Penney's Quick Silent Demos

Introduction to Gas Laws

FLINN SCIENTIFIC CHEM FAX!

Introduction

A group of simple, quick demonstrations to interest students in the gas laws.

Concepts

- Guy-Lussac's Law
- Boyle's Law
- Charles's Law
- Surface tension

Safety Precautions

These laboratory activities are considered nonhazardous. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Part 1. The Expanding Marshmallow

Materials

- Felt-tip pens (optional)
- Miniature marshmallow, fresh
- Syringe tip cap (optional)
- Syringe, without needle, plastic, 30-mL

Procedure

1. If desired, use a felt-tip pen to draw a happy face on the end of a miniature marshmallow.
2. Remove the end cap from the tip of a 30-mL plastic syringe.
3. Remove plunger from the syringe and insert the marshmallow into the syringe.
4. Place plunger back in syringe so the volume reading is approximately at the 15-mL mark.
5. Place a syringe tip cap over the tip of the syringe or seal the tip of the syringe with a finger. Pull the plunger out—decreasing the pressure inside the syringe. The marshmallow should expand—its volume increases.
6. Now push the syringe in—increasing the pressure inside the syringe. The marshmallow should shrink—its volume decreases.

Discussion

When the syringe plunger is pulled out, the volume of the chamber increases but the amount of gas remains constant because it is in a closed system. The pressure inside the syringe chamber decreases. The lower pressure on the marshmallow causes its volume to increase according to Boyle's Law. The expansion is due to the many trapped air bubbles (like small "internal balloons") within the marshmallow that initially are at atmospheric pressure. As the pressure outside these air bubbles (within the chamber) is reduced, the bubbles will expand to many times the original volume in order to equilibrate the pressure on either side of the bubble wall. Thus, as the pressure decreases (P), volume increases (V) in an inverse relationship according to the following equations.

$$PV = nRT$$ *Equation 1 – Ideal Gas Law*

$$P_1 \cdot V_1 = P_2 \cdot V_2$$ *Equation 2 – Boyle's Law*

This increase in volume makes for a memorable visual event and a great stimulus for the discussion of the elements of Boyle's Law. Students can visualize the loss in pressure and easily see the increase in volume.

Part 2. The Charles's Law Bottle Demo

Materials

Dime

Water, tap

Bottle, narrow-neck, glass

Procedure

1. Lightly moisten the rim of a glass bottle with tap water.
2. Carefully, place a dime over the opening of the bottle. This traps a fixed amount of air inside the bottle.
3. Place both hands around the bottle and hold firmly. *Note:* Warm hands if necessary.
4. Observe the dime and listen for a quiet "burp."

Discussion

As the air in the bottle is warmed by the heat transferred from your hands, the volume of the air will increase. The pressure builds inside the bottle until it is enough to lift the dime, allowing some of the pressurized, warmed air to escape the bottle. Once the pressure inside the bottle is equal to that of the surrounding air, the dime will settle back into place once again separating the atmosphere inside the bottle from that outside the bottle.

Part 3. Surface Tension Jar

Materials

Jar with screw-on ring lid

Liquid detergent (optional)

Laminated card

Plastic tub or bucket

Screen

Tap water

Procedure

1. Place the screen inside the lid of the jar and screw the lid tightly onto the jar.
2. Pour tap water through the screen until the jar is about three-quarters full.
3. Place a laminated card over the top of the jar and hold the card down tightly with one hand. *The water will form an adhesive seal with the laminated paper.*
4. Quickly invert the jar 180° over a sink or other container, such as a plastic tub or bucket.
5. While holding the jar steady, remove your hand from the laminated card. *The card will remain in place over the mouth of the jar! The water forms a tight adhesive seal and external air pressure holds the card in place.*
6. Carefully slide the card out from under the jar with one hand while holding the jar steady with the other hand. *A little water may spill out, but most of the water will stay in the jar! The mesh screen provides a surface for the formation of hundreds of tiny surface-tension "membranes" that, in addition to air pressure, will support the weight of the water.*
7. Tilt the jar a few degrees to allow air to enter the jar. The water will immediately spill out of the jar—gravity still works!
8. *(Optional)* After performing the demonstration once for the students, ask for a student volunteer to repeat the demonstration. Dip a finger into detergent that is hidden from view and inconspicuously run the finger over the screen after the jar has been filled with water. When the student inverts the jar, the laminated card may stick for a short time due to the counter-force of air pressure acting on the outside of the card. *When the card is removed, however, the water will rush out. The detergent interferes with the hydrogen-bonding network in water, which drastically reduces the surface tension of water and modifies its adhesive properties.*

9. Alternatively, you may show students that the demonstration will work without the laminated card, simply by covering the jar mouth with your hand and then quickly removing it.

Discussion

Water is a unique liquid—the surface tension of water is substantially greater than that of alcohols and other liquids. Surface tension is a net attractive force that tends to "pull" adjacent surface molecules inward toward the rest of the liquid. Surface tension is a result of uneven attractive forces experienced by molecules at the surface of a liquid versus those in the rest of the liquid. Molecules in the liquid are bound to neighboring molecules all around them. Molecules at the surface, however, have no neighboring molecules above them. Because the forces acting on the surface molecules are not balanced in all directions, the surface molecules are drawn inward toward the rest of the liquid.

When the jar is first inverted, a small amount of water probably leaks out from the jar. This creates a slight partial vacuum in the space above the water in the jar. The water in the jar also forms a tight adhesive "seal" with the card—in addition to forming strong intermolecular cohesive forces with other water molecules, water also forms strong adhesive forces to many other molecules or materials. External air pressure, acting in all directions, applies a net upward force on the card and the water and prevents the water from spilling out of the jar.

When the card is removed, the surface tension of water provides an additional force keeping the water in the inverted jar. The high surface tension of water arises because of strong hydrogen bonding among water molecules. As an analogy, the surface tension of water may be thought of as an invisible, "elastic" film that expands as needed to counteract the force of gravity and prevent the water from spilling out of the jar. The numerous tiny holes in the mesh screen provide a larger total surface area for the formation of thousands of invisible surface membranes.

When the jar is tilted, the forces become off-balanced and there is no longer a greater pressure on the outside of the jar. The surface tension "breaks" and the water spills out of the jar.

Part 4. Oobleck

Materials

- Food coloring dye (optional)
- Starch, corn
- Water, tap
- Plastic utility pan

Procedure

1. Mix two parts corn starch to one part colored water and mix well.
2. Add water or corn starch as needed to create the Oobleck, which should seem solid when squeezed and liquid when held loosely.

Discussion

Oobleck is an example of a *non-Newtonian fluid*. This technical term simply means that the viscosity of a fluid (its resistance to flow) depends on factors *other* than just temperature. (The viscosity of all liquids decreases as the temperature increases.) The two factors that typically affect the viscosity of a non-Newtonian fluid are shear stress and time. Shear stress may be thought of as any force that is applied to the liquid. Stirring a liquid is an example of shear stress, as is squeezing or pulling. Most non-Newtonian fluids are shear-thinning—their apparent viscosity decreases when a force is applied. Many polymer solutions and suspensions are shear-thinning. Oobleck is an example of the far less common non-Newtonian fluid—a shear-thickening mixture. When stress is applied to a shear-thickening mixture, like Oobleck, the viscosity appears to increase.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Oobleck may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- A finger may be used to "seal" the syringe instead of a syringe tip cap, if needed.
- Test whether the surface tension jar demonstration will work with different amounts of water in the jar. Fill the jar completely; add only enough water to cover the screen, etc.
- Traditionally, Oobleck is green but it can be any color or plain white.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Evolution and equilibrium
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Penney's Quick Silent Demos* activity, presented by Penney Sconzo, is available in *Introduction to Gas Laws* and in *Silent Demonstrations*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Penney's Quick Silent Demos* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1732	Syringe, 30 mL
AP1297	Felt-tip Pen, Black
AP8958	Syringe Tip Cap
AP6648	Surface Tension Jar
AP9176	Plastic Utility pan
S0124	Starch, corn, 500 g
V0003	Food coloring dyes, set of four colors

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.