Instant Hot Air Balloon

Kinetic Molecular Theory and PTV

Introduction

Hot air balloons provide a wonderful example of applied science. The gas laws, in conjunction with the concepts of density and Archimedes' Principle are brought to bear on one of mankind's oldest preoccupations—flight! Hot-air balloons have found their way into science museums and exhibit halls around the world, and many classroom activities have recently been developed for constructing workable, small-scale models, usually made out of tissue paper or light-weight plastic. The following describes the simplest imaginable hot-air balloon model—easy to build and quick to launch!

Concepts

- Conservation of mass
- Density
- Gas laws
- Kinetic molecular theory

Materials

Balloon, Mylar®, helium-filled (at least one side must be free of any dark-colored ink)

Camping stove, electric hot plate, or Fischer burner

Scissors

String or ribbon

Styrofoam® cup

Tape, masking

Twist-tie, plastic

Safety Precautions

A "hot" camping stove or hot plate looks exactly like a cold one! To avoid burns, place a HOT sign next to the hot apparatus before the demonstration and also afterwards to warn students and other teachers that the stove or hot plate is indeed hot. Wear chemical splash goggles whenever working with heat, chemicals or glassware in the laboratory.

Procedure

1. Cut off the neck of the Mylar balloon, and squeeze out a small portion of the helium (about 5%) to allow some noticeable slack in the balloon. *Note:* Don't overdo it; you can always squeeze out more, but you can't always put it back! See the *Tips* section for an alternative method of removing some helium from the balloon.
2. Twist the neck of the balloon, and use the plastic twist-tie to close it off.
3. Cut off the top of the Styrofoam cup, saving the bottom 5 cm or so to use as a gondola. Use some string to attach the cup to the bottom of the balloon (see Figure 1).
4. Add weight (pieces of masking tape or paper towel) to the cup to make the entire balloon assembly just barely sink.
5. Preheat the hot plate on high. Show the class that the balloon has lost some of its helium, and that it no longer has enough buoyancy to lift the attached gondola. Have the students brainstorm different ways the balloon could be made to float again (add more helium, lighten the load, flood the room with a denser gas...).
6. Then hold the balloon shiny side down over the hot plate—but not too close to cause melting. *Note:* Any dark lettering or images needed to be kept on top, away from the heat source. If not, these dark areas will absorb the heat and possibly melt holes through the mylar. (This is a neat effect, but probably not the one you want to show!) *Caution:* If using a camping stove or a Fischer burner with a well-spread

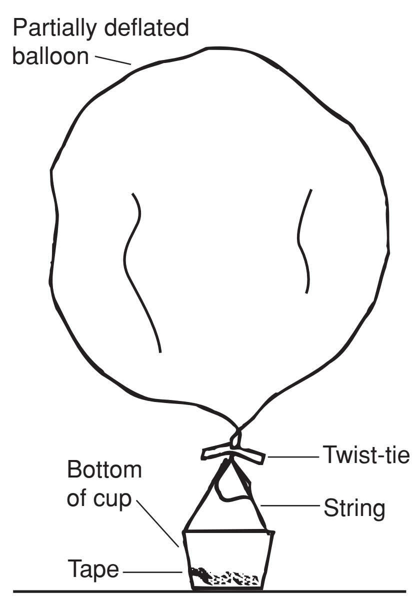

Figure 1.

out flame, the balloon should be held at least 50 cm above. Rule of thumb—if it is too hot to place your hand there, then it is also too hot to place the balloon.

7. The balloon will noticeably expand as it is heated. When it appears to be inflated to capacity, release the balloon, and observe it as it rises to the ceiling. This is especially impressive in an auditorium with a high ceiling. Then, as it cools back to room temperature, observe as it descends back down to the floor.

Tips

- To release some helium without cutting the balloon, insert a rigid plastic tube (such as the stick from a small Mylar balloon) into the neck of the balloon. When the end of the tube extends beyond the sleeve inside the balloon, helium will escape. When enough helium has been released, withdraw the tube. No need to tie off the neck of the balloon—the pressure inside seals off the sleeve.
- The amount of helium expelled, the amount of weight added, and the duration of the heating all depend on the size of the balloon and the output of heat source. None of these factors, however, are all that critical, so long as the balloon has sufficient helium left in it and sufficient room to expand, and so long as the balloon is not overly weighted down. It is best to "play around" with these variables until the desired effect is obtained. Once it is, the balloon should last several days with little adjustment needed.

Discussion

The model made in this activity is not a perfect replica of a down-scaled hot-air balloon. A classroom discussion, however, concerning the similarities and differences between the two systems would likely enhance the understanding of both. Real hot air balloons are filled with hot air rather than hot helium, but given the limited temperature increase, even the light-weight balloon is too heavy to be buoyed up by such a small volume of hot air, so helium is necessary. Also, hot air balloons are open systems—not closed, but again, the use of helium necessitates that the balloon be closed. In addition, hot-air balloons carry their heat source on board and can stay aloft as long as their fuel lasts. The model's small scale again makes this unfeasible. In effect, the helium balloon model is best thought of as a cross between a blimp (dirigible) and a hot-air balloon. Whatever the case, the demonstration is effective in conveying the main idea behind hot-air balloons—that as the temperature of a gas sample rises, its density decreases, and its buoyancy increases.

It is especially effective to show students the demonstration first, and then have them explain it while showing it to them a second time. While heating the balloon ask, for example, "What is happening now to the mass of the balloon?" This usually elicits three different responses. Those who confuse mass with how big an object is (volume) will say the mass is increasing. This misconception is worth discussing. Those who anticipate that the balloon is about to float away and must therefore be getting lighter will argue that the mass is decreasing. This misconception also warrants discussion. Those who really understand the concept of mass will know that the mass must be staying constant (with nothing entering or leaving the system, how could it be otherwise?). With mass remaining constant and volume quite visibly increasing, the density must clearly decrease, and when the density drops below that of air, the balloon is able to lift off. Once aloft and away from the heat source, the balloon begins to cool. As it does, its volume decreases, its density increases, and the balloon sinks back down to the floor.

One student asked if the balloon could be kept from cooling off by heating up the entire room. The class agreed that this might keep the balloon fully inflated, but that it would also decrease the density of the air in the room and would thus prevent the balloon from ever taking off at all. It is important that students understand it is not the hot air (or hot helium) that lifts the balloon; it is actually the surrounding air. We tend to think of gas particles as being in true random motion, completely uninfluenced by gravity. Yet these particles do have mass—albeit small—and are therefore slightly attracted to the Earth. (Indeed, if they were not, we would have no atmosphere at all surrounding our planet.) Since they are attracted to the Earth, the particles are invariably more concentrated closer to the Earth's surface. This is quite evident when one compares air at sea level with air at the top of a high mountain, but it also holds true over smaller distances—the air is slightly more concentrated beneath a given object than it is above it. Like all objects, the balloon is thus being struck by more gas particles per unit time on its under-side than on its top. This amounts to a slight buoyant force acting upward on the balloon. This buoyant force acts upward on all objects surrounded by air, including ourselves, but it is usually negligible compared to the weight of the object. For very low density objects, however, this buoyant force can be substantial, and can even overcome the object's weight—as it does in the case of the hot-air balloon.

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
Form and function

Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces, transfer of energy

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, motions and forces, interactions of energy and matter

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Instant Hot Air Balloon* activity, presented by Bob Becker, is available in *Kinetic Molecular Theory and PTV*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Instant Hot Air Balloon* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8387	Hot Plate, Temperature Controlled
AP1190	Cups, Styrofoam®, 6.4 oz, Pkg/50

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