STEM IN THE LAB

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Idaho National Laboratory

LAUNCH HOMEMADE BAKING SODA ROCKETS

Have you ever enjoyed watching something lift off into the air, like fireworks at a show or a spacecraft launching? It can be an amazing experience. It is thrilling to see something lift off against Earth's gravity. To launch a spacecraft, its rockets give it a strong push that is due to a chemical reaction. This means that every time you see a spacecraft launch, you are watching chemistry at work. In this activity you will get to blast an object into the air using two simple ingredients— baking soda and vinegar. Investigate how to mix these ingredients to get the best lift off, and then you could give your friends and family a homemade, gravity-defying show!

Idaho National Laboratory and NASA collaborate to develop new nuclear fuels that will make nuclear thermal propulsion (NTP) rockets a reality. The goal is to identify the best materials, composite structures, and optimum uranium compounds needed for production of fuels that are robust, reliable, and cost-effective for the harshest of environments. Nuclear thermal propulsion (NTP) rockets use a nuclear reaction to heat liquid hydrogen. When the hydrogen is heated, it expands and is forced through a nozzle to produce thrust. This is similar to how air can stream out of the stem of a balloon and cause it to fly across the room. With rockets, this happens with much greater speed and force. INL researchers use the Transient Reactor Test Facility (TREAT) to determine if new candidate fuels can endure the extreme heat and pressure that would exist in a nuclear thermal rocket.

GRADE LEVELS: K-8

VOCABULARY

Chemical reaction- *a process that involves rearrangement of the molecular or ionic structure of a substance, as opposed to a change in physical form or a nuclear reaction.*

Gravity- *the force that attracts a body toward the center of the earth, or toward any other physical body having mass.*

Rocket- *a cylindrical projectile that can be propelled to a great height or distance by the combustion of its contents, used typically as a firework or signal.*

MATERIALS

- *Plastic film canister with a lid and tight seal. Fuji or Kodak canisters should work. Tip: Try asking a local camera shop for empty canisters.*
- *Baking soda*
- *Measuring spoons*
- *Wax paper or bowl*
- *Spoon*
- *Water*
- *Vinegar*
- *An open outdoor area at least two meters from buildings. It is ideal to have a hard, flat surface, like a paved patio or driveway.*
- *Safety goggles*
- *Rag or paper towel*
- *Optional: Construction paper, transparent tape, stickers, and scissors*

PROCEDURE

PREP WORK

1. *In this activity when you launch your film canister rocket, be sure to wear eye protection! The rockets really do fly with a lot of force and should not be pointed at people or breakables.*

INSTRUCTIONS

1. *If you want, you may decorate your film canister rocket. You could wrap a piece of construction paper around the film canister and cut the paper, so it just covers the canister's sides (but does not go above or below the sides). After evenly wrapping the paper on the canister, secure it with some tape. You can add additional flat decorations, like stickers or drawings. Make sure it is still easy to put the lid on.*
2. *Place 1 teaspoon (tsp.) of baking soda onto the wax paper or bowl. Add 1/8 tsp. of water to the baking soda and mix it in well. (If you do not have 1/8 tsp. measuring spoon, fill a ¼ tsp. measuring spoon about half full.) If you are using wax paper, you can carefully use the wax paper to fold the damp baking soda onto itself to help mix in the water.*
3. *Turn the film canister lid upside-down and pack the inside of the depression with the damp baking soda. (Do not put baking soda where the canister snaps onto the lid.) Pack it tightly. Turn the lid right side-up again for a moment. Does the damp baking soda stay in place? If it stays, move on to preparing the vinegar, in the next step. If the baking soda falls out, then add a little bit more water to the baking soda and mix it in but try to add as little water as needed. The baking soda will not need to be able to stay in the lid long.*

4. *Add 1 tsp. of vinegar to the canister at a time, filling it almost to the top. You need to add as much vinegar to the canister as possible without the vinegar and the baking soda coming into contact when you later snap the lid onto the canister. Depending on the exact canister, this may be around 5 tsp. of vinegar. How much vinegar did you use?*
5. *Go outside to an open area at least six feet from buildings.*
6. *Put on your safety goggles. Stoop down near the ground on a flat, hard spot and quickly snap the lid onto the canister to seal it. Immediately turn the canister over, so the lid is on the ground, and quickly move away. Wait for the chemical reaction to occur.*

   How long does it take to happen? When the lid pops off, the rocket should launch — how high does the canister go?

7. *Tip: If the rocket did not launch, the lid might not have been sealed tightly enough. (If this happens you may simply see many bubbles coming out of the canister.) The rocket may not have launched right for some other apparent reason (such as not sealing the lid fast enough). If it did not launch right, try preparing and launching the canister rocket again. You may need a little practice to get used to launching the rocket.*
8. *Carefully rinse out the lid and canister with water and then dry them. If your canister is covered by construction paper, make sure it does not get too wet.*
9. *Prepare the damp baking soda and vinegar as before but this time use a little more than half the original amount of vinegar. For example, if you used 5 tsp. of vinegar, this time use 3 tsp. (Still use 1 tsp. of baking soda.)*
10. *Again, put your safety goggles on and launch your newly prepared canister rocket.*

    Does it take longer, shorter, or about the same amount of time as the first rocket did to launch? Does it go a higher, shorter, or about the same distance?

11. *Lastly rinse the lid and canister with water, dry them, and prepare them as before but this time use 1 tsp. of vinegar (or around 1/5 the original amount of vinegar that you used). Put your safety goggles on and launch the canister rocket. How long does it take to launch compared to the other two launches? How high does the canister go compared to the previous two times?*
12. *If you are unsure of any of your results, you can try repeating them (using the same amount of baking soda and vinegar).*

    What amount of vinegar led to the highest launch height? Why do you think this is?

CLEANUP

If you launched your rocket on a concrete surface, spray the surface down with some water to clean it when you are all done doing your launches.

WHAT HAPPENED?

When baking soda and vinegar are mixed, the reaction produces water and carbon dioxide gas. Do not worry — the small amount of carbon dioxide is not harmful to you! It is one of the gases you breathe out when you exhale, and a gas that plants want to take in when they do their version of "breathing".

In the capped film canister, the carbon dioxide gas builds up until the pressure of all the contained gas causes the canister to pop open. The pressurized carbon dioxide then quickly escapes the canister through the open bottom. The rapid escape of the gas forces the rest of the canister to be tossed in the air — just like the release of air from the open end of a balloon can cause a balloon to fly. This is how the chemical reaction provides the thrust the canister needs to launch.

You may have noticed that when the least amount of vinegar was used, it took a little longer to launch than when more vinegar was used but the launch height was higher. Because there is less vinegar in the canister, there is more space for carbon dioxide gas to fill. It takes longer for enough carbon dioxide gas to be made to fill this larger space so that there is enough pressure in the canister to pop the lid open like it did before. In our trials, the rocket nearly full of vinegar launched roughly 6 feet up into the air, but the rocket filled with the least amount of vinegar flew more than twice as high — nearly 15 feet!

THE SCIENCE BEHIND IT

Unlike a liquid (like water) or a solid (like rock), a gas can be squeezed (technically we say it is compressed) so that more of it fits in the same space. This is because a gas has lots of space between its molecules. You can think of it like a stuffed teddy bear. The cotton stuffing has lots of empty air space too, which means you can keep squeezing (compressing) the stuffing and adding more. As you add more stuffing, the bear gets firmer. Eventually if you added too much stuffing the pressure would be so great that the teddy bear's seams would split. This is close to what happens in this rocket experiment. The vinegar and baking soda react making carbon dioxide. The longer they react, the more gas is made. The carbon dioxide compresses in the empty part of the container until the pressure is so great it causes the cap and canister to pop apart. The lid is pressed downwards by the pressure, but it is lying on the ground, so it goes nowhere. The canister is pressed upwards and thus flies into the air.

When the rocket is built with a lot of empty space inside of it (in other words, when it has very little vinegar), there is more room for the carbon dioxide to fill, so it becomes more fully filled with the gas. This means that it also takes longer (the reaction that makes the carbon dioxide can only happen so fast) for the pressure to build up. The result is a longer wait time for a much higher rocket launch.

EXTENSIONS

- *You can try varying the amount of vinegar even more and see how this affects the rocket's launch, such as using 1 tsp., 2 tsp., 3 tsp., etc., of vinegar. (You could also repeat the same conditions you tested to see how consistent your results are.) How does changing the amount of vinegar in the canister change how it launches?*
- *You could try changing the amount of baking soda (but keeping the amount of vinegar the same) and see how this affects the canister's launch. For example, you could try comparing 1 tsp., ¾ tsp., ½ tsp., and ¼ tsp. of baking soda. (Adjust and use just enough water for the baking soda to stick to the depression in the lid.) How does changing the amount of baking soda in the lid affect the canister's launch?*
- *Add a cone and fins to your rocket (such as out of construction paper) and launch it again using the best conditions you found. How does adding these components affect the canister's launch?*

RESOURCES

- *https://www.sciencebuddies.org/stem-activities/rockets-baking-soda#summary*

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