Homemade Fire Extinguishers and the Ideal Gas Law

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Question: How far will a homemade fire extinguisher shoot if we change the bottle size or the amount of baking soda?

Answer: The distance a homemade fire extinguisher shoots is proportional to the pressure inside the bottle. The pressure inside the bottle is governed by the ideal gas law given by

$$PV = nRT \tag{1}$$

P is the pressure inside the bottle
V is the volume of the bottle
n is the number of moles of gas inside the bottle (essentially the amount of gas in the bottle)
$R = 0.082057 \frac{atm \cdot L}{mol \cdot K}$ is the ideal gas constant
T is the temperature in Kelvin

If we solve the equation for pressure, we get

$$P = \frac{nRT}{V} \tag{2}$$

Changing the Bottle Size
Changing the bottle size means you are changing the volume. If you use a bigger bottle (keeping everything else the same), then V is larger. Since we divide by V in the idea gas equation to find P, that means that when V is larger, P is smaller.

$$P \downarrow = \frac{nRT}{V \uparrow} \tag{3}$$

This means that if you make the bottle bigger, there will be less pressure in the bottle and the fire extinguisher will not shoot as far.

Changing the Amount of Baking Soda
Changing the amount of baking soda changes the amount of gas produced when the baking soda reacts with vinegar (assuming you use enough vinegar to react with all of the baking soda). That means that if you use more baking soda, you will produce more gas. Having more gas means that you have more moles of gas which means that n gets bigger. Since we multiply by n in the idea gas equation to find P, that means that when n is larger, P is larger.

$$P \uparrow = \frac{n \uparrow RT}{V} \tag{4}$$

This means that if you use more baking soda, there will be more pressure in the bottle and the fire extinguisher will shoot farther.

Making the Fire Extinguisher Shoot the Farthest
In order to get the homemade fire extinguisher to shoot the farthest, you will want to use a small bottle and a lot of baking soda. However, keep in mind that the size and shape of the bottle opening will also affect how far the fire extinguisher shoots. Always remember to be careful and wear safety goggles when experimenting. Creating high pressures in closed bottles can cause dangerous explosions.