guide for each article to learn more. |
| **Evaluate** | Students write a short summary of what they learned that describes how it connects to their lives. Students may also present their learning to their classmates or others.<br><br>Here is a template for an exit slip:<br>● I used to think…<br>● But now I know…<br>● And this is how I learned it… |

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Demystifying Everyday Chemistry

# Teacher's Guide

## Milk: It's What's Growing in the Garden

## *February 2025*

## Table of Contents

Name: _____

# Anticipation Guide

**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. Fats are nonpolar. |
| | | 2. Nonpolar molecules are hydrophilic. |
| | | 3. Phospholipid molecules have a hydrophilic head and a hydrophobic tail. |
| | | 4. Acids change the shape of proteins. |
| | | 5. Different milks (like cow's milk and plant milks) react differently to steaming and frothing. |
| | | 6. The foaminess in milk depends on fats. |
| | | 7. Nuts, beans, and seeds contain oil bodies that are similar in size to fat globules in dairy milk. |
| | | 8. Plant milks are not pasteurized or homogenized. |
| | | 9. Fats make milk creamy. |
| | | 10.The liquid from a can of chickpeas can be used to make a meringue. |

# Student Reading Comprehension Questions

Name: _____

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

1. How is buttermilk made?
2. What happens when you use nonfat (skim) milk to make buttermilk?
3. Define hydrophilic and hydrophobic. What makes a substance one or the other?
4. Explain the difference between suspensions and emulsions
5. Describe the process of denaturing
6. Why would we want to homogenize milk? How does this process keep particles in milk from settling?
7. Why does denaturing cause milk to float on coffee?
8. Define viscosity (you may need to do an internet search). Why do you think longer chain molecules would be more viscous than more compact molecules?
9. What are the two different ways to make emulsions more stable? Describe each one and how they work.
10. Using intermolecular forces, explain why nonpolar fats do not mix well with water, which is a polar molecule.

SHORT ANSWER

"Why do I need to learn chemistry if I want to be a barista?" Using the info you read in the article, explain why chemistry is so important in the coffee business, as well as any form of food service.

# Graphic Organizer

Name: _____

**Directions**: As you read, complete the graphic organizer below to describe the chemistry of different kinds of milk.

| Term | Meaning or Description | Examples from the article |
|---|---|---|
| **Emulsion** | | |
| **Lipids** | | |
| **Proteins** | | |
| **Fats** | | |
| **Gums** | | |
| **Starches** | | |

**Summary:** On the back of this sheet, write three interesting facts about plant milks that you learned from the article.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. How is buttermilk made?
   Buttermilk is made by adding an acid to milk which causes the fat in milk to curdle. The acid can be lemon juice or vinegar.

2. What happens when you use nonfat (skim) milk to make buttermilk?
   Because there is no fat, the acid has nothing to react with and curdle. The solution will be milk and vinegar or lemon juice.

3. Define hydrophilic and hydrophobic. What makes a substance one or the other?
   Hydrophilic substances are attracted to water, where hydrophobic substances are repelled by water. A substance is hydrophobic when its electrical charges are evenly distributed, making it non-polar, not regions of partial or full charge. A hydrophilic substance is usually polar, where one end or another carries either a full charge or a partial charge.

4. Explain the difference between suspensions and emulsions
   A suspension is a mixture where the particles will eventually settle to the bottom due to gravity. In an emulsion, the particles are much smaller and carry a similar charge on the outside so that they repel each other. This means that in an emulsion, the particles remain in the mixture much longer.

5. Describe the process of denaturing
   Denaturing is the process by which a protein loses its shape and its inherent properties. For example, an enzyme, a special kind of protein that speeds up reactions, needs to have a specific shape for it to be reactive. Sometimes heating an enzyme is enough to change its shape, that means that the enzyme loses its ability to react with a substrate and it is said to be denatured.

6. Why would we want to homogenize milk? How does this process keep particles in milk from settling?
   When milk is homogenized, the fat globules are broken into much smaller particles. This gives the milk more consistency and prevents the suspended particles from settling over time. Whole milk that has not been homogenized, will form a layer of cream at the top. This is how skim milk is made, the cream is allowed to rise to the top and is then skimmed off leaving behind milk with a much lower fat content.

7. Why does denaturing cause milk to float on coffee?
   The denaturing changes the proteins' structure (unfolding), which exposes the water repelling components of the proteins, it makes the proteins hydrophobic. This prevents the milk from mixing.

8. Define viscosity (you may need to do an internet search). Why do you think longer chain molecules would be more viscous than more compact molecules?
   Viscosity is a molecule's resistance to flow. This means that the molecules will not move freely around each other. Larger molecules tangle with each other like spaghetti strands, making it harder for them to move around each other. When poured out, they don't flow easily. More compact molecules, like macaroni pieces, can move around more easily and when they are poured, the liquid can flow. Water is made of compact bent molecules like macaroni, while oil is like long strands of spaghetti.

9. What are the two different ways to make emulsions more stable? Describe each one and how they work.
   One way to make emulsions more stable is to add emulsifiers, like casein. Casein prevents the different substances in milk from clumping up into solids which would settle.

   Another process would be homogenization, where the milk is pushed through tiny holes to make the fat particles smaller. Smaller particles remain in the solution longer.

10. Using intermolecular forces, explain why nonpolar fats do not mix well with water, which is a polar molecule.
    Water is a polar molecule which means that it has a partially positive end (the hydrogens) and a partially negative end (the oxygen). This makes water a polar molecule. These poles interact with each other through hydrogen bonding and dipole to dipole intermolecular forces. Conversely, fats are nonpolar, the electrons are evenly distributed throughout the molecule and there are no regions of partial charge. Because fats are non-polar, they are not attracted to water and the two liquids, water and oil, do not mix.

SHORT ANSWER

"Why do I need to learn chemistry if I want to be a barista?" Using the info you read in the article, explain why chemistry is so important in the coffee business, as well as any form of food service.
Answers may vary, but should include:

- Knowing how milk reacts with other substances (i.e. acids) or with heat in order to make the correct product.
- Knowing how suspensions and emulsions play an important role in creating different drinks and foods. These different types of solutions create different styles and tastes.
- Knowing how milk substitutes will act similarly or differently when making these coffee drinks.

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# 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 and Teaching Strategies

## Additional Resources

### ❖ Labs and demonstrations

- ➢ https://teachchemistry.org/classroom-resources/exploring-intermolecular-forces
- ➢ https://teachchemistry.org/classroom-resources/magic-milk
- ➢ https://teachchemistry.org/classroom-resources/salad-dressing-science-emulsions

### ❖ Lessons and lesson plans

- ➢ https://teachchemistry.org/classroom-resources/making-sense-of-milk
- ➢ https://teachchemistry.org/classroom-resources/dietary-fats
- ➢ https://i0.wp.com/www.compoundchem.com/wp-content/uploads/2018/06/The-chemistry-of-milk-v2.png?ssl=1

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students if they use plant-based milks. Ask how plant-based milks compare to cow's milk. Their initial ideas can be collected electronically via digital whiteboards or similar technology. As they read, students can find information to confirm or refute their original ideas.
- After students have read and discussed the article, ask students what they learned about the chemistry of different types of milk.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Physical properties
- Molecular structure
- Organic chemistry
- Polymers
- Solubility

## 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.

**Disciplinary Core Ideas:**

- PS.1.A: Structure and properties of matter

**Crosscutting Concepts:**

- Structure and function
- Stability and change

**Science and Engineering Practices:**

- Obtaining, evaluating, and communicating information

**Nature of Science:**

- Science is a human endeavor.

See how *ChemMatters* correlates to the **Common Core State Standards** online.

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# Teacher's Guide

## Can Plants Fuel Champions?

## *February 2025*

## Table of Contents

Name: _____

# Anticipation Guide

**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. Vegetarian and vegan athletes compete and win in the Olympics, NBA, WNBA, and other elite athletic events. |
| | | 2. Your saliva contains enzymes that begin the process of digestion. |
| | | 3. Most of the energy humans need comes from proteins and carbohydrates. |
| | | 4. Carbohydrates and fats are broken down into glucose. |
| | | 5. Proteins are needed to make and repair many types of body tissues. |
| | | 6. There are no plant food sources that contain all 9 essential amino acids. |
| | | 7. Eating a variety of foods during the course of a day is important for getting micronutrients. |
| | | 8. Plant cells usually contain $Fe^{2+}$, but not $Fe^{3+}$. |
| | | 9. The primary protein in red blood cells is hemoglobin. |
| | | 10. According to the evidence so far, eating a plant-based diet does not affect athletic performance. |

# Student Reading Comprehension Questions

Name: _____

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

1. Explain the role that saliva plays in the digestion of food.
2. a. What are the three macromolecules found in food?

   b. What role do these molecules play in athletic performance?

   c. Identify the molecule(s) that are primarily used for energy.
3. What are the main differences between omnivore and plant-based diets?
4. Where is energy stored in compounds?
5. a. What is the difference between saturated and unsaturated fat molecules?

   b. Which type of fat contributes more to health problems?
6. a. Amino acids are the building blocks of proteins. Study the image of the amino acids in the article. How many essential amino acids are there and where do they come from?

   b. Draw or build models for two amino acids; identify the amino and carboxyl groups.

   c. Which part of the amino acid molecule gives it unique characteristics?
7. The nine essential amino acids are found in animal-based diets. What plant foods contain all of the essential amino acids?
8. Give some examples of micronutrients and explain why these are so important to human health.

# Student Reading Comprehension Questions, cont.

**Questions for Further Learning**

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

9. Diagram the process of glycolysis. (You may consider using this video explanation: https://www.youtube.com/watch?v=JagPP3MX5ks)

10. Research redox reactions and write the reaction for the reduction of $Fe^{+3}$ to $Fe^{+2.}$

# Graphic Organizer

Name: _____

**Directions**: As you read, use information from the article to complete the graphic organizer below to describe how vegans and vegetarians get nutrition they need for peak athletic performance.

| | Plant Source | Chemicals and chemical processes involved |
|---|---|---|
| **Energy** | | |
| | | |
| **Building materials for the body** | | |
| | | |
| **Importance of iron** | | |

**Summary:** Write a short email to a vegetarian friend, explaining how chemistry can inform their food choices.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Explain the role that saliva plays in the digestion of food.
   Digestion begins in the mouth. Saliva contains enzymes that help convert starch, long molecules composed of multiple connected sugar units, into individual sugar molecules. Additionally, saliva wets the food which helps it travel throughout the digestive tract.

2. a. What are the three macromolecules found in food?
   The three macromolecules found in food are carbohydrates, fats, and proteins.

   b. What role do these molecules play in athletic performance?
   All of them assist in athletic performance, carbohydrates and fats provide energy while proteins help repair the muscles after exercise.

   c. Identify the molecule(s) that are primarily used for energy.
   Carbohydrates and fats provide most of the energy humans require.

3. What are the main differences between omnivore and plant-based diets?
   Omnivore diets are higher in total energy and fat, specifically, saturated fats. Plant-based diets are higher in unsaturated fats and fiber. Additionally, plant-based diets are lower in critical omega-3 fatty acids. Variety is required in a plant-based diet as not all plants provide all of the essential amino-acids. An omnivorous diet provides all of the amino acids needed.

4. Where is energy stored in compounds?
   Energy is stored within the chemical bonds of molecules. Energy is released when the bonds are broken in ATP to make ADP during chemical reactions.

5. a. What is the difference between saturated and unsaturated fat molecules?
   Saturated fats contain carbon chains with only single bonds between carbon atoms, whereas unsaturated fats may contain one or more double bonds between carbon atoms.

   b. Which type of fat contributes more to health problems?
   Saturated fats are considered less healthy and contribute to health issues.

6. a. Amino acids are the building blocks of proteins. Study the image of the amino acids in the article. How many essential amino acids are there and where do they come from?
   There are nine essential amino acids that come from food.

   b. Draw or build models for two amino acids; identify the amino and carboxyl groups.
   The amino group is the $NH_2$ (blue) and the carboxyl group is the COOH (red).

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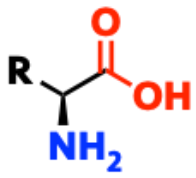


**Generic structure of an amino acid**

c. Which part of the amino acid molecule gives it unique characteristics?
The R group (side chain) is what makes each amino acid unique.

7. The nine essential amino acids are found in animal-based diets. What plant foods contain all of the essential amino acids?
   Plants like quinoa and soy contain all nine essential amino acids. These plants are called complete plant-based proteins.

8. Give some examples of micronutrients and explain why these are so important to human health.
   Micronutrients are vitamins and minerals such as zinc, folate, iron, iodine, and Vitamin A and D that are needed in small (micro) amounts but are critical for specific reactions in the body. Each micronutrient performs specific tasks, for example iron is needed in the heme of the red blood cells to carry oxygen to different parts of the body. Vitamin A is an essential element that protects vision. Micronutrients may not be needed in large amounts but without them our bodies do not function at their best.

**Questions for Further Learning**

9. Diagram the process of glycolysis. (You may consider using this video explanation: https://www.youtube.com/watch?v=JagPP3MX5ks)
   The presentation of the information may vary but it should include that the reactants are glucose, 2 NAD+, and 2 ADP molecules. The products are 2 ATP, 2 NADH, and 2 pyruvate molecules.

10. Research redox reactions and write the reaction for the reduction of $Fe^{+3}$ to $Fe^{+2}$.
    Oxidation-reduction reactions (redox) involve the transfer of electrons. Electrons are lost in oxidation reactions, and gained in reduction reactions. Plants have iron in the $Fe^{+3}$ state which is not bioavailable to humans. In the intestine, reactions take place to transform the $Fe^{+3}$ to $Fe^{+2}$, which can be absorbed.

    $Fe^{+3} + 1e^{-1} \rightarrow Fe^{+2}$

`

# 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. |
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| 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 and Teaching Strategies

## Additional Resources

### ❖ Labs and demonstrations

- ➢ Students will investigate macromolecules in terms of designing the best diet for mealworms. https://teachchemistry.org/classroom-resources/the-effect-of-different-foods-on-mealworms
- ➢ In this simulation, students test various food samples in the laboratory to identify carbohydrates, fats, and proteins. https://gizmos.explorelearning.com/find-gizmos/lesson-info?resourceId=452

### ❖ Lessons and lesson plans

- ➢ Each student can study one of the 20 amino acids shown in the article, learning about its molecular structure, significance, and food sources. Students can create an informative poster on their amino acid.
- ➢ Dietary Fats: Students will learn about dietary fats by analyzing a food label and calculating calories from each macromolecule. Then, they will examine the chemical structures of different fats. (There is also an article on dietary fats included in the lesson.) https://teachchemistry.org/classroom-resources/dietary-fats

### ❖ Projects and extension activities

- ➢ Students read about the correct balance of proteins in our diets. https://teachchemistry.org/chemmatters/april-2018/the-protein-myth-getting-the-right-balance
- ➢ Students can conduct a self-study to learn how to name fatty acids. https://courses.lumenlearning.com/pierce-nutrition/chapter/fatty-acid-naming-food-sources/

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students if they think athletes who eat a plant-based diet can perform as well as their omnivorous peers. Ask them how carbohydrates, fats, and proteins contribute to a healthy diet. Their initial ideas can be collected electronically via digital whiteboards or similar technology.
  - As they read, students can find information to confirm or refute their original ideas.
- After they read, ask students how a knowledge of chemistry can help them make decisions about healthy nutrition.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Organic chemistry
- Molecular structure
- Polymers
- Saturated vs. unsaturated

## Correlations to Next Generation Science Standards

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

**HS-LS1-5.** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy

**HS-LS1-6.** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

**Disciplinary Core Ideas:**

- PS.1.A: Structure and properties of matter
- LS1.A: Structure and function
- LS1.C: Organization for matter and energy flow in organisms

**Crosscutting Concepts:**

- Energy and matter
- Structure and function
- Stability and change

**Science and Engineering Practices:**

- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

**Nature of Science:**

- Science is a human endeavor.

See how *ChemMatters* correlates to the **Common Core State Standards** online.

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# Teacher's Guide

## Bringing Back the Sense of Smell

## *February 2025*

## Table of Contents

Name: _____

# Anticipation Guide

**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. Having a sense of smell alerts you to dangers you would not notice otherwise. |
| | | 2. Your sense of smell is based on chemicals in the air. |
| | | 3. All molecules produce a smell. |
| | | 4. Substances with strong intermolecular attractions have a higher volatility. |
| | | 5. Smells are stronger in hot weather. |
| | | 6. Hydrophilic molecules are smellier than hydrophobic molecules. |
| | | 7. Much of the flavor of food comes from smell. |
| | | 8. E-noses contain semiconductor sensors. |
| | | 9. Our brains interpret signals from our smell receptors. |
| | | 10. Implants that help people who have lost their sense of smell are available now. |

# Student Reading Comprehension Questions

Name: _____

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

1. Each of the human senses involves a part of the body interacting with some external stimulus (*something outside of the body that interacts with the body*) which triggers a response in the nerves to allow us to perceive it. For the sense of smell, what is the external stimulus?

2. There are a lot of molecules in the air that may enter the nasal cavity, yet we don't perceive all of them to have a "smell". Two characteristics that scientists have determined are necessary in any substance for a human to perceive a smell from it are high vapor pressure (or volatility) and hydrophobicity

    a. What is vapor pressure?

    b. Why does a substance need to have high vapor pressure for a human to perceive it?

    c. What is hydrophobicity?

    d. Why does a substance need to be hydrophobic for a human to perceive it?

3. What is a semiconductor?

4. How does a semiconductor act as an electronic nose in certain sensing devices?

5. Why isn't an electronic nose enough to restore a person's sense of smell?

6. Describe, using the particulate view, why the vapor pressure of a substance is higher at a higher temperature.

7. At room temperature, substance A is a liquid and substance B is a solid. Compare the following properties for the two substances: kinetic energy, vapor pressure, strength of intermolecular forces, boiling point.

8. Why is lack of smell considered to be a danger to a person?

# Graphic Organizer

Name: _____

**Directions**: As you read, complete the graphic organizer below to describe why our sense of smell is important, how our sense of smells works, and how implants may help those who have lost their sense of smell.

| | |
|---|---|
| **Three important ways your sense of smell helps you** | |
| | |
| | |
| **Challenges to developing an implant to aid smell detection** | |
| | |
| | |

***In the table below, describe how each property on the left is affected by intermolecular attraction and temperature.***

| Property | Intermolecular Attraction | Temperature |
|---|---|---|
| **Volatility** | | |
| **Vapor Pressure** | | |
| **Hydrophobicity** | | |

**Summary:** On the back of this sheet, write three new things you learned about our sense of smell.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Each of the human senses involves a part of the body interacting with some external stimulus (*something outside of the body that interacts with the body*) which triggers a response in the nerves to allow us to perceive it. For the sense of smell, what is the external stimulus?
   Specific molecules in the air enter the nasal cavity

2. There are a lot of molecules in the air that may enter the nasal cavity, yet we don't perceive all of them to have a "smell". Two characteristics that scientists have determined are necessary in any substance for a human to perceive a smell from it are high vapor pressure (or volatility) and hydrophobicity

   a. What is vapor pressure?
      The measured amount of pressure caused by molecules that have vaporized from the surface of a substance in a closed container. Related, volatility is the ease with which a molecule can be vaporized from the surface of its bulk substance.

   b. Why does a substance need to have high vapor pressure for a human to perceive it?
      The molecule must be able to easily travel through the air, into the nasal cavity, and make it through the body's natural barriers all the way to the protein receptors deep inside.

   c. What is hydrophobicity?
      "Water hating". Molecules that do not mix easily with water due to their molecular structure.

   d. Why does a substance need to be hydrophobic for a human to perceive it?
      A molecule that easily mixes with water will get trapped within the watery substances in the body, such as mucus, and thus will not reach the receptors.

3. What is a semiconductor?
   A material that is able to conduct electricity somewhere between a conductor (a material that conducts electricity easily) and an insulator (a material which does not conduct electricity at all).

4. How does a semiconductor act as an electronic nose in certain sensing devices?
   These are created to detect specific types of chemicals. They are built such that a particular molecule will interact with the semiconductor and change its ability to conduct. This triggers a signal that sounds an alarm.

5. Why isn't an electronic nose enough to restore a person's sense of smell?
   The molecule being detected can produce a signal, but the nerve pathways that lead to a person perceiving smell are still unknown and are very difficult to mimic.

6. Describe, using the particulate view, why the vapor pressure of a substance is higher at a higher temperature.
   Vapor pressure measures the quantity of molecules that can escape from a liquid or gas surface at a given temperature in a closed container. Temperature measures the average kinetic energy of the particles in a sample. When temperature is higher, more particles will have enough kinetic energy to break free from the surface, thus increasing the pressure of the vapor.

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7. At room temperature, substance A is a liquid and substance B is a solid. Compare the following properties for the two substances: kinetic energy, vapor pressure, strength of intermolecular forces, boiling point.
   Higher Kinetic Energy – neither. Both have the same temperature, so both have the same average KE.
   Higher Vapor Pressure – substance A
   Stronger Intermolecular forces – substance B
   Higher boiling point – substance B

8. Why is lack of smell considered to be a danger to a person?
   Our sense of smell can alert us to hazards. It can tell us that a food has spoiled, that there is a gas leak, or that there has been some change to the environment that could be from a safety hazard.

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# 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 and Teaching Strategies

## Additional Resources

### ❖ Labs and demonstrations

- TED-Ed Video: How do we smell? https://youtu.be/snJnO6OpjCs
- Journal article (for teacher background): Is It Possible to Predict the Odor of a Molecule on the Basis of its Structure? *Int. J. Mol. Sci.* 2019, *20*(12), 3018; https://doi.org/10.3390/ijms20123018
- ACS Activity: Amazing Aromas https://www.acs.org/education/celebrating-chemistry-editions/2022-ccew/amazing-aromas.html
- ChemMatters Article, Dec 2001: How We Smell and Why We Stink https://teachchemistry.org/chemmatters/december-2001/chemsumer-how-we-smell-and-why-we-stink
- AACT Simulation Activity: Intermolecular Forces https://teachchemistry.org/classroom-resources/simulation-activity-intermolecular-forces-2
- AACT Simulation Activity: Comparing Attractive Forces https://teachchemistry.org/classroom-resources/simulation-activity-intermolecular-forces
- ChemMatters Toys: The Amazing Drinking Bird https://teachchemistry.org/chemmatters/october-2005/the-amazing-drinking-bird
- ChemMatters As a Matter of Fact: Why Do Eggs Take Longer to Cook in the Mountains? https://teachchemistry.org/chemmatters/february-2000/as-a-matter-of-fact-why-do-eggs-take-longer-to-cook-in-the-mountains
- AACT Lesson, The Great Race: A Study of van der Waals Forces https://teachchemistry.org/classroom-resources/the-great-race-a-study-of-van-der-waals-forces
- AACT Lesson, Properties of Common Molecular Substances https://teachchemistry.org/classroom-resources/properties-of-common-molecular-substances

### ❖ Lessons and lesson plans

- Kinetic Molecular Theory and movement of gas particles
- Intermolecular Forces and properties of liquids and solids
- Energy of Phase Changes
- Study/synthesis of Esters

### ❖ Projects and extension activities

- Why is smell tied to memory and emotions?
- How is Machine Learning helping scientists who study smells?
- What are some applications of an electronic nose (e-nose)?

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students why their sense of smell is important. Ask them how we identify smells, and the challenges that may arise in developing brain implants for people who have lost their sense of smell.
    - As they read, students can find information to confirm or refute their original ideas.
- After they read, ask students what they learned about their sense of smell and the challenges in developing implants that may help people who have lost their sense of smell.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Gases
- Vapor pressure
- Intermolecular forces

## 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-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**Disciplinary Core Ideas:**

- PS1.A: Structure and properties of matter
- ETS1.A: Defining and delimiting engineering problems

**Crosscutting Concepts:**

- Structure and Function
- Systems and system models

**Science and Engineering Practices:**

- Constructing explanations (for science) and designing solutions (for engineering)

**Nature of Science:**

- Science addresses questions about the natural and material world.

See how *ChemMatters* correlates to the **Common Core State Standards** online.

ChemMatters®
Demystifying Everyday Chemistry

# Teacher's Guide

## Beyond Glass: Making Wood Transparent

## *February 2025*

## Table of Contents

Name: _____

# Anticipation Guide

**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. Lignin is rare in nature. |
| | | 2. Lignin, cellulose, and hemicellulose are all hydrophobic. |
| | | 3. Light can pass through organic materials. |
| | | 4. Bleaching chemically changes compounds. |
| | | 5. Cellulose is the most abundant polymer on Earth. |
| | | 6. Air interferes with transparency. |
| | | 7. Light bends when it slows down. |
| | | 8. Air and water have the same refractive index. |
| | | 9. In general, thicker materials are more transparent than thinner materials. |
| | | 10. Transparent wood can withstand more force than plexiglass. |

# Student Reading Comprehension Questions

Name: _____

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

1. What is the primary chemical process used to make wood colorless?
2. How does the removal of lignin affect the optical properties of wood?
3. Why is lignin essential to wood in its natural state?
4. What is the difference between transparent and translucent materials?
5. How does the refractive index of a material affect the way light passes through it?
6. What happens to light as it moves from a medium with a lower refractive index to one with a higher refractive index?
7. Why do some materials appear opaque even if they have the potential to be transparent?
8. Why might transparent wood be considered safer than glass for certain applications?
9. Can a material's transparency change under different conditions? Provide an example.
10. What are some potential applications for transparent wood?
11. What chemical properties of lignin make it challenging to remove?
12. Describe the environmental impact of the chemicals used in lignin removal.
13. How does temperature affect the polymerization process used to fill wood voids?
14. What makes transparent wood more sustainable compared to traditional materials?
15. Discuss the role of hydrogen bonding in the structural integrity of cellulose within transparent wood.

# Graphic Organizer

Name: _____

**Directions**: As you read, use information from the article to complete the graphic organizer below to describe how transparent wood can be developed.

| | Description | Connection developing transparent wood |
|---|---|---|
| **Lignin** | | |
| **Cellulose** | | |
| **Transparency** | | |
| **Refraction** | | |
| **Advantages of transparent wood** | | |

S**ummary:** On the back of this sheet, write a short summary (20 words or less) of the article.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What is the primary chemical process used to make wood colorless?
   The process involves removing lignin, a colored compound in wood that gives it its natural brownish hue. This is achieved through a chemical treatment, often using an oxidizing agent like hydrogen peroxide or sodium chlorite.

2. How does the removal of lignin affect the optical properties of wood?
   Lignin is responsible for the color of wood. Different woods have different amounts of lignin. A dark wood such as walnut has more lignin than beech or pine. The chemical structure of lignin also varies such that the wood absorbs different wavelengths of light. Rosewood, for example, appears pink due to the different chemical units and connections in the structure of the lignin it contains.

3. Why is lignin essential to wood in its natural state?
   Lignin is a polymer that provides rigidity and structural support to wood. It helps bind cellulose fibers together, contributing to the mechanical strength of the material.

4. What is the difference between transparent and translucent materials?
   Transparent materials allow light to pass through without significant scattering, resulting in a clear image. Translucent materials scatter light as it passes through, producing a blurry image.

5. How does the refractive index of a material affect the way light passes through it?
   The refractive index determines the speed at which light travels through a material. A higher refractive index means light slows down more, bending as it passes from one medium to another.

6. What happens to light as it moves from a medium with a lower refractive index to one with a higher refractive index?
   When light moves into a material with a higher refractive index, it slows down and bends toward the normal (the perpendicular line to the surface at the point of contact).

7. Why do some materials appear opaque even if they have the potential to be transparent?
   Materials appear opaque, some light passes through but what is behind the material cannot be seen, when their internal structure scatters or absorbs most of the light, preventing it from passing through. This can occur due to impurities, uneven surfaces, or mismatched refractive indices within the material.

8. Why might transparent wood be considered safer than glass for certain applications?
   Wood is more impact-resistant than glass, meaning it is less likely to shatter into dangerous shards upon impact.

9. Can a material's transparency change under different conditions? Provide an example.
   Yes, transparency can change with conditions like temperature, pressure, or chemical treatment. For instance, glass can become opaque when exposed to extreme heat due to structural changes.

10. What are some potential applications for transparent wood?
    Potential applications include energy-efficient windows, solar panels, and durable, lightweight building materials.

11. What chemical properties of lignin make it challenging to remove?
    Lignin is highly cross-linked, has a random structure, and is resistant to degradation, which means it requires strong oxidizing agents or harsh chemical treatments to break it down.

12. Describe the environmental impact of the chemicals used in lignin removal.
    Some of the chemicals, such as sodium chlorite, can be hazardous and produce harmful byproducts. However, researchers are exploring greener alternatives to minimize environmental impact.

13. How does temperature affect the polymerization process used to fill wood voids?
    Higher temperatures can accelerate the polymerization process, ensuring that the polymer cures evenly and bonds effectively with the cellulose structure.

14. What makes transparent wood more sustainable compared to traditional materials?
    Transparent wood utilizes renewable resources, such as fast-growing trees, and can be produced with less energy compared to traditional glass or plastics.

15. Discuss the role of hydrogen bonding in the structural integrity of cellulose within transparent wood.
    Hydrogen bonding between cellulose fibers provides mechanical strength and stability, ensuring the treated wood maintains its structural integrity after lignin removal and polymer infusion.

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# 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 and Teaching Strategies

## Additional Resources

### ❖ Projects and extension activities

- ➢ In the Shattered Glass Mystery lab, students take on the role of a Forensic Scientist to solve a hit and run investigation by exploring material properties such as density and refractive index. https://teachchemistry.org/classroom-resources/the-shattered-glass-mystery
- ➢ In this video by the Longway Planetarium, a scientist discusses the difference between translucent, transparent and opaque. https://www.youtube.com/watch?v=px3WGDF9Xws
- ➢ In this article "More than Meets the Eye" students can explore refractive index and find the density of glass in two activities. https://teachchemistry.org/pdf/2021/11/17/19/53/56/c4d166d9-0d93-4bdc-a184-1ac66fee87df/glass-more-than-meets-the-eye.pdf

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students if they have ever heard of transparent wood. Ask them what wood is made of, and why wood is not considered to be transparent. Ask them what the advantages of transparent wood might be, and how it might be produced. Their initial ideas can be collected electronically via digital whiteboards or similar technology.
  - As they read, students can find information to confirm or refute their original ideas.
- After they read, ask students what they learned about transparent wood, and where they might find it in their future.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Molecular structure
- Polymers
- Physical properties

## 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-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**Disciplinary Core Ideas:**

- PS.1.A: Structure and properties of matter
- ETS1.C: Optimizing the design solution

**Crosscutting Concepts:**

- Scale, proportion, and quantity
- Structure and function

**Science and Engineering Practices:**

- Asking questions (for science) and defining problems (for engineering)

**Nature of Science:**

- Scientific knowledge assumes an order and consistency in natural systems.

See how *ChemMatters* correlates to the **Common Core State Standards** online.