The Atmosphere: Liquid Nitrogen (LN_2), Liquid O2 (LO_2), Solid CO_2 (dry ice) & Water Vapor

This experiment involves using LN_2 to let the students "see" the major components in the air around us. LN_2 has a temperature of −196ºC and freezing and shattering a flower is always impressive. Pouring LN_2 into an empty soda can causes a thin layer of liquid oxygen to form on the outside and drip off. CO_2 is one of the things we exhale and solid CO_2 can be dropped in a container of water to make a "witches brew" effect. Having the students blow air into the LN_2 causes water vapor to condense out making "clouds".

Supplies Needed

- 30 flowers *(you provide*)
- 2 Styrofoam cups
- 30 straws (*you provide*)
- Water in container (*you provide*)
- Roll of paper towels for clean-up (*you provide*)
- Clear plastic top from a large disposable aluminum roasting pan (*you provide*)
- Inflated translucent skinny balloons (*we provide and blow up with O_2*)
- 600 mL beaker for dry ice/water demo (*we provide - you must return*)
- Empty styrofoam container for LN_2 (*we provide - you must return*)
- Liquid nitrogen in 5 or 10 L dewar (*we provide – you must return)*
- Dry ice (solid CO_2) in styrofoam container (*we provide – you must return the container*)

Liquid Nitrogen (LN_2) Experiment

Safety Note: You will be given a dewar with 4-10 L of liquid nitrogen. LN_2 is extremely cold! Spilling it on you can cause serious frost-bite burns! Pouring some on unprotected skin is less dangerous than on clothing in contact with skin. Your skin is so hot relative to LN_2 that there is an initial shielding effect called the Leidenfrost Barrier that offers short-term protection against the freezing effects of LN_2. You will notice this if you pour some on a non-carpeted floor. The LN_2 rolls around as if it is a little hover-craft. This is the case as the floor temperature is so hot relative to the very cold LN_2. As the LN_2 comes in contact with the floor, the vaporization of LN_2 to gaseous N_2 causes an insulating layer of N_2 gas to form between the LN2 and the floor. This cushions the LN_2 and allows it to "float" above the hot floor. The same effect will briefly protect you skin from contact with LN_2. Thus, you can quickly dip your fingers/hand into the LN_2 and experience no ill effect (aside from it feeling a little cold). Keeping it in contact with LN_2 for more than a few seconds, however, will cause enough heat to be drained away from your skin to minimize the Leidenfrost Barrier effect and allow the LN_2 to come in contact and cause extremely serious frostbite burns. Once you tell the students about how cold the LN_2 is they will usually be quite good about NOT touching it. Short contacts with LN_2 should NOT cause any damage. Pouring it on clothing is potentially more dangerous since it "soaks" into the cloth and if the cloth is right against the skin that can cause quicker frostbite burns. On the other hand, if the cloth is not right against the skin little to any damage should be done. Make sure that the LN_2 Dewar is well-secured (seat belted in) when you put it in your car to drive to the school. *If the Dewar tips over, the LN_2 will spill out.*

You should start your demo by talking about the air around us. We can't see the air but we can feel it. Have the students wave their hands in the air and blow air through their mouths to "feel" the air. Explain to them what a gas, liquid and solid is. Tell them that air is made up of four main gases (explain that chemicals are what makes up everything around us – they don't know about atoms or molecules yet): nitrogen (N_2, 77%), oxygen (O_2, 20%), water vapor (H_2O, 2% here in LA), argon (Ar, 0.9%) and carbon dioxide (CO_2, 0.03%). Write the formulas of N_2, O_2, H_2O and CO_2 on the blackboard and have the class say their names (nitrogen, oxygen, water and carbon dioxide). Note that K-2nd graders do not know about % amounts, so you should just state that air is mostly nitrogen, then oxygen, a small amount of water, and very small amount of CO_2. Note that here in Louisiana due to the high humidity the H_2O content in air is usually around 2%.

Pour the LN_2 into the Styrofoam container and then a small amount onto the floor – make sure that the students are not very close. Tell them that this is nitrogen gas cooled enough to turn it into a liquid that we can see. Tell them that LN_2 is at a temperature of −196ºC or −321ºF and that water freezes at 0ºC or 32ºF (room temperature is about 22ºC or 72ºF). You probably just want to use ºF to keep things simple. Explain that when any gas is cooled enough it turns into a liquid. Pour some LN_2 into a couple of Styrofoam cups placed inside one-another and walk about the room showing the bubbling LN_2 to them. If they ask you what the white "smoke" is coming off the LN_2 tell them that you will explain that later. To demonstrate how cold the LN_2 is place a flower in the LN_2 in the larger container for about 45 seconds. Then take it out and immediately smash it in the clear plastic tray/lid (use the clear plastic top from a large aluminum roasting pan to contain the flower "mess"). It will shatter like glass! You can also crush it with your hand (the low heat capacity of the flower petals won't freeze your hand). Ask for volunteers to come up and freeze and shatter more flowers (2-4 at a time). You should have enough flowers for each student to participate.

Liquid O_2 Experiment

Now insert one of the O_2-filled balloons into the LN_2 and watch how it dramatically shrinks in size. As soon as it has shrunk completely, remove it. If you leave the balloon in too long it will get brittle and crack letting the O_2 out. At the bottom of the balloon is a light blue liquid, which is liquid O_2. You can discuss how gases expand as heated (hot air balloons) and shrink as cooled. When a gas turns into a liquid, the liquid occupies 600-800 times less space (volume). Once you take the balloon out of the LN_2 it will grow back to its original size. Let the students try this. LO_2 has a boiling point of −183ºC (−297ºF). Since LN_2 is colder, oxygen gas will condense inside the balloon causing the dramatic shrinkage. If you flip the balloon upside down and back it will inflate much more quickly. The students can see and feel the LO_2 flowing back and forth. So long as you/they hold the balloon lightly there is little danger of any frostbite. The other way to visualize LO_2 is to fill an empty aluminum soda can with LN_2. LO_2 (and some liquid Argon and solid CO_2) will condense on the outside of the can and drip off. If you do this, please use a pair of pliers to hold the can from the top rim (vise-grips work best). Walk around the class to show the students the LO_2 dripping from the can. You can see the level of the LN_2 inside the can by the "wetness" of the LO_2 on the outside of the can. It only will condense out where the LN_2 is touching the inside of the can. Tilting the can at a 45º angle makes the LO_2 drip off at the lowest point of the can bottom.

Water Vapor Experiment

Water gas or water vapor is also certainly present in air here in Louisiana where the humidity can be quite high. Explain to the students that humidity means that there is a fair bit of water in the air as a gas or vapor. When they exhale they are also putting out water vapor, which as a colorless gas is invisible. You can get them to see the water in their breaths by having them blow through straws over the top of the LN_2. Have 3-4 of them at a time come up and take turns

blowing through the straw onto the surface of the LN_2 (not directly into the LN_2) in the Styrofoam container. The white cloud that forms is not smoke, but rather condensed water vapor. It forms tiny droplets of water that makes the white cloud. The very cold LN2 causes the water vapor in the air and from their breaths to condense out forming the white clouds. The clouds almost immediately disappear because the water droplets warm right back up and re-evaporate back to form invisible water vapor. This is how fog forms. When it is humid enough and the temperature drops enough you get lots of tiny water droplets forming – that's fog! A good question at this point to ask them is whether it is cold or hot up in the sky where clouds are. The answer, of course, is that it is colder which causes the water to condense out of the gaseous form to make tiny droplets of water that makes clouds. When clouds are loaded with enough water, the tiny droplets of water combine to make rain!

Dry Ice Experiment

The last thing to show them is solid CO2 or dry ice.

> **Safety Note:** Dry ice is very cold, –78ºC or –108ºF. It will give you frostbite faster than LN_2 because it isn't as cold. That sounds contradictory, but it is because there is less of a Leidenfrost Barrier effect to protect your skin due to the smaller temperature differential between your skin and the dry ice. **Do not let students touch or play with the dry ice!** You can hold a piece safely in your bare hand so long as you hold it very lightly and move it from one hand to another.

Walk around the classroom and use your pliers to crush a small piece of dry ice on several of the student's desks. It will rapidly evaporate to gaseous CO_2. This is why it is called "dry ice" – because it doesn't leave a liquid behind. It evaporates directly from a solid to a liquid (this is called sublimation). Talk about how all animals (insects too) breath in O_2 and exhale some CO_2. We use O_2 to "burn" food in our bodies to provide energy to keep us alive. One of the waste products is CO_2, which we exhale. Let them see the solid CO_2 and tell them how cold it is (not as cold as LN_2 or LO_2). Take your glass container and half fill it with water. Drop several pieces of dry ice into the water and let the students see the bubbling and cloud that forms. Ask them what the white "smoke" is (it is condensed water vapor). Ask them why if we and all animals are exhaling CO_2 why there isn't more in the air. Discuss the importance of plants that use light energy and consume CO_2 to make food that we (and animals) eat.