Hot Air Balloons

GAS AND GO

By Claudia Vanderborght

The tires hum a deeper song as we slow down; then they crunch on gravel as we make the turn. The headlights bounce, slicing a path through the darkness. Already, the stars are fading as daylight approaches. The ground crew waits for us in the recently plowed field. As we join them, the aroma of coffee and fresh doughnuts overwhelms the dewy, earthy smell of the early spring morning.

PHOTO FROM GETTY IMAGES

Everyone gets busy unpacking the large gasoline-powered fan, lifting the wicker basket from the pickup bed, and unrolling the hundreds of meters of nylon. The pilot releases a small helium balloon and studies the air currents that whisk it away. With a noisy growl, the fan starts up. The yellow and blue panels lift off the ground and undulate. In the predawn light, the inflating balloon looks like some weirdly colored monster slowly rising out of the earth.

Into a sky streaked with red and orange, the sun bursts over the distant mountains. The propane burner blasts its noise and heat into the morning. As the air inside the balloon warms, the balloon expands, and the nylon envelope is pulled from the ground.

The wicker creaks as we climb into the basket. Within minutes, the balloon towers over us, tugging at the ropes that fetter it to the earth. At the pilot's signal, the ground crew loosens the ropes and the balloon pops into the air. We wave to the crew, already occupied with packing up gear and loading it into the vehicles that will follow us.

Up and away

As air inside the balloon heats up, the molecules move faster and faster. If the balloon were sealed, pressure would soon build to the bursting point. But molecules are free to escape. Before long, the hot air inside the balloon is less dense than the cool air that surrounds it. Just as an object less dense than water rises to the surface, our balloon filled with hot air rises through the surrounding air. And we are off!

Gaston, our pilot, checks two gauges—the *variometer* measures the balloon's rate of ascent or descent. We've been climbing steadily for the past five minutes. The *altimeter* indicates our distance from the ground. We're 350 meters above the ground—a nice cruising height—so Gaston shuts off the propane burner.

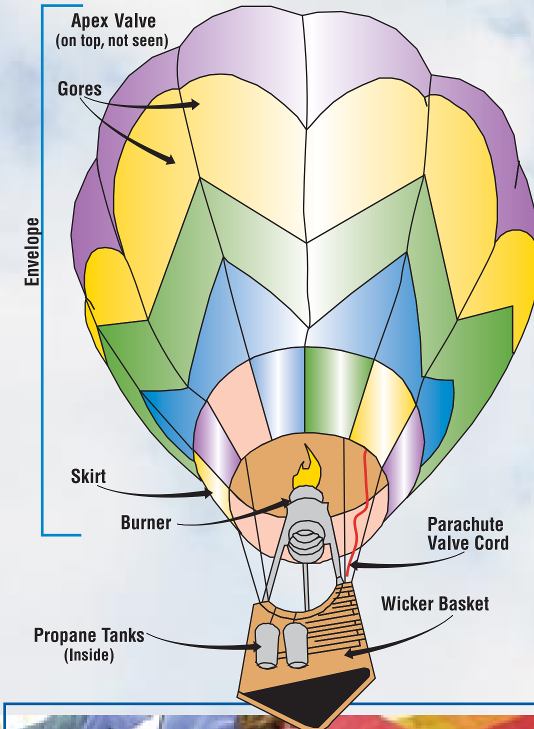
It is amazingly quiet up here! Montgolfières (the French term for hot air balloons) are propelled by the wind. But we are only aware of floating. In a balloon you neither feel nor hear the wind, since you are traveling with it. That is why a ground crew is essential. You never quite know where you're going to end up because the wind, not the pilot, determines the flight path.

Early balloonists discover the gas laws

Many of our gas laws were discovered by balloonists. The Montgolfier brothers came up with the idea of launching and testing hot air balloons after observing that smoke never flowed down a chimney. Jacques Charles, a French physicist, knew that the newly identified hydrogen gas would lift balloons far better than hot air. His first experiment, launched from Paris, was supremely successful! The unmanned balloon shot a mile into the sky and eventually landed 25 km away, terrifying the peasants, who hacked at the flying "monster" with pitchforks until it no longer "breathed".

Charles' law—the volume of a gas will increase as its temperature increases, when kept at a constant pressure—is named after its discoverer. Professor Charles applied his discovery to making improvements to the airships. Early flights were brief because the balloons quickly deflated. The buoyant gases escaped through the silk fabric's weave. Charles coated the silk with rubber dissolved in turpentine, sustaining flights by slowing the diffusion of hydrogen or hot air from the balloon. He suggested adding a vent to the top of the balloon. The vent allows pilots to release gas from the apex, thus giving them control over the descent.

Early balloons had an alarming tendency to explode. Pilots, hoping to set new altitude records, heated the flammable hydrogen to decrease its density. Not surprisingly, some met their deaths in spectacular, fiery crashes. Sometimes the inexperienced balloonist failed to balance the amount of air inside the envelope with the rate at which it was heated. The rapid ascent to high altitudes strained the silk beyond the tolerance limit. The balloon burst, plunging the occupants to their untimely deaths.



CLIP ART FROM ACS FILES

Students at the Lowell School in Washington, DC, make careful measurements as they construct their balloons.

PHOTOS COURTESY OF THE LOWELL SCHOOL, WASHINGTON, DC

Our balloonist Gaston fires the burner again, reheating the air to regain our lost altitude. It's good to know that skirts of contemporary balloons are treated with a flame retardant. The average sporting balloon stands about seven stories tall and, depending on its design, is made from about 1000 square meters of nylon. Deflated, it weighs 85 kilograms (about 190 pounds). Inflated, however, our balloon displaces nearly three tons of air!

The flight ceiling

As the density of the balloon approaches the density of the surrounding air, our ascent levels off. We've reached our flight ceiling at 1500 meters (or about 5000 feet) above sea level.

Many balloons attain even greater altitudes, but flying conditions deteriorate and danger increases. The air pressure at 3000 meters is barely 70% of the pressure at sea level. As the total pressure decreases, the partial pressure of oxygen also decreases—making it more difficult to ignite the propane.

Or to breathe! Many early balloonists lost their lives by suffocation as they tried to set higher altitude records. The lucky ones only lost their fingers and toes to frostbite, since air is much colder at higher altitudes. As a general rule, the temperature drops 10 °C for every kilometer of ascent.

Sunlight dances on the hills below us, adorned with the lacy greens of spring foliage. We've been aloft for nearly an hour when Gaston radios the ground crew to discuss suitable landing sites. Ballooning is safest during dawn or dusk. Our morning air is becoming bumpy with turbulence. Warmed by the sun, the air rising from the hills reaches us sooner than the air from the valleys. As a result, we lose altitude in the less dense warm air, but we are quickly buoyed up as we drift over the valley. It's fun, but our thermal roller coaster ride can become dangerous if the pilot loses control over the balloon.

Different materials heat up at different rates. Air over a recently plowed field will heat up and cool down faster than air over a lake. As the sun climbs higher and shines directly down on the earth, these thermal contrasts become more intense.

In preparation for landing, Gaston pulls the cord to the vent. Hot air at the balloon's apex escapes, cool air rushes into the appendix to replace it. We slowly descend as our balloon becomes filled with denser air. Finally, gravity wins.

Landings can be a little rough, but Gaston is an experienced pilot. Just before we land, he pulls the rip cord, which opens the top of the balloon and deflates it behind us. The wicker basket flexes and creaks as we touch ground, absorbing most of the landing energy, so that the passengers are barely upset. The ground crew rushes up with smiles, paper cups, and a bottle of champagne. It's the traditional French way to celebrate a successful balloon flight.

Claudia Vanderborght is a high school chemistry teacher and science writer in Swanton, VT. Her recent article "Maple Syrup: Sweet Sap Boils Down to This" appeared in the February 2002 issue of *ChemMatters*.

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ACTIVITY:

Try it! Make your own Hot Air Balloon

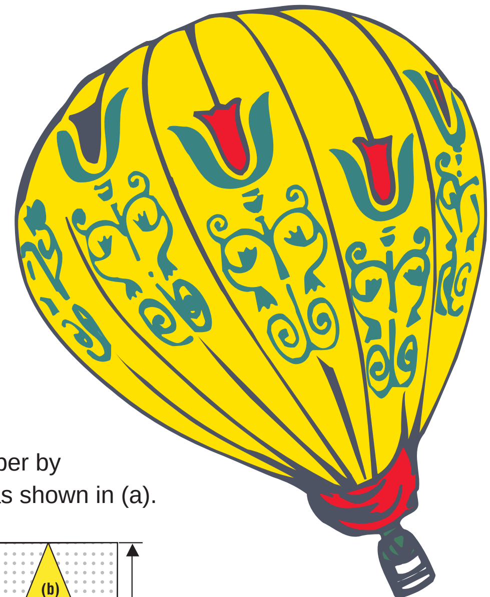


ILLUSTRATION FROM ACS GRAPHICS CLIPART FILE

Make your own hot air balloons and launch them from your school grounds. Although there is probably little risk of terrifying the local "peasants" with your "monsters", it's a good idea to get clearance from local authorities before you launch.

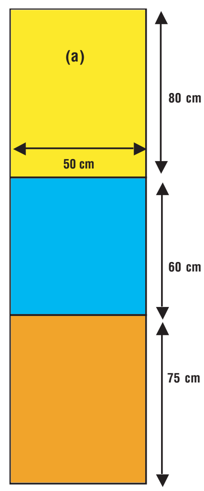
Assemble materials

- 24 sheets of tissue paper, various colors
- Scissors
- Glue
- Masking tape
- Thermometer
- String and/or streamers cut from tissue paper
- Small camp stove with fuel
- Short section of stovepipe
- Short ladder for standing while you read the thermometer
- Heatproof mits for handling the hot stovepipe
- Fire extinguisher
- Balance suitable for weighing the balloon assembly

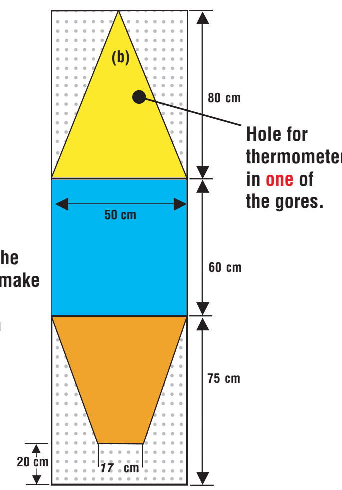
Build it

1. Prepare a total of 8 panels of tissue paper by gluing together three separate sheets as shown in (a).

2.



Next, stack the panels and staple them together at the corners. Trim the stack of panels to make 8 "gores" with the dimensions shown in (b).



3. Separate the gores. Glue each edge to a neighboring gore to form the balloon. Reinforce the open bottom edge with masking tape, and attach several evenly spaced streamers and/or pieces of string to the bottom. These should increase the stability of your balloon.

Determine the mass of your balloon assembly

Do this if you are going to do the calculations your teacher may assign at the end of the activity. After the glue dries, gently fold the balloon. Either weigh it directly, or weigh it enclosed in a tared container.

Check for safety

Do this activity outdoors on a nonwindy day, away from flammable materials. These directions are for supervised classes only. Have a fire extinguisher on site, and review instructions for using it. Wear heatproof mits when handling the hot stovepipe.

Launch it

Record the outside air temperature at time of launch. These temperature readings are important for doing the calculations your teacher may assign.

Punch a small hole in the top section of the balloon, just big enough to lower a thermometer suspended on a string Ignite a small camp stove, and surround it with a few upended bricks. Place your stovepipe section over the camp stove. Position the bottom of the balloon over the stovepipe, and hold the balloon while it inflates with the warm air.

Try to adjust the heat to the point where the balloon just "hovers", neither rising nor falling. Note this temperature. Then, increase the temperature a few more degrees, remove the thermometer, stand back, and let 'er go!

Think about it

Assuming your balloon survives intact, try launching again with either a lower or higher initial launch temperature. What's the effect of the temperature change on altitude?

Your balloon rises because it is an object at lower density than the air around it. Suppose you had "molecular snapshots" of the way air molecules were arranged inside and outside the balloon. How would they compare?

Send pictures!

By all means, let *ChemMatters* help you celebrate your success. Send pictures and some notes about your launch to *ChemMatters,* American Chemical Society, 1155 16th St., NW, Washington, DC 20036. Or you can send in digital format to **chemmatters@acs.org**. We'll post them on the Web at **www.chemistry.org/education/chemmatters.html**.