KA—BOOM! Measuring the Explosivity of a Volcanic Eruption

What's 10 x 10? That's easy—100. OK, so what's 10x10x10? Hmmm... 1,000.
And how about 10 x 10 x 10 x 10? Wait! Is this a math quiz or an activity about volcanoes?
It's both, actually.
Volcanic eruptions are measured according to a logarithmic scale called the Volcanic Explosivity Index, or VEI. Volcanic eruptions are classified from 0 to 8 on the VEI scale. An eruption classified as a VEI-1 is ten times more explosive than a VEI-0 eruption, and a VEI-4 is 10 x 10 x 10 x 10 times more explosive than the VEI-0. The Richter Scale, comparing magnitudes of earthquakes, and Moh's Hardness Scale, which compares the hardness of minerals, and star brightness – called magnitude - are expressed in a similar logarithmic manner

The table below gives you a feel for how the scale applies to actual volcanic eruptions that have occurred throughout Earth's history. Note the numbers that indicate the volume of tephra that is expelled during an eruption. For the VEI, ***all*** volcanic material, including lava, ash, rock is included in that volume.

VEI	Tephra Volume (km^3)	Plume Height	Description	Example
0	Not rated	< 100 m	Nonexplosive	Kilauea (Hawaii), continuing
1	>0.0001	100 – 1000 m	Gentle	Poas (Costa Rica), 1996
2	>0.001	1 – 5 km	Explosive	Stromboli (Italy), 2004
3	>0.01	3 – 15 km	Severe	Surtsey (Iceland), 1963 Etna (Italy), 2003
4	>0.1	10 – 25 km	Cataclysmic	Pelee (West Indies), 1902 Paracutin (Mexico), 1943
5	>1	20 – 50 km	Convulsive	St. Helens (Washington), 1980 Vesuvius (Italy), 79 AD
6	>10	> 50 km	Colossal	Krakatoa (Indonesia), 1883 Pinatubo (Philippines), 1991
7	>100	> 50 km	Supercolossal	Tambora (Indonesia), 1815 Mazama (Oregon) , 5700 BC
8	>1,000	> 100 km	Megacolossal	Yellowstone (Wyoming), 2.1 mya, 1.3 mya, 640,000 ya

Tephra volume isn't the only piece of data used to measure an eruption's explosivity. Volcanologists also look at the plume height, or how high the erupting cloud of ash reached into the sky during an eruption. Volcanologists also measure distances of impact - that is, how far into the surrounding area the erupting gas and tephra are blown.

When Mt. St. Helens blew in May 1980, it belched out 2 km^3 of tephra in a powerful explosion that rated a 5 on the VEI scale. The eruption propelled an ash and gas column almost 15 miles into the atmosphere, high enough to reach the top of the troposphere and into the lower stratosphere. Within the eight mile region closest to the volcano (the direct blast zone), virtually everything was obliterated or blown away. Destruction reached another 11 miles from this zone, impacting a region nearly 20 miles wide adjacent to the volcano.

Yet, comparing the 1980 Mt. St. Helens VEI-5 blast to a VEI-8 eruption would be like comparing a firecracker to a nuclear bomb. As large as the Mt. St. Helens blast was, the explosion produced from a VEI-8 volcano would be 1,000 times greater, causing widespread destruction for hundreds of miles. A VEI-8 eruption would be powerful enough to propel huge volumes of fine ash and dust up into the stratosphere - so much so that Earth's climate could cool as a result of global shading by the ash and gas cloud and some species of living things would die and go extinct.

On the other extreme, volcanic activity at Kilauea in Hawaii is nonexplosive - it tends to churn out lots of lava without explosive fanfare. If Mt. St. Helens is a firecracker, then Kilauea is an overheated chocolate bar oozing out of its packaging. This explains why Kilauea can attract so many visitors and tourists – like myself - to explore and photograph it. It is also the most monitored and studied volcano in the world – more volcanologists, geophysicists, geochemists and other type of geologists have spent time studying Kilauea and its features and effects.

Why are volcanoes so different in their explosive behavior? The answer is as complex as the number of volcanoes on Earth - each behaves in unique ways as the result of many factors. However, it is possible to make some generalizations about explosivity, based on the nature of the magma within a volcano. Magmas that are very viscous and contain large amounts of trapped gas (water vapor, carbon dioxide, and sulfur dioxide) tend to erupt violently. Gases cannot escape from these viscous magmas easily - the more viscous the magma, the larger the energy needed to expel gases within it. Trapped, these gases build up pressure until they achieve enough force to blast out of their underground confinement. Then, ...KA-BOOM! The gases are released in a single, explosive event. Low explosivities occur when magma is thin and runny. Gases escape readily from such magmas and find their way out from under ground through cracks and crevices. Fluid lava burbles out periodically and nonexplosively in such cases.

<u>The KA—BOOM! Activity</u>

A volcano erupts when the pressure of gases within an underground magma chamber becomes great enough to break it way through confining rock to the surface. In a similar way, this experiment allows you to create pressurized gas within closed plastic bottles, and then you need to stand back to watch your volcanoes "erupt." The familiar stomach aid Alka-Seltzer is the source of gas - these tablets contain both citric acid and sodium bicarbonate, which react to form carbon dioxide once they are mixed in water. Liquid dish detergent provides the foaming action to simulate superheated magma.

As we now know, the Volcanic Explosivity Index (VEI) uses the volume of material that is ejected from a volcano as a measure of the power of its explosion—the greater the explosive energy, the greater the amount of volcanic material released. You can simulate lava by using dishwashing liquid dissolved in water, and measure how much each "volcano" produces by catching the "lava' in a container and then measuring the volume that you collect. You can also estimate the eruption height as well as the overland distance traveled by the erupting material. With a timer, you can measure how long the eruption lasts. By varying the amount of Alka-Seltzer you use, you can vary the pressure inside your "volcanoes" and then determine the resulting effect on the eruption.

<u>Materials:</u>
Plastic water bottle, liquid dish detergent, large dishpan, plastic wrap, rubber bands, toothpicks or paper clips, meter stick, small measuring cup or graduated cylinder, Alka-Seltzer tablets

<u>Directions:</u>

1. Place the dishpan in the center of the lab table.
2. Fill a plastic bottle with water to a designated level, leaving a small gap of air at the top. Add about ½ to 1 tablespoon of the liquid dish detergent to the bottle. Place the bottle upright in the dishpan at a location where you can observe it from a distance of a few feet.
3. But first - **<u>complete your hypothesis</u>** on a separate piece of paper. A good hypothesis form for budding volcanologists like yourselves is the "If…then" or "when…then" form. Incorporate this hypothesis into your lab report. For example:
   - When the alka seltzer tablet is added to the water-detergent mixture, then…
   - When the number of tablets added to the water-detergent mixture *<u>is increased</u>*, then…

4. NOTE: YOUR HANDS MUST BE DRY FOR THIS STEP! Alka-Seltzer tablets are too large to fit through the bottle openings, so break them in half. Use a towel to cover them when you break them.
5. Start the smallest "volcano" by adding one tablet of Alka-Seltzer to the bottle. ***<u>Immediately – extremely quickly!</u>*** - after adding the tablet, cover the opening with plastic wrap and secure it <u>very tightly</u> with a rubber band. Wait approximately 30-45 seconds. Using a toothpick or paper clip, poke some tiny holes in the center of the wrap.

6. Record your observations of the eruption:
   a. Measure the <u>approximate height</u> of the eruption's "plume," as well as how far it spews its "tephra' over the ground. Have one member use a ruler or meter stick to do so.
   b. Measure the <u>duration</u> of the eruption.
   c. Pour any "lava' that collects in the dishpan into the measuring cup or graduated cylinder to determine the <u>volume of ejected material</u>. Group members should assist in pouring liquid "lava" from pan into cylinder/beaker.
   d. Record any <u>sounds and write a visual account</u> of the eruption.
   e. Record all this data in a table that you create on your own.

7. Repeat the procedure using two and three whole tablets of Alka-Seltzer, each cut in half to fit through the bottle openings. Record your data.
8. Ranking explosivities of your various "volcanoes" will not be difficult if you use the combination of your various measurements, as well as the sight and sound differences you observe during each eruption. Include <u>this explosivity ranking data</u> in your table.