Be the Molecule:

Kinesthetic Exploration of Phase Changes

A laboratory experiment from the Little Shop of Physics at Colorado State University

In a solid, the molecules are linked together.

Grade Level

- 3rd and above

Science Focus

- Solid
- Liquid
- Gas
- Molecules
- Energy

Time Required

- 15 minutes

Overview

Students tend to be very familiar with the different phases of matter, although they may not formally realize it. If you were to ask students to name a few examples of a solid, a liquid, or a gas, this would not be too difficult of a task, but the relationship between the different phases and the transformation from one to another is not as easy to comprehend. This activity is a variation on our classic *Molecules in a Box* activity that answers the question: "What causes pressure?" Here instead, we are exploring the question: "What happens to molecules when they get more energy?" We also are exploring the question, "What happens to molecules when they give energy away?"

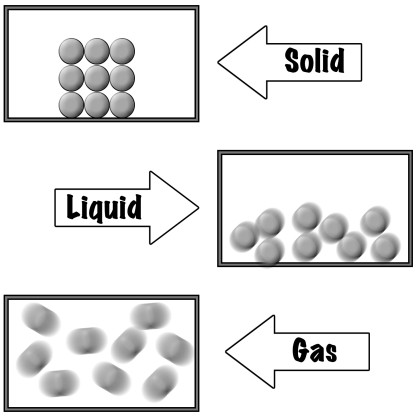
Theory

By looking at what is happening at an atomic-scale, we can gain a better understanding of what is going on during a phase change. Let's look at a common material that people are familiar with for our first stage of exploration: water. A molecule of water will travel in a straight line until it hits something, either

Necessary materials:

- one long rope (Optional - perhaps borrowed from the PE teacher)
- a large open area in the classroom or the playground

In this experiment students act out being molecules that are undergoing phase changes. You will need to designate an area within which to contain your "molecules" which is partially the purpose of the rope. The secondary function of the rope is a visual representation of energy transfer. You can do this experiment without the rope, however, by designating an area in which the "molecules" must stay. You must signify an increase or decrease in energy. This could be achieved by playing music and changing the volume or by having the students clap their hands faster or slower depending on how much energy they, as molecules, have.



the side of the container or another molecule. Then it bounces off and moves in another direction. The speed with which each molecule travels is determined by how much energy it has and this determines what phase that the material is in: solid, liquid or gas.

Water in the solid form has a defined shape as molecules move very little. They have very little energy. Liquid water will fill the container it is in, up to a certain level. The molecules are moving faster than they were in the solid phase and they bounce off the walls of the container and the other molecules as well. In the gas phase, the molecules completely fill the entire container, moving quickly, continuing to bounce off the sides of the container and other molecules.

How can a material, like water, change phase? How can it transform from a solid to a liquid or a gas? The answer is energy.

Water is commonly found in all three phases because the points at which it can change from one phase to another are within the normal day-to-day experience here on Earth. Water freezes (becomes a solid) at 0°C and boils (becomes a gas) at 100°C. We are not used to experiencing many other materials in all three phases. For example, nitrogen gas is very common (78% of the atmosphere is nitrogen in the gas phase) and we sometimes can see liquid nitrogen, but solid nitrogen is something most people will never see, as nitrogen freezes at -210°C!

What causes the transition from solid to liquid to gas can be difficult to grasp. In this activity we will ask students to step into the shoes of a molecule undertaking this journey with a fun, kinesthetic atomic model.

Doing the Experiment

Depending on the level and background of your class, you might want to start out with some leading questions: What is matter? What is a molecule? What are the three phases of matter? (solid, liquid, and gas). Ask students to name some examples of each. Ask them to name a few examples of things they *never* see in the liquid form, the solid form, the gas form, and then ask them to speculate why they've never seen these forms before. Some examples to suggest are oxygen, nitrogen, or helium as a solid. Have they seen copper or iron as liquid or gas? Leave this question open and ask students to keep it in mind while they participate in this kinesthetic activity that will demonstrate how and why phase changes occur.

If you use a rope, select four students to hold the rope taut between them to form a square or rectangle. Explain to the class that the rope acts as the sides of your container and choose one side to be the "bottom." Have the rest of the students step inside the roped off area and explain to them that they will be acting out the part of water molecules, and will be changing from one phase to another based on your instructions. There are two rules that students will follow at each stage. Rule 1: They are always pulled towards the "bottom" of the container by gravity. Rule 2: Have the students hold their hands clasped in front of them with elbows out to the sides. Instruct them to maintain this position throughout the activity.

SOLID

Start with the students being a solid: an ice cube. The rule here is that, in the solid form, they must always be elbow-to-elbow with at least one other student but otherwise they are allowed to move. Based-on this rule, the students should form a cluster in the roped off area against the bottom of the container. Ask the students to talk about themselves as molecules and ask these questions: Are they moving fast or slow? Do they have an abundance of energy or not so much? What needs to happen for them to "melt" and become liquid water? Most students will answer heat–the ice needs to be heated up. Heating the ice gives each individual molecule more energy which allows it to move more quickly. Have the four students holding the rope gently shake it–this simulates putting energy into the container.

LIQUID

Now the students inside can "melt" and become liquid. As a liquid, the rule they must follow is this: they must be touching another student with their elbow but they do not have to be elbow-to-elbow. They will notice that now they can move slowly around the bottom of the container. As they are moving around, ask them again to talk about themselves as molecules. Are they moving faster or slower than they were as a solid? How much energy do they have? What needs to happen for them to move from the liquid phase to the gas phase? Again, most students will answer heat. Have the students holding the rope shake it quickly, simulating a large amount of energy going into the system.

GAS

Now the students inside can "evaporate" and become a gas. The rule in this phase changes yet again. Now students may not touch another student with their elbows. If, as they are moving around, they bump into each other. They will bounce apart but will not maintain contact. In this situation, they can move quickly around the container, bouncing off the walls and each other. Again, ask them to talk about themselves as molecules. Are they moving faster or slower than they were as a liquid? How much energy do they have?

It's important to now run the activity backwards: have the students holding the rope shake it slower, simulating the removal of energy from the system. The students inside now condense into a liquid. Have the students holding the rope shake it just a little. The students now freeze into a solid. This is a natural way to bring them back together and refocus them for a closing discussion as well.

For a follow-up discussion, ask students to revisit the question posed at the beginning of the activity: Why do we never see some materials in certain phases? (reference some of the examples they provided) What would it take to have liquid copper or solid helium?

Summing Up:

This activity is a great way to explore phase changes on an atomic level. After participating in this activity, students will have experienced the basic characteristics of the different phases and have an understanding of how energy dictates these changes. Phase change ideas are central to the understanding of many scientific disciplines.

What about our initial questions: What happens to molecules when they get more energy (heat)? What happens when they give energy away? Everything is made of molecules, and molecules are sticky. When things get hot, the molecules vibrate. If they vibrate too much, they pull apart and a phase change happens (solid to liquid or liquid to gas). If the molecules give away energy, they vibrate less and start sticking together and a phase change (gas to liquid or liquid to solid) happens.

For More Information:

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu