Make a Comet Activity Instructions and Narrative

To be used with the instructional Web pages on the site "The Comet's Tale" at http://cse.ssl.berkeley.edu/Segway/lessons/CometsTale/com.html

Introduction:

The Make a Comet activity gives insight into the "dirty snowball" model of comets as being composed of material from the early solar system in the form of frozen water and gases, simple organic compounds, dust, and silicate (silicon-based) particles. We suggest playing the "What's in a comet anyway?" game beforehand to start students thinking and give some ideas. The activity can also lead to questions and explorations about what makes the cold dirty snowball into the brilliant nighttime objects shown in the Gallery.

Collect all ingredients/materials in advance, using the on-line list in the Make a Comet section of the "Comet's Tale." It is strongly advised that you try the activity yourself first. Set up the classroom with as many work stations as you will have groups, including a demo-station for yourself where everyone can see you. Paper cups are handy for pre-measuring ingredients if you have enough help. Have a minimum of 2 other adults on hand; one adult for each work station is ideal.

A note about the dry ice: To save time, get adult help with crushing the dry ice during the prep and setup time, then store it in a cooler and measure it out to each group when they are ready. Dry ice can be broken into chunks with a hammer and ice pick or chisel, then wrapped in newspaper or cardboard inside a large garbage bag and crushed with a good-sized hammer or small hand sledge. Do this out of the sun, on a hard surface like a concrete floor or a granite lab counter.

As the class does the activity, use the instructions in the left column to direct students at each step. Use the narrative from the right column to

explain each step. *(Don't read the parts in parenthesized italic type aloud.)* Vocabulary words that are listed in the on-line glossary are underlined.

Instructions	Narrative
Step 1: Begin this activity by arranging all the ingredients and utensils in front of you on a sturdy work table. *(Read the list of materials and have each group check out their materials.)*	Everyone needs to be conscious about safety! We'll be using dry ice today. It can cause cold "burns" and flying chips can be damaging to eyes, so whoever handles the dry ice must always wear protective gloves and goggles. Everyone in your group is responsible for following this rule.
Step 2: Open up one garbage bag and use it to line your mixing bowl. This will help you shape your comet, and make cleaning up easier at the end.	In our solar system, comets were part of what nature didn't clean up. As the matter around the sun cooled, it formed small planetesimals which then accumulated to form the planets. Comets were the leftovers, like the bits of dough left in the bowl after making cookies.
Step 3: Add the 2 cups of water to the mixing bowl.	Water (H_2O) is made from the gases hydrogen and oxygen. Hydrogen, oxygen, and water vapor were probably all present in the solar nebula, from which the sun, planets and comets formed. There is at least 10 times as much hydrogen in the universe than any other substance.
Step 4: Add 1/4 cup sand or dirt, stirring well.	You can't buy interplanetary dust at the store, so we have to use sand and dirt in its place. Sand and dirt have the minerals, and simple compounds that are found in comets. But dirt also

	contains bacteria, and mold, which are not found in comets. These other things have been created over the eons since the earth was formed.
Step 5: Next, add a dash of organic material *(e.g. corn syrup)*, stirring until well mixed.	Organic material means anything made up of carbon, hydrogen, nitrogen, and oxygen. All living things are made mostly of these four substances. Sugar, alcohol, and methane are also organic compounds. Scientists have discovered that our Milky Way galaxy actually contains a very simple kind sugar that probably existed before the planets were formed! Corn syrup represents simple organic compounds that were probably present in the solar nebula, and helped form life later on.
Step 6: Add about 1/8 cup *(2 Tablespoons)* of ammonia and stir some more. You should have a muddy, slightly smelly sludge.	Ammonia, the same compound we use to clean windows, is another organic compound which existed in the solar nebula. The atmospheres of the giant planets Jupiter and Saturn contain large amounts of ammonia.
Step 7: When you are ready, appoint someone in your team to handle the dry ice. That person must put on heavy gloves and goggles before coming to collect your dry ice.	Dry ice is frozen carbon dioxide, The same gas that makes bubbles in soda pop. Most of the atmosphere of Mars is carbon dioxide. When a comet is far from the sun, its carbon dioxide is frozen into dry ice.
Step 8: *(If your dry ice has already been crushed, read the narrative and go immediately on to Step 9.)*	We crush the dry ice to make it mix with the water, dirt and organic material. All the "ingredients" in the original solar nebula were pretty evenly mixed, so your comets' ingredients

Put the dry ice inside several plastic bags and crush it by pounding it with a hammer. You will need 2 cups of the crushed dry ice.	should be well mixed with no really big lumps.
Step 9: Add the dry ice to the other ingredients in the mixing bowl while stirring vigorously. Be sure to mix the ingredients quickly, for about 30 seconds. Move fast, as the dry ice will start to freeze the water right away.	Your stirring is like the rotation of the solar nebula that "mixed" the original batch of comets as it whirled through space. Mixing also brings all the ingredients to the same temperature.
Step 10: Now take your spoon out and just let the comet sit for a minute or two.	Although your laboratory, and most of your ingredients, are at room temperature, about 20 degrees Celsius, the dry ice is about -79 degrees Celsius. The dry ice cools the other ingredients until they are frozen solid. In space, real comets are usually so far away from the sun, they are even colder than this.
Step 11: Lift the comet out of the bowl by the plastic liner. Have one person hold the bag loosely. The person with the gloves should use their hands to compress and mold the contents for at least a minute. If you have more gloves, get others to help.	If the person holding the bag shuts it too tightly, the bag starts to blow up, or inflate. This is because some of the carbon dioxide is sublimating, or turning from dry ice into carbon dioxide gas. It's called "dry" ice because it never becomes a liquid. If a comet's orbit takes it near the sun and the sun heats it up, the surface of the comet starts to sublimate and break down. Some comets go so near the sun that they completely evaporate and burn up.

Step 12: Unwrap your comet from the plastic bag, and you're done!	Don't worry if your comet doesn't look round and smooth. Real comets aren't either. To see at a real comet passing by the earth, go to the Gallery and look at the close-up picture of Comet Halley taken by the Giotto spacecraft in 1986.

Discussion and closure: If you have one available, you may want to set up a heat lamp to demonstrate the how a comet's coma forms. Point the lamp at the ceiling and hold a comet over it (with gloves on!)and you may see plumes of steam coming off. This steam is really water vapor that is condensed by the super-cold CO_2 sublimating from the surface.

An astronomer named Fred Whipple suggested in 1950 that comets were a lot like "dirty snowballs." He was right--they are mostly frozen water, with some other gases and dirty stuff. Comets spend most of their time as frozen globs traveling far away from the sun on huge orbits, that may or may not go near the sun. However we also know that a few times each century, we see one in sky, often with long fiery tails. You might want to discuss what your students think causes these drastic changes.

Clean Up: Make sure everyone helps to clean up. The comets themselves can be placed in a large container like a detergent bucket, until the dry ice is completely sublimated. Students should not touch the comets with bare hands except very briefly. After they have melted again, dispose of the sludge in a well-lined garbage can or toilet.

The disappearance of the comets might raise questions about what happens to real comets. When you move on to the section on Orbits, you will have a chance to discuss how comets get close to the sun, how they are heated and "shed" material near perihelion in the form of gas, dust, and meteoroids, and thus gradually disintegrate.