

**Teacher’s Guide**

**How Sticky Innovations Changed the World**

***October 2020***

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

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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. The idea for duct tape came from a woman working in an ammunition plant during World War II. |
|  |  | 1. Archaeologists have found evidence that early humans made adhesives. |
|  |  | 1. Mortar made from limestone has lasted for thousands of years. |
|  |  | 1. Early adhesives were made from plant and animal materials. |
|  |  | 1. Most adhesives today are made of polymers. |
|  |  | 1. Adhesion and cohesion are the same. |
|  |  | 1. Van der Waals forces are as strong as covalent bonds. |
|  |  | 1. Most synthetic adhesives work well under water. |
|  |  | 1. Unwanted nonpolar adhesives can be removed by using polar products. |
|  |  | 1. Scientists look to nature to develop synthetic adhesives. |

# Student Reading Comprehension Questions

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

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

1. What was the original use for duct (duck) tape? What was the problem with the tape previously used?
2. Explain the differences between a monomer and a polymer.
3. Briefly state the process of making lime mortar. What other substances were added to make the mortar stronger?
4. What monomer is polymerized to make acrylate? What is the chemical name for this popular polymer?
5. Why is it a good idea to press on tape to make it stick to a surface?
6. State the components of the first two adhesives made by humans.
7. Consider two main differences between the terms cohesive and adhesive. Why are adhesive forces needed for tape? Why are cohesive forces needed?
8. Briefly describe ionic and covalent bonds. Compare the strength of these bonds to van der Waals forces, and explain any differences.
9. Consider the phrase “like dissolves like.” What makes a nonpolar substance better at dissolving sticky polymers than water? What type of substances dissolve well in water?

**Student Reading Comprehension Questions, cont.**

1. If you read the directions on commercial adhesives, they typically state that the surface must be clean and dust free. How would a dirty surface affect the adhesive properties?
2. Why would adhesives like DOPA work better than other adhesives underwater?
3. What makes carbon an ideal element to make polymers?

**Questions for Further Learning**

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

1. Research popular adhesives and some of their ingredients. What are some of the additives used to increase the strength of the adhesives?
2. Teflon is the brand name for a chemical coating that is found on many typical cookware items. It’s popular because cooked food does not stick to the Teflon coating, making the cookware very easy to clean. Look up the composition of Teflon, and explain why it has low adhesive properties.

# Graphic Organizer

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

**Directions**: As you read, complete the graphic organizer below to describe adhesives

|  |  |  |
| --- | --- | --- |
| **Adhesive** | **Description and Chemical Formula (if in the article)** | **Approximately when invented and why** |
| **Duct tape** |  |  |
| **Tar** |  |  |
| **Lime mortar** |  |  |
| **Acrylate polymer** |  |  |
| **Biomimetic polymer** |  |  |

**Summary:** In the space below or on the back of this sheet, write three interesting new things you learned about adhesives.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. **What was the original use for duct (duck) tape? What was the problem with the tape previously used?**

*Duct tape was originally designed during World War II to keep ammunition boxes closed with a waterproof seal, but can be easily opened. The previous tape was waterproof, but the pull tab was easily broken.*

1. **Explain the differences between a monomer and a polymer.**

*A polymer is a long chain of similar molecules, typically containing carbon atoms. Each individual part of the chain is called a monomer.*

1. **Briefly state the process of making lime mortar. What other substances were added to make the mortar stronger?**

*When limestone is heated, it decomposes into calcium oxide and carbon dioxide. Water is added to the calcium oxide to make lime putty (calcium hydroxide). This putty is mixed with sand or other hardening agents, and allowed to react with the carbon dioxide in the air to harden into limestone again, as it bonds with the other materials.*

1. **What monomer is polymerized to make acrylate? What is the chemical name for this popular polymer?**

*The monomer n-butyl acrylate forms the polymer chain poly n-butyl acetate. This polymer is the sticky substance in tape.*

1. **Why is it a good idea to press on tape to make it stick to a surface?**

*When you press on the tape, the adhesive will go into and adhere to the insides of the cracks. This extra surface area creates a better adhesion.*

1. **State the components of the first two adhesives made by humans.**

*The first two types of adhesives made by humans composed of heated birch that made a sticky tar, and limestone.*

1. **Consider two main differences between the terms cohesive and adhesive. Why are adhesive forces needed for tape? Why are cohesive forces needed?**

*Cohesive forces are forces between molecules of a substance. This keeps the substance together. Adhesive forces are the forces that attract one substance to another. Tape needs adhesive forces to stick to other objects, but it also needs strong cohesive forces to stay together and not come apart on the other object.*

1. **Briefly describe ionic and covalent bonds. Compare the strength of these bonds to van der Waals forces, and explain any differences.**

*Ionic bonds are positive and negative ions attracted to each other by opposite charges. Covalent bonds are bonds formed by sharing of valence electrons between two atoms. These bonds are much stronger than van der Waals forces. Van der Waals are weak attractions between atomic or molecular particles, and are only effective when the particles are close to each other.*

1. **Consider the phrase “like dissolves like.” What makes a nonpolar substance better at dissolving polymers than water? What type of substances dissolve well in water?**

*Non-polar substances will dissolve polymers better than water because polymers are long carbon chained molecules that have little to no polarity. Water molecules are small and polar. Water will dissolve other polar molecules (like sugars) as well as ionic compounds (like salt).*

1. **If you read the directions on commercial adhesives, they typically state that the surface must be clean and dust free. How would a dirty surface affect the adhesive properties?**

*A dirty surface would prevent the sticky part of the tape to adhere in the grooves of the surface of the object. The dirt would instead be attracted to the adhesive, which means less attraction to the surface.*

1. **Why would adhesives like DOPA work better than other adhesives underwater?**

*DOPA type adhesives contain molecules that have hydrogen bonding in them. Hydrogen bonding is much stronger than van der Waals forces. Since water and other materials have polar or ionic bonds, the hydrogen bonding of the adhesive will form a stronger attractive force with the surface of the object.*

1. **What makes carbon an ideal element to make polymers?**

*Carbon has four valence electrons, which gives it the ability to covalently bond with up to 4 other atoms. This could create a long chain of covalently bonded carbon atoms which would produce a strong, stable polymer.*

**Questions for Further Learning**

1. **Research popular adhesives and some of their ingredients. What are some of the additives used to increase the strength of the adhesives?**

*Duct (Duck) Tape: Contains rubber compounds that increase the strength and longevity of the adhesion.*

*Elmers glue: contains polyvinyl acetate, a common bonding agent. When it dries, it forms the sticky bonds between the surfaces.*

*Super glue: cyanoacrylate is the main bonding ingredient. It bonds instantly with trace amounts of water present.* [*https://home.howstuffworks.com/question695.htm*](https://home.howstuffworks.com/question695.htm)

*Gorilla glue: Polyurethane is the main ingredient. Water activates its bonding properties (which is why you should moisten the area first).* [*www.gorillatough.com*](http://www.gorillatough.com)

1. **Teflon is the brand name for a chemical coating that is found on many typical cookware items. It’s popular because cooked food does not stick to the Teflon coating, making the cookware very easy to clean. Look up the composition of Teflon, and explain why it has low adhesive properties.**

*The formula for Teflon is polytetrafluoroethylene (PTFE). The molecule is a chain of carbon atoms surrounded by bonded fluorine atoms. The bond between carbon and fluorine is very strong. This makes Teflon extremely non-reactive, and can withstand high temperatures. The intermolecular forces of Teflon are very weak, which means the adhesive properties of Teflon is also very weak. Additionally, the composition of Teflon gives the substance very low friction, which helps food slide off easily during cooking.*

*You can find more information here:* [*https://lifehacker.com/why-nothing-sticks-to-teflon-pans-and-cookware-1790527904*](https://lifehacker.com/why-nothing-sticks-to-teflon-pans-and-cookware-1790527904)

*YouTube video:* [*https://youtu.be/uXaP43Zbz7U*](https://youtu.be/uXaP43Zbz7U)

**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

**Lessons and lesson plans**

**Intermolecular Forces Activity:** In this activity, students will represent molecules and energy to investigate the different types of intermolecular forces. They will interact with each other to model the relative strengths of the three types of intermolecular forces.   
<https://teachchemistry.org/classroom-resources/intermolecular-forces-activity>

**Testing Tape Stickiness:** In this activity, students will test the stickiness of different adhesive tapes.

<https://www.acs.org/content/acs/en/education/outreach/celebrating-chemistry-editions/2020-ncw/testing-tape.html>

**How Many Times Can You Stick a Post-It Note?** In this activity, students investigate the stickiness of Post-It notes. <https://www.acs.org/content/acs/en/education/outreach/celebrating-chemistry-editions/2020-ncw/post-it-note.html>

**Exploring Intermolecular Forces:** In this lab, students will investigate the idea that “like dissolves like” by discovering which liquids are best suited for dissolving various substances. This can serve as a great inquiry lab prior to teaching intermolecular forces.

<https://teachchemistry.org/classroom-resources/exploring-intermolecular-forces>

**Making Homemade Glue:** Make your own glue from common household items. Discover how easy it is—all you need is milk, vinegar and baking soda!<https://www.flinnsci.com/making-homemade-glue/dc10207/>

**Other Resources**

**Celebrate National Chemistry Week** October 18–24, 2020 with the theme, "Sticking with Chemistry." Find more educational resources at [www.acs.org/ncw](http://www.acs.org/ncw).

**How Adhesive Tape Works** article: <https://science.howstuffworks.com/innovation/everyday-innovations/adhesive-tape.htm>

**The Different Types of Adhesives** YouTube Video: <https://youtu.be/6qutTkJ4rO8>

**Periodic Graphics – Chemistry of Glue** Infographic: <https://cen.acs.org/content/dam/cen/95/36/09536-sci2.pdf>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Molecules & Bonding
* Intermolecular forces
* Polymers
* Solubility rules

**Correlations to Next Generation Science Standards**

This article can be used to achieve the following performance expectations and dimensions of NGSS:

**HS-PS1-2**

Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

**HS-PS2-6**

Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

**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
* PS2.B: Types of Interactions
* ETS1.B: Developing Possible Solutions

**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 is a human endeavor.

**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 where they use adhesives in their everyday lives, and how they think adhesives are developed. After they read, ask students to give examples of adhesives manufactured throughout history, as well as the future of adhesive development.