HOW TO MAKE A COMET

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The primary mandate of NASA is the study of the nature and origin of the solar system. The study of comets provide us with unique information about conditions and processes at the beginning of the solar system. Short period comets and their relatives, the near Earth asteroids may prove to be second only to the sun in importance to the long term survival of civilization for two reasons. They are a possible candidate for the cause of mass extinctions of life on Earth; and they may provide the material means for the expansion of civilization into the solar system and beyond. They almost certainly represent the most primitive material of the solar system, still tantalizingly unavailable until space craft bring us first-hand information. In the meantime we must study comets by remote means. Laboratory investigations using synthetic cometary materials may add to our knowledge of these interesting objects.

Comets are presumed to be made of ices with noncontacting dispersions of micron and sub-micron sized particles (Whipple, F.L., Ch. 1, Comets, page 67 in McDonnell J.A.M., Cosmic Dust, New York, NY, Wiley & Sons, 1978). The most difficult physical characteristic to simulate is the dispersion of particles in ice in a way that prevents them from touching one another. This requirement is crucial because if the particles touch one another they are unlikely to be separated by the fluid dynamic forces (or electrostatic forces) at the subliming ice surface and the observed free flowing dust plume (comprising the comet's tail) will not be possible. It is possible, however, that even if the particles are not touching in the ice they may not escape the subliming surface and thus may form a mantle under some low rate of solar insolation. It is the study of these two processes, dust and mantle formation, that is the objective of this ongoing laboratory experimental investigation.

If a dispersion of particles in liquid water is frozen by ordinary means the freezing ice crystals push the particles ahead of the freezing solid-liquid interface. The particles are trapped in the ice where the ice crystals collide with one another. In the materials purification industry this phenomenon is referred to as zone refining. This phenomenon must be avoided if particle contact is to be prevented. In synthesizing comet ices we tried several methods of high-speed freezing the liquid dispersions of particles to obtain the requisite noncontacting particle dispersions in ice.

The most reliable means of freezing required that we spray a very dilute dispersion (100:1) of montmorillonite clay in water into liquid nitrogen through a very small nozzle (< 10 microns) at high pressures (500 psi). The nozzle must be within a few milimeters of the surface of the liquid nitrogen so that the droplets hit the liquid at high velocity and are frozen quickly. Because the orifice is nearly as small as the particles, means must be provided for continuously unplugging the nozzle. This was accomplished by using an adjustable coaxial needle valve orifice that could be continuously vibrated to remove any plugs produced by the submicron montmorillonite clay particles.

A slurry of water ice particles was formed in the liquid nitrogen. The liquid nitrogen was decanted and the concentrated slurry was poured into two stainless steel hemispherical salad bowls. A fine wire thermocouple was inserted into a small hole in the center of one hemisphere of the consolidated slurry. The other hemisphere was then joined to the first to form a spherical body of weakly sintered ice particles.

This "snow ball" (0.3 gm/cm3) was then suspended in a fine nylon hair net from a small spring scale. The entire assembly was then hung inside a cryotrapped, diffusion-pumped high-vacuum chamber. The chamber was pumped down to (10 -4 Torr) before all of the absorbed liquid nitrogen evaporated. The thermocouple indicated that some of the liquid nitrogen was in fact frozen during pumpdown.

This miniature "comet" sublimed away its water ice over the next seven days while the vacuum pressure, ice temperature and the weight of the body were recorded periodically. At the end of the experiment the sublimate residue that was left formed a sphere nearly the same size and shape as the original snow ball (.009gm/cm3).

Three slightly different "comet" sublimation experiments were performed in which the dust compositions (graphite was added) and concentrations (500:1) were varied. The sublimate residue spheres formed were similar in most respects (the 50% graphite made a weaker gray residue). They all took 7 to 8 days to sublime completely. The lowest temperature recorded after the solid nitrogen had sublimed was in the range of -60^0 C. The ice probably reached lower temperatures near the end of the experiment but, because the thermocouple lead conducted a significant amount of heat into the ice body the ice probably sublimed away from it early in the experiment. The vacuum chamber pressure continued to drop during the sublimation period (final pressure was 10-7Torr). This indicates that as the sublimate residue became thicker its insulating properties increased and the ice temperature dropped thus reducing the water vapor pressure in the chamber.

During the pumpdown small pieces (< 1 mm) of ice were ejected from the surface of the spherical body. These pieces of "snow" sublimed very quickly once they came in contact with the room temperature floor of the vacuum chamber. No indication of any free dust coming off the ice or from the sublimate residue was observed. The 300K walls of the vacuum chamber apparently did not produce enough radiation load onto the ice to produce a dust plume or the dust plume was so tenuous that we could not observe it. Future experiments using a solar simulator may be able to produce dust plumes. Some form of nephelometry will be used in these subsequent experiments to observe the dust if it is released. The amount of electrostatic charging produced due to the sublimation and the effect of induced electrostatic charge will also be measured.