THE FRANKLIN INSTITUTE

Post-Show

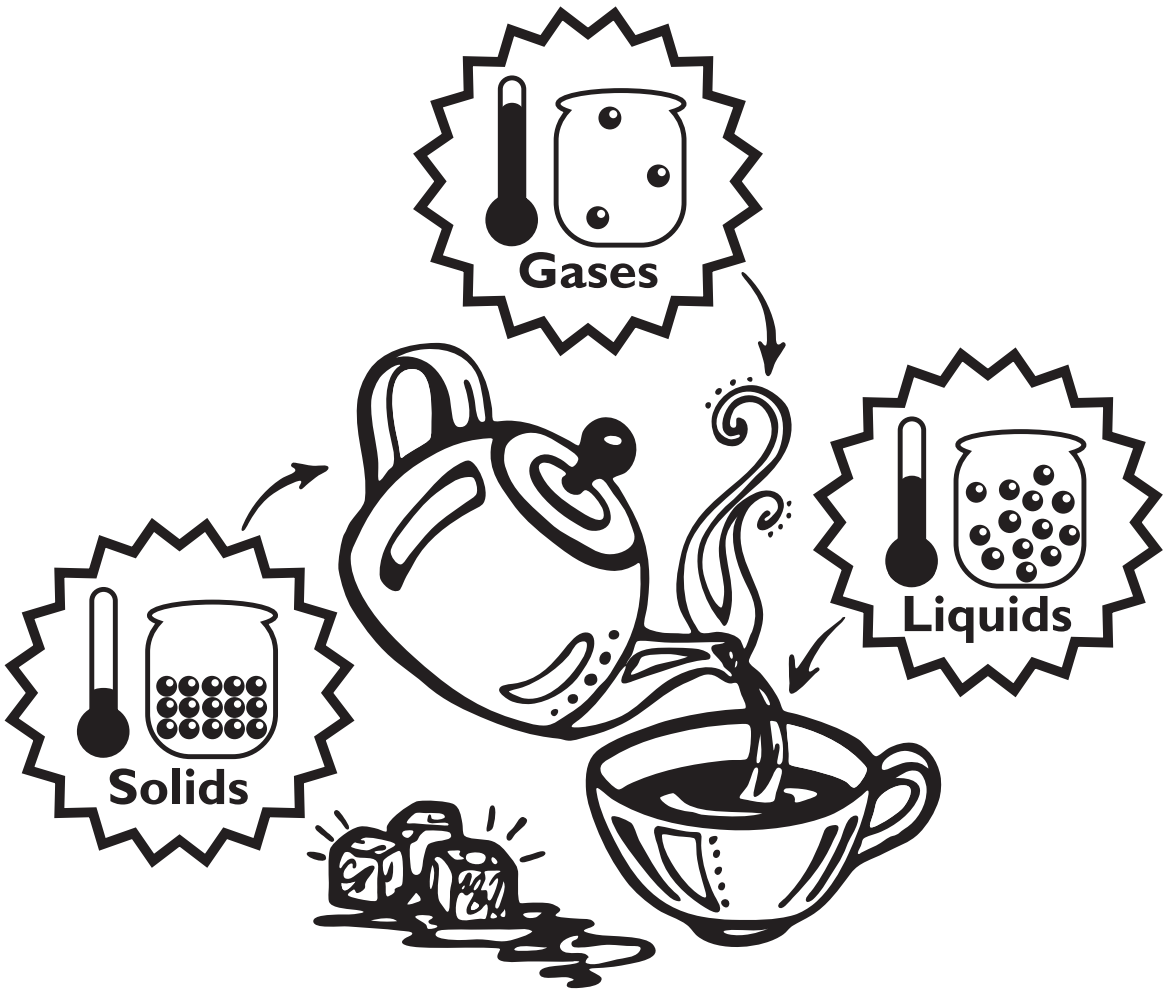
HOT AND COLD

After the Show

We recently presented a Hot and Cold show at your school, and thought you and your students might like to continue investigating this topic. The following activities are designed to review and extend the ideas covered in the show.

Please remember to use appropriate safety measures for all activities. An adult instructor should always supervise students during experiments.

Visit us online at www.fi.edu/TSS or contact us at tss@fi.edu.



CLOUD IN A BOTTLE

FOR GRADES 1-4

We learned during the show that matter can change from a solid to a liquid to a gas. Recall that when we brought liquid nitrogen into a warm room, it evaporated into a gas. It also cooled down some of the water vapor in the air, which made that water vapor condense into a cloud. In this activity, students will simulate cloud formation in a bottle.

EQUIPMENT

Clear 2-liter plastic bottle with cap
Water
Matches

PROCEDURE

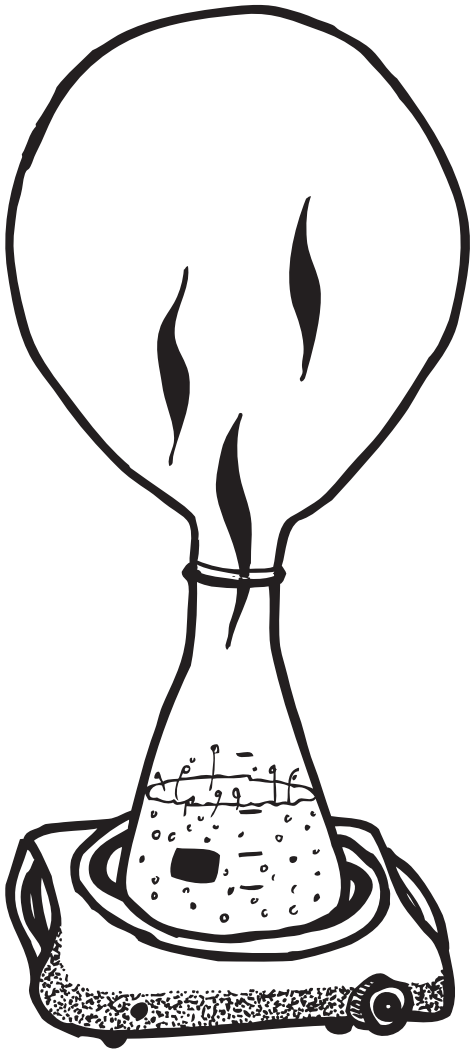
1. Place about one tablespoon of water in the bottom of the bottle, not quite enough to cover the bottom.
2. Light a match and drop it into the bottle. Quickly cap the bottle.
3. Squeeze the bottle as hard as you can, then release. What do you observe? What is the cloud made of? What state of matter is it?

WHY?

Squeezing the bottle increases the air pressure inside the bottle, causing the temperature inside to increase. When you release the bottle, the pressure and temperature both drop. This temperature decrease causes invisible water vapor in the air to condense, or change into little drops of liquid water. The smoke from the match provides tiny, solid particles for the newly formed drops of liquid water to grab onto. When small drops of water condense onto those particles, you have a cloud!

BALLOON GYMNASTICS

FOR GRADES 3-6



A gas, as we saw during the show, is a collection of molecules that are spread far apart and moving around quickly. When we add heat energy to a gas, the molecules spread even farther apart and move even faster. In this activity, students will observe what happens to a balloon as the air inside is heated and then cooled. Note: always wear gloves when handling hot glass containers!

EQUIPMENT

Water
Glass bottle or flask with narrow neck
Balloon
Hot plate
Gloves

PROCEDURE

1. Pour about one-half cup of cold water in the glass bottle. Place the neck of a balloon over the opening. Place the glass on a hot plate and heat it. What happens to the balloon as the water heats up? Why? Does this remind you of anything you saw during the show?

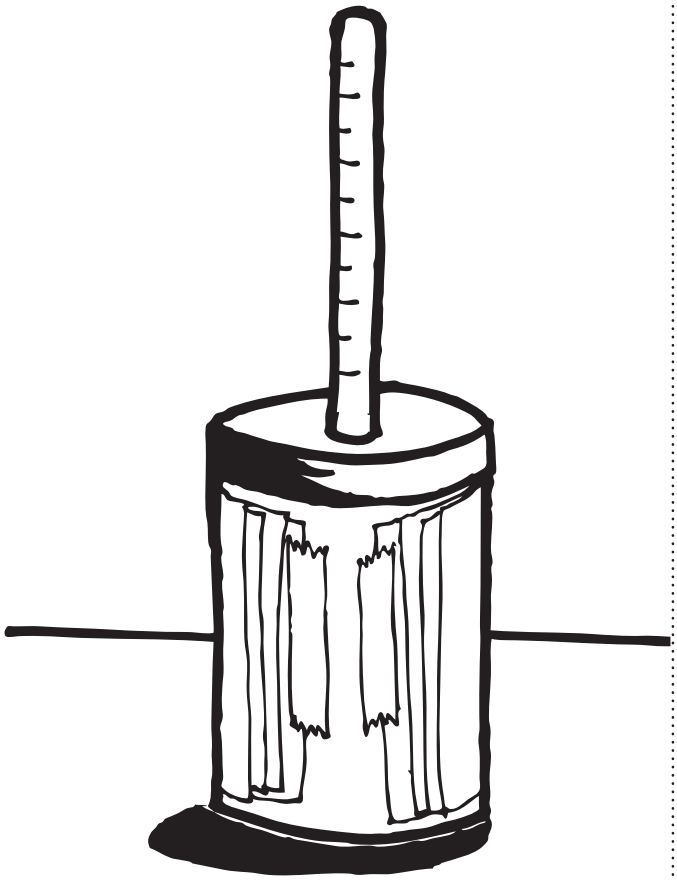
2. While wearing gloves, remove the balloon. Heat the bottle on the hot plate until the water boils. While wearing gloves, carefully take the bottle off the hot plate and allow it to cool for about ten seconds. Place a balloon over the opening. What happens to the balloon as the water cools? Why?

WHY?

As the air inside the bottle is heated, the molecules of air spread out and the air becomes less dense. This expanding air inflates the balloon. When the hot air is cooled, the air contracts, pulling the balloon into the bottle. This is summarized by Charles's Law: as the temperature of a gas increases, the volume of the gas increases. Or as we like to say at the Franklin Institute, "Hotter, bigger; colder, smaller!"

INSULATION CHALLENGE

FOR GRADES 5-8



During the show, you saw us use a special container called a Dewar to store the liquid nitrogen. Each Dewar has vacuum insulation, which is very effective because heat cannot travel through a vacuum. Aside from creating a vacuum, how else can we insulate a container? In this activity, students test the insulation capabilities of different materials.

EQUIPMENT

Film canisters with lids
Thermometers
Hot water
Scissors
Tape
Rubber bands
Samples of various materials – felt, cotton, nylon, newspaper, plastic wrap, etc.

PROCEDURE

1. Give each pair or small group of students a film canister and lid. Punch a hole in the lid through which the thermometer can fit.

2. Challenge students to use the materials to construct an insulator for the container. The goal is to keep hot water in the container as hot as possible for as long as possible. Keep the thermometer hole in the lid accessible.

3. After students have designed their insulation, fill each insulated canister with hot water. Record the initial temperature of the water. Then record the temperature at five-minute intervals for 25 minutes.

4. Chart or graph the temperatures. Did the water in the various containers cool off at the same rate? Which materials were the most effective insulators? What was the best design, or method of construction?

WHY?

A thermal insulator is a material that prevents heat transfer. For example, fiberglass insulation is used to keep heat from entering a building in the summer, and to keep heat from escaping during winter. Conductors are the opposite of insulators. In general, denser materials are better conductors because atoms can transfer heat more efficiently when close together. Likewise, less dense materials are better insulators. What are some other examples of thermal insulators and conductors?

MORE INFORMATION...

We've provided the following information to help refresh your memory about the topics we covered during the show, and to deepen your understanding about liquid nitrogen and states of matter.

Matter: Any substance that has mass and volume; in other words, all the "stuff" around us. Matter is made up of atoms and molecules.

State of Matter: A physically distinctive form of matter. The even, consistent arrangement of molecules determines the properties of a state of matter.

Solid: The molecules in a solid substance are tightly packed together and do not have enough energy to move freely. For this reason, solids have a fixed shape and volume. A substance in its solid state is relatively colder than its liquid and gas states.

Liquid: The molecules in a liquid have enough energy to move freely relative to each other, so liquids do not have a fixed shape. Thus, they are able to flow when poured. However, liquids do have a fixed volume, given that temperature and pressure are constant. A substance in its liquid state is relatively warmer than its solid state.

Gas: In a gaseous substance, the molecules have enough energy to spread out and occupy the entire space of the container. A gas has no definite shape or volume. A substance in its gaseous state is relatively warmer than in its solid or liquid state. Gases are also called vapors.

Evaporation: The transition from liquid to gas, which happens near a substance's boiling point. When heat or pressure is added to a liquid, its internal energy increases. As the molecules get more energy, they speed up and spread apart until they are in the gaseous state. A few materials, such as dry ice, go through a process called sublimation, in which they change from a solid to a gas without passing through the liquid state.

Boiling Point: The temperature at which a given liquid evaporates into a gas. The boiling point of water is 212°F, and the boiling point of liquid nitrogen is -320°F.

Condensation: The change from a gaseous state to a liquid state. Upon the cooling of a gaseous substance, the molecules slow down and move less freely, and are brought together to a fixed volume. Condensation is the opposite of evaporation.

Melting Point: The temperature at which a given solid turns into a liquid. The melting point of liquid nitrogen is -346°F and the melting point of water is 32°F.

Freezing: The opposite of melting; the transformation of a liquid into a solid. The molecules in the liquid slow down to the point where they can no longer move freely.

Heat: The process of energy transfer from a warmer object or system to a cooler object or system. Heat is also described as the amount of kinetic energy (or energy of motion) of the particles in a system. The rapidly moving molecules in a gas have more energy and therefore more heat than the slow-moving molecules in a solid.

Temperature: A measurement of the kinetic energy (or energy of motion) of the molecules in an object or system. Temperature can be measured with a thermometer or calorimeter.

Thermal Expansion: When substances undergo a temperature change, they tend to change in volume. When heated, the molecules in the substance begin to move around and spread out, causing the substance to expand. For instance, when liquid nitrogen boils and transforms into gas, it expands to 700 times its liquid volume. When a substance is cooled, the molecules lose kinetic energy, and so they slow down and come together. One well-known exception to this rule is water, which expands slightly when it freezes into ice.

Pressure: Pressure is the amount of force acting on an area. If you try to put a lid on a container of liquid nitrogen, the force that is produced as the container fills up with nitrogen gas puts increasing pressure on the lid, and eventually pops it off.

Density: A measure of how tightly packed together the molecules are. It is calculated by dividing the mass of an object by its volume. In general, solids are the densest form of matter, and gases are the least dense.

Liquid Nitrogen: Nitrogen in a liquid state at a very low temperature. It boils at -320°F. It is used as a refrigerant, to cryopreserve blood and reproductive cells, in cryotherapy (such as freezing off warts), and more. It causes rapid freezing on contact with living tissue. That is why you saw your presenter wearing safety gloves and goggles!

Dewar: A double-layer container. The layers are sealed together at the neck, and the air between the two layers is sucked out to form a near vacuum. This minimizes heat transfer, making it a very good insulator. Thus, a hot liquid inside will stay hot for much longer than if it were in a regular container, and a cold liquid will stay cold for much longer. Dewars also have a very loose lid, which allows the release of gas pressure as the liquid nitrogen evaporates.

MORE RESOURCES...

The Franklin Institute: The Franklin Institute: On your next field trip, look for examples of various states of matter throughout our exhibits. Find exhibit guides at http://www.fi.edu/teacherresources/.

Introduction to Matter: Visit http://www.fi.edu/msp/matter/index.html for a collection of teaching resources on matter. You'll find lesson plans, videos, games, and more!

Physical Science Hotlist: Check out http://www.fi.edu/learn/hotlists/physical.php for a collection of websites related to physical science topics, including links to labs, biographies of scientists, and even interactive simulations.