

## **NREEd: Teaching Science at Home**

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### **Background**

*Energy can be an overwhelming topic. Especially when you start thinking about all the ways energy is used every minute of every day. There is electrical energy, chemical energy, thermal energy, radiant energy, and the list goes on. Luckily, since it is so important to our lives, the easiest place to start is just by talking about energy! Simple but meaningful [conversations](#) are some of the best teaching tools available.*

*Energy is defined as the ability to do work. NREL studies many different sources of [renewable energy](#). These sources provide us with many different types of energy like electricity and heat. Heat is a necessary energy component to all experiments. (Heat is also critical to our perception of time. Here is a [super interesting podcast](#) exploring just that.) Anytime a reaction occurs, heat is either required to push the reaction forward (endothermic) or it is a product of the reaction (exothermic).*

### **Invisible Ink!**

*In this experiment, heat will catalyze the reaction between the paper and citric acid and reveal a secret message!*

### **What you need:**

- Lemon juice, vinegar, orange juice, grapefruit juice, lime juice, apple juice, milk, or any other acid
- Paper
- Q-tip
- Hair dryer, iron, or high-wattage lightbulb (think old incandescent)

### **Optional:**

- Rubbing alcohol, water, or other liquids that you have lying around
- Pencil or pen

### **Procedure:**

1. Dip the Q-tip into the lemon juice to soak it. Now draw on the paper. You can write words, draw pictures, and be creative. Let the paper dry completely (10-15 minutes).

What can you see? Is it hard to read your message or see your picture?

2. Hold the hair dryer five inches from the dry page and turn it on. Keep heating until the message begins to appear. (If using an iron, you will want to move quickly so the paper does not catch on fire. This is better done by an adult.)

The acid in the different liquids breaks down the cellulose of the paper. Where this reaction has occurred, oxidation is able to take place at a lower temperature than the rest of the paper, so the message turns brown, and the rest of the paper stays white.

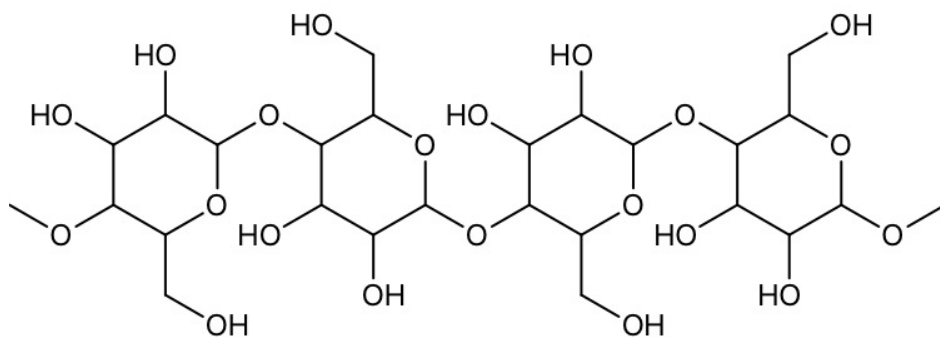
## Further Discussion:

If you used more than one liquid, which worked the best? What do you think this means about this acid's acidity? Did rubbing alcohol work?

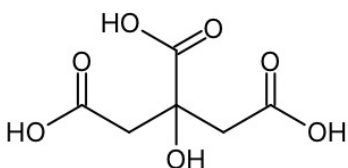
For more information about oxidation in food, check out this [link](#)!

## The Science

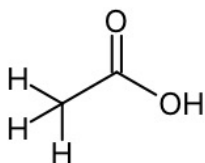
At the Education Center, we are always helping students and adults understand more about energy and the research NREL is doing around energy. Just like this reaction, we like to take things that seem magical, and help people understand how science makes it happen! Here are the key players in the above reaction that makes your message appear.



Cellulose is a polymer. This means it is a long chain of sugars. Specifically, cellulose is long chains of glucose. The cellulose shown above is made up of three glucose molecules. Can you find them?



Citric acid is found in citrus fruits. It is what gives lemons and limes their sour taste. It is an organic acid, which means it is made of carbon, hydrogen, and oxygen. Compared to other acids, it is fairly weak. Strong acids are chemicals like hydrochloric acid and sulfuric acid.



Acetic acid is found in vinegar. Even though most vinegars are only between 5-10% vinegar (meaning it is mostly water), what you smell and taste is the acetic acid. This is also the compound that reacts with baking soda to make the explosive reaction that you might have seen before. It also makes an excellent cleaning solution!