

Science Lessons for Several Grade Levels (3-5, 6-8, 9-12)

“Exploding Trash Can Volcano”

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Discipline: Geology, Volcanology

Grade: 3 to 5, 6 to 8, 9 to 10, 11 to 12

Standard

Project 2061 Benchmarks: 1A/E1*, 1A/E2**, 1A/M1b, 1A/H3bc*, 1B/E1*, 1B/E2a*, 1B/E2b, 1B/E3a, 1B/M1b*, 1B/M2ab, 1B/H2, 1B/H9**, 1C/E1, 2B/M1*, 4B/E1, 4B/M3, 4C/M1, 4C/M2a

Purpose/Goals

Students should know that explosive volcanic eruptions are gas driven phenomena and that there is no ‘hot fire’ that causes the eruption.

Students should also know that changing the amount of gas or the amount of material on top of the gas will change the size and intensity of the eruption.

Students should be able to calculate the height of the eruption column using trigonometry and should be able to calculate eruption velocity and pressure by rearranging and solving given equations.

Context

A common misconception is that there is some kind of fire or hot explosive involved in volcanic eruptions. This is not true. Explosive volcanic eruptions are fundamentally gas-driven phenomena. Hot magma at depth has volatiles dissolved in it. As this magma moves towards the surface, it cools and is exposed to less pressure, both of which decrease the amount of dissolved volatiles it can hold. As these gases exsolve out of the magma, they aid the magmas ascent and drive the eruption. When the pressure is released, it is similar to what happens when you shake a soda bottle and open the top, but much larger and more sustained.

Preparation

Students need to have a knowledge of the rock cycle and generally how igneous rocks form. They should also be able to do trigonometry or handle it if it is explained to them. The other calculations are just algebra and should be pretty straightforward. The materials needed are: a 32-gallon industrial strength rubber trashcan, 2 bricks, duct tape, multiple 16oz-2L soda bottles with caps, safety glasses, insulated gloves, plastic funnel, liquid nitrogen, hose.

The teacher will also need to print off activity sheets describing the experiment and safety measures as well as how to do the calculations.

Website

None

Motivation

Have a discussion with the students about volcanoes either before you’ve talked about them in your earth science section or before you do this activity to find out what the students think is the cause behind volcanic eruptions. During this discussion, you will find out if there are any misconceptions among the students such as thinking that there is a hot explosive causing volcanoes to erupt. Talk with the students about the materials that are ejected from volcanoes during explosive volcanic eruptions and find out what they think about how big they are, how fast they can move through the air, and the kind of pressures required to make these objects move so fast. These are some of the major questions being investigated in this activity.

Description

The Exploding Trash Can Volcano lesson is a lesson about explosive volcanic eruptions and what drives them. First the teacher should do a review of volcanoes or teach the students about volcanoes as part of the class. Focusing on the nearest recently active volcanoes is a good idea because it makes the lesson more real for the students because they may have been to those places or seen pictures of them. Describe the activity to the

students making sure they understand how dangerous liquid nitrogen can be and that it must be handled carefully. Have the students come up with hypotheses regarding how to affect the column height. Will changing the amount of liquid nitrogen alone do it? Will changing the size of the bottle do it? Will changing the amount of water over the bottle affect the column height? What about a combination? After the students make their hypotheses and design a few experiments to test them, go outside to start the experiment. Fill the trash can $\frac{3}{4}$ full with water from the hose. Duct tape the bottle to the bricks and test to make sure it submerges and stays upright. Then get the two demonstrators in place, one being the teacher, the other being an aide or a very responsible and trusted student. The two demonstrators should have on safety glasses and rubberized or insulated gloves. Do a practice run or two without liquid nitrogen to make sure both demonstrators know their roles. One should be holding the funnel in the top of the soda bottle that is duct taped to the bricks, leaving a gap around the sides of the funnel so gas can escape out the top of the bottle otherwise the liquid nitrogen will just bubble out the top of the funnel. The other demonstrator should be pouring the liquid nitrogen into the funnel carefully so it doesn't spill too much or splash all over the other demonstrator. The standard amount of liquid nitrogen to pour in is ~1 inch depth in the bottom of the bottle. Once the liquid nitrogen is in the bottle, the demonstrator doing the pouring should cap the liquid nitrogen container and walk away. While they are doing this, the other demonstrator should toss away the funnel, cap the bottle and then quickly (within ~10 seconds of capping) place the bottle assembly in the water and walk away quickly. The students should have been placed a safe distance away (~25-30 feet) and should be waiting with compasses with clinometers to measure the angle to the top of the column at its highest point. Once this measurement is obtained from each experiment, the calculations can be done. Calculate the height of the column by doing the tangent of the angle to the top of the column. You know the angle and the adjacent side (distance from trash can), so just rearrange and solve. Then use the standard projectile equation ($\text{Height} = \frac{U^2}{2g}$; $U = \text{ejection velocity}$, $g = \text{acceleration due to gravity}$) to calculate the ejection velocity of the water. Then you can use the modified Bernoulli equation to calculate the pressure it took to propel the water out of the trash can [$\frac{1}{2}U^2 = \frac{(P_i - P_s)}{S}$; U is same, $P_i = \text{reservoir pressure}$ (what you want), $P_s = \text{atmospheric pressure}$ (typically 101,325 Pascals), $S = \text{density of fluid}$ (water is typically 1000kg/m³)].

Assessment

Have students research a specific volcano and document its eruption style and history. Does it erupt the same way every time or does it vary? Why might these variations occur? Think about what you varied in the exploding trash can experiment. You could also give the students scenarios with different starting values and see if they can do and understand the calculations on their own.

Follow-Up Activities

Consider having students do a research project on a volcano that interests them and make a presentation to the class. For older classes such as high school, you could consider having the students make a website about their volcano.