



## Polymer Chemistry and Biofuels

### Objective

- How do the results of chemical reactions change when making and breaking bonds in a process that absorbs or releases energy.
- Explain how different factors can affect the rate of a chemical reaction.

**Skill Level:** Middle school

**Class time:** 25 min

### Materials

- 1 small container (per group)
- ½ tsp. of Borax, divided
- 2 tbsp. of White craft glue
- 1 stirring rod
- 1 Ziploc bag
- 1 Marking pen
- Food coloring (optional)

### Next Generation Science Standards

**Disciplinary Core Idea:**

PS1: Matter and its interactions

**Performance Expectations:**

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

**Practices**

- Asking questions / defining problems
- Developing / using models
- Planning / carrying out investigations
- Analyzing / interpreting data
- Math / computational thinking
- Constructing explanations / design solutions

**Crosscutting Concepts**

- Patterns
- Cause and effect: Mechanism / explanation
- Scale, proportion, and quantity
- Systems and system models
- Energy / matter: Flows, cycles, conservation
- Structure and function



Engaging in argument from evidence  
 Obtaining / evaluate / communicate

Stability and change

## Background Information

### **Introduction:**

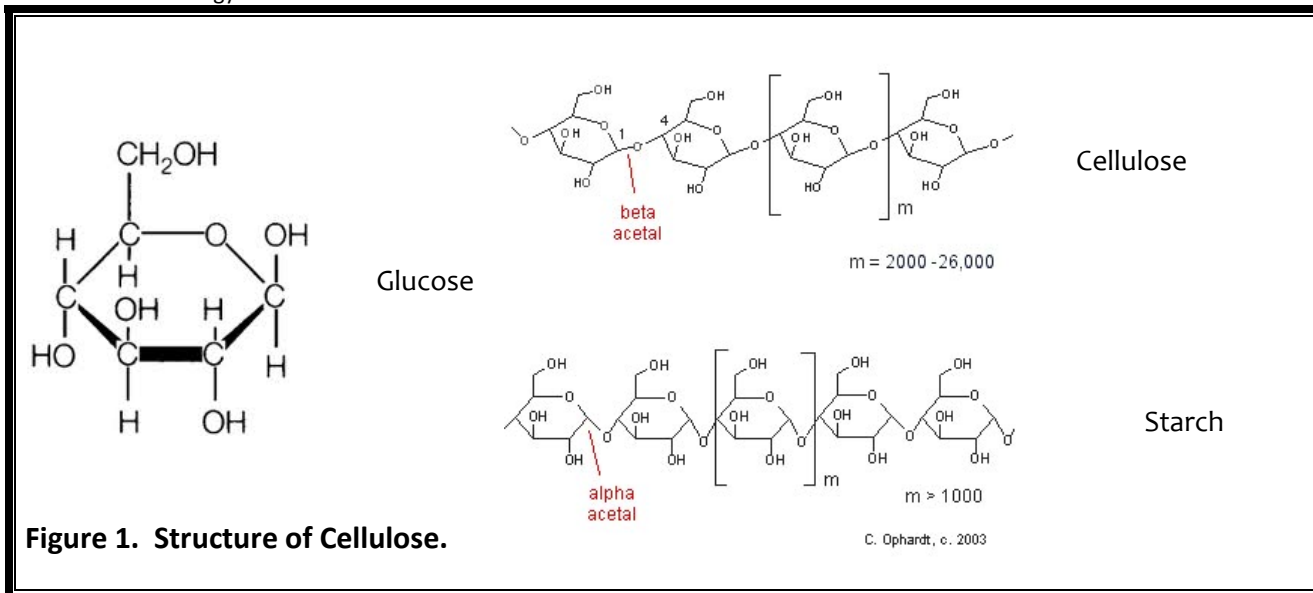
In the production of biofuels, it is important for scientists to understand the chemical structure of various polysaccharides, a polymer of sugar, because the biofuel production process involves breaking these down into simple sugar monomers, such as glucose, which can then be used to produce biofuels like ethanol. The activity below is analogous to what plants do when building polysaccharides like starch and cellulose out of glucose, a product of photosynthesis. Students will be taking monomers found in glue, and using borax to create a polymer.

### **Background:**

The word "poly" comes from the Greek word "many" and "mer" means parts. All *polymers* are made of small repeating molecules, called *monomers*. Polymers can have different properties based on both the individual monomers that form the polymer chain and the arrangement of the polymer chain. Polymers are made up of many molecules strung together in a long chain. Polymers can be made of any molecules but most of them contain Carbon, Hydrogen and Oxygen. Usually, a polymer is made up of one or two types of molecules that repeat down the chain. Polymers can also have branches and multiple chains. Linear polymers have a tight arrangement that leads to a sturdy and rigid polymer. There are many types of polymers that we interact with on a daily basis. For example plastics are made up of polymers that determine the properties of plastic. Teflon, soft-drink bottles, milk containers and garden hoses are examples of products that are from linear polymers. Branched polymers are softer and more flexible than linear polymers because they have a looser structure. Examples of branched polymers are soft, flexible plastics such as plastic food wrap and ketchup squeeze bottles. Polymers are everywhere! Erasers, grocery bags, disposable dishes and utensils, shoes, CDs, clothing, car parts – all of these are made of polymers.

Polymers can be either natural or man-made. The building blocks for making plastics are small molecules that contain carbon along with other substances. They generally come from oil (petroleum) or natural gas, but they can also come from other organic materials such as wood fibers, or corn.

Oil and natural gas are the major raw materials used to manufacture most plastics. Replacing petroleum-based plastics with plastics made from renewable raw materials, such as plants, reduces our dependence on fossil fuels. Replacing petroleum-based plastics with plastics designed to degrade, biodegrade, or compost can provide even more environmental benefits.



## Engage

Natural polymers such as silk and wool aren't very abundant, so it's hard to mass-produce things using them. Manmade polymers are usually made from fossil fuels that are scarce and cause pollution.

Energy can be saved and pollution can be prevented if we reduce the amount of plastic we use by making biodegradable plastic that can degrade soon after it has been thrown away. Research has shown that under optimal conditions (such as an industrial compost center), biodegradable plastic will degrade in 45-100 days compared with manmade plastics, which takes at least 100 years. Biobased and compostable plastics, also known as bioplastics, hold the potential to reduce dependence on fossil fuels, foster the development of more sustainable products, and increase the diversion of food waste from landfills. However, bioplastics also present challenges and create uncertainty for a wide array of stakeholders. Inconsistencies in product labeling and a lack of accepted definitions for industry terms cause confusion for consumers upon purchasing and when discarding the products. Improperly sorted bioplastics can contaminate recycling streams, contaminate feedstock for composting operations, or end up buried in a landfill. Inconsistent rates of decomposition from product to product can impede commercial composting operations. When bioplastics are disposed in the trash and sent to the city landfill, the plastic won't degrade any faster than any other plastic. This is because heat, sunlight and oxygen are required for the decomposition of the poly(lactic acid) and it is difficult for sunlight and oxygen to penetrate the tons of soil and thick plastic liners of a landfill. It is also difficult to achieve the required composting conditions in the compost pile in ones backyard.



## Explore

### Experiment Questions:

- Plastics are polymers, what kind of examples of them can you think of in everyday life? Make a list of all the polymers that you see around. Can you recognize which ones are synthetic and which ones are natural?
- What are some of the characteristics of polymers?
- What are some examples of things that are not polymers? (brick, glass, metals etc).
- Use paperclips to create linear and branched polymers. Pull strands tight and notice how they become rigid and how the branched polymer retains flexibility while keeping a rigid structure.
- Work in groups to design a polymer ball before starting the experiment. Do you want a ball that will be bouncy? Last the longest?

### Procedure:

1. Draw the polymer chains of glucose, starch, and cellulose for students. Walk them through the carbon structure and answer any questions they may have about the basic chemical bonds of polymers.
2. Pour 1 tablespoon of white glue into the small container.
3. Add  $\frac{1}{4}$  tsp. borax to the dish.
4. Add food coloring (if desired).
5. Wait 15 seconds to allow the ingredients to react.
6. Stir vigorously with a stir stick until the mixture becomes a gummy, solid mass.
7. Roll the ball between the palms of your hands to mold it into a sphere.
8. Once the ball is no longer sticky, go ahead and bounce it!
9. You can store your plastic ball in a sealed ziploc bag when you are finished playing with it.
10. Don't eat the materials used to make the ball or the ball itself.

## Explain

- What, if any, of your observations are indicative that a polymer was forming/ formed?



- Compare balls with other members of the class. What makes them different?
- Why do you think the balls are sticking together? What is holding it together? What conclusions can you draw about the properties of polymers?
- Could you break the ball back down into its smaller components or to its original form? Why would this be challenging? Are all polymers easy to breakdown to monomer units?
- How does knowing about polymers help us understand biofuel creation?

### Elaborate

- Use gel craft glue (1 tbsp.) instead to make the bouncy ball. What is the difference? Why would there be a difference? What does this tell us about cell walls?
- Experiment with using different concentrations of glue and borax. What would happen if more or less glue, water, and borax was used? What if borax wasn't added to the mixture?

## Resources

### Additional Resources:

- This activity was adapted from the U.S. Department of Energy, Energy Efficiency and Renewable Energy Program's K-12 Lesson [Cell Wall Chemistry of Biofuel](#). (Click links)
- [Chemistry – Fun with Polymers!](#)
- [Biomass Energy From Plant Matter](#)
- [Biomass Energy Basics](#)
- [Exploring Ways to use Biomass](#)
- [PennState Center for nanoscale science](#)
- Nobel Prize [website](#)
- Bioplastics 101 -A [primer](#) on bioplastics the compostable alternative.
- [Compostable Plastics 101](#): An overview of compostable plastics.
- Polymer [prezi](#)
- Industrial composting [guide](#)