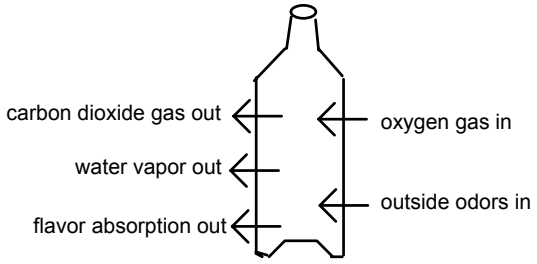
PET Bottle

Grades: 6-8

Purpose:
(Investigation One) To compare the volume of a PET 2-liter soft drink bottle to that of a PET 1.89-liter juice bottle (Ocean Spray®) before and after exposure to boiling water.
(Investigation Two) To use mathematics to predict the size of a square on the surface of a PET bottle.

Science Standards: Content Standard A: Science as Inquiry; Content Standard B: Physical Science; Content Standard E: Science and Technology

Background: In the spring of 1977, the PET soda bottle was introduced by Pepsi® followed soon by Coca-Cola®. The early designs had a round base which was enclosed in a HDPE cup. This added problems for the recyclers since the two plastics had to be separated at the recycling plant. Now the PET bottle has four or five protuberances on the base that form feet. A 1-liter bottle weighs 34 g and a 2-liter bottle weighs 48 g. There are many factors that influence the taste of carbonated beverages. Below is a figure of a PET bottle and some of the factors that packaging people must consider.



Schematic Drawing of a PETE Bottle

PET is a plastic that can successfully provide a clear, strong bottle, and one that is mostly impermeable to carbon dioxide. Bottles, larger than one-half liter, have a shelf life of three months. Bottles less than one-half liter cannot hold the pressure that long.

Wholesalers of "Spring" water or "Natural" water sold in plastic containers have many choices for packaging their product since these are not carbonated like soda or "pop". Europe has used PVC bottles with their clear, high gloss appearance and consistent taste of the water for years. The U.S. market has stayed away from PVC since the 1974 scare about residues in the plastic causing cancer. This problem is now solved but the adverse publicity lingers. HDPE containers are translucent and would not display the clear water very well to the consumer. PP containers are not in the recycle loop. So the PET bottle is the most widely used. About 70-80% of the resin consumption is used for soft-drink bottles.

Producers of barbecue sauce also use PET bottles which allows for the oxidation of the sauce by oxygen gas going into the bottle. The sauce turns brown! However, the sauce is brown already. The browning of red ketchup would not be acceptable to consumers. In 1991, Heinz announced that it would be using a construction of PET/EVOH/PET/EVOH/PET with only 1.5 % EVOH. (EVOH is ethylene-vinyl alcohol copolymer.) These layers can be easily separated and so the bottle is recycled.

Investigation One:

Materials for investigation one: (for a pair of students)

One empty 2-Liter soda PET bottle
One empty 1.89-Liter PET juice bottle (Ocean Spray®)
Source of boiling water- 4 liters
Graduated cylinder - 100 mL or larger is preferred
Sink or tub that will hold the bottles

Procedure for investigation one:

1. Fill the 2-liter soda bottle to the brim with water. Pour the contents of the bottle into the graduated cylinder (many times) to measure the exact amount of water that the container will hold. Record the total volume of the bottle.
2. Fill the juice bottle to the brim with water. Pour the contents of the bottle into the graduated cylinder to measure the exact amount of water that the bottle will hold. Record the total volume of the bottle.
3. Place both bottles in a sink or tub. Have your teacher pour 4 liters of boiling water over the two bottles. Let them cool.
4. Find the total volume of water that each bottle will hold. Record.
5. Calculate the percent change for each bottle. Percent Change =([volume of original - volume of heated bottle]/ volume of original) x 100

Data Table:

Bottle Type	Total Volume in mL	Total Volume in mL after boiling water	Percent Change
PET 2-Liter soda			
PET 1.89-Liter juice			

Conclusions:

1. Compare your data of percent change with others in the class. What can you conclude?
2. Based on your observations, which liquid (soda or juice) was heat-filled as it was packaged? Why?
3. Besides the shape of the two bottles, what do you notice about the differences in the two bottles?
4. Explain the behavior of the PET soda bottle when exposed to boiling water using a "molecular" description. In other words, what are the chains of PET doing to explain your observations? (Hint: Think about the Saran Wrap experiment.)

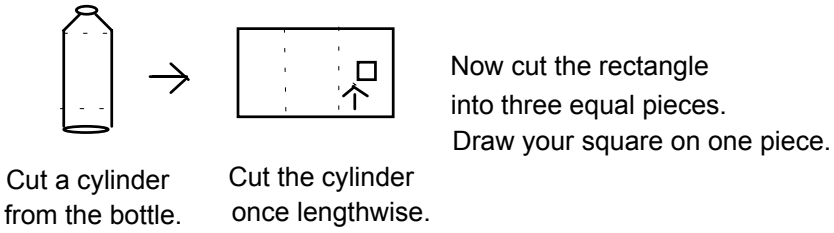
Investigation Two:

Materials for investigation two: (for a pair of students)

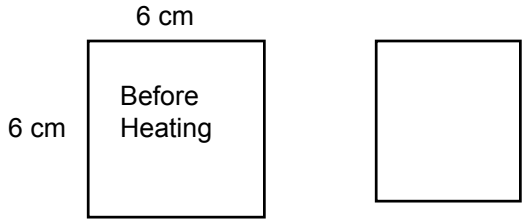
One empty 2-Liter PET soda bottle
Scissors
Permanent marker
Metric ruler
Boiling water and tongs

Procedure:

1. Cut a cylinder from the PET soda bottle. Cut the cylinder with only one cut through the cylinder. See the diagram below:



2. Cut the rectangle of PET plastic into about three equal 11 cm wide pieces.
3. Using a permanent marker, draw a square 6 cm x 6 cm in the center of one of the 11 cm pieces. Draw an arrow on the plastic piece to show the lengthwise direction.
4. Place your plastic in boiling water for 15 sec. Remove with tongs. Let cool.
5. Measure the rectangle in cm. Record the new dimensions on the rectangle below.



6. Using your skills in mathematics, calculate the rectangle that must be drawn on the second piece of PET plastic so that when it is exposed to boiling water, the resulting figure will be a square with 5 cm dimensions. Remember the width and length shrink at different rates!

7. Draw your rectangle on the PET piece and place it in boiling water for 15 sec. Remove with tongs and let cool. Were you successful? If not, there is one more piece of plastic to draw your second rectangle.
8. Turn in the plastic piece with the best 5 cm x 5 cm square to your teacher. Add your names to the plastic with the permanent marker.

Teacher Notes for PET Bottle:

The maximum shelf life for a 1.5 -2 liter bottle is about 16-17 weeks. At the end of this time, the carbonation will have dropped and the flavor of the product will have deteriorated. Reclaimed PET is in demand for fiber, sheeting, nonfood containers, strapping, and molding compounds. The demand for recycled PET will approach 1 billion pounds by the end of the 90's.

PET oven trays allow frozen food to go directly into the oven. These trays are a fast-growing new market for PET. They are heat-set to prevent deformation during cooking. They will not change shape when boiling water is poured over them like when PET soda bottles are subjected to boiling water. The new trays are suitable for the conventional oven and the microwave. They are light weight and attractive to the consumer.

PET film has great tensile strength, chemical resistance, light weight, elastic and is stable from -60 to 220°C. So this makes it ideal for a "boil-in-a-bag" idea. It is fine to take the frozen product and put it in boiling water. The film is stabilized by annealing or heat-setting it under restraint. This reduces the tendency to shrink under heat. The juice bottles are also stabilized by heat-setting so that this container can withstand heat filling of the juice. The neck of this particular juice bottle is white compared to the neck of the soda bottle which is clear. Note: Not all heat-set PET bottles have white necks.

Bottle Type	**Total Volume in mL**	**Total Volume in mL after boiling water**	**Percent Change**
PET 2-Liter soda	2048	1460	28.7%
PET 1.89 L juice	1980	1980	0%

In investigation two, students must be able to solve problems using proportions. All PET soda bottles will shrink in size when exposed to boiling water. The sides of the bottle are used in this experiment. Students need the "cylinder" of the bottle only. This may be cut from the bottle before the laboratory if scissors are a safety concern with students. Permanent marker will not wash off in the boiling water. One pot of boiling water for the class is fine since it only takes 15 seconds to shrink a piece of PET. Both colorless, clear and green bottles will work. Not all bottles shrink the same amount but since all do shrink some amount, any soda bottle will be fine for this experiment. A Pepsi® clear bottle had this data:

6 cm x 6 cm square was reduced to 4.9 cm x 5.4 cm rectangle after exposed to boiling water.

The width measurement decreased more than the length.

Students are asked to draw a rectangle of the correct size so that the square will be 5 cm x 5 cm after the plastic is put into boiling water. The mathematics are: $\frac{6\text{ cm}}{4.9\text{ cm}} = \frac{x\text{ cm}}{5\text{ cm}}$ for width $\frac{6\text{ cm}}{5.4\text{ cm}} = \frac{x\text{ cm}}{5\text{ cm}}$ for length

$x = 6.1$ cm for width $x = 5.6$ cm for length

Allow for the dimensions of the square to be 4.9 to 5.1 cm per side.

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