What's Artificial Snow, and How Is It Made?

By Emma Hiolski/C&EN

When nature won't cooperate, people use myriad methods to craft snowscapes for all occasions.

WINTER SNOWFALLS HERALD ALL manner of fun and games: snowball fights, skiing, tobogganing, snowboarding, and every four years, couch potato-ing as people all over the world watch the Winter Olympics. But what's a winter sports enthusiast to do if the coveted precipitation doesn't make an appearance?

That's when artificial snow comes in.

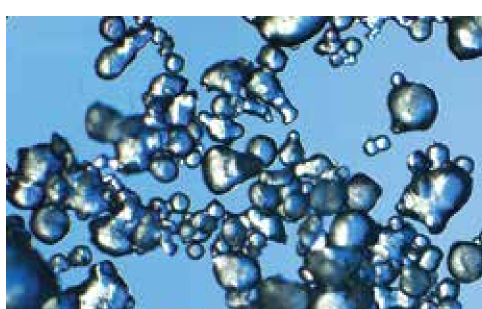
Over the years, human ingenuity has provided several ways to create or enhance snowscapes in all kinds of scenarios. One of the earliest ways to fake snow was simply by pulverizing large blocks of ice and spreading the shavings, but the material is very heavy and melts quickly. Nowadays, faux snow is no problem, whether you need to spruce up a ski slope or create a picture-perfect scene for the silver screen.

Using machines to make snow is commonplace for outdoor winter sports, including downhill skiing and snowboarding. To extend the season or simply enhance existing natural snow, ski resorts pump water and pressurized air uphill to "snow guns" stationed along the slopes. The snow guns atomize the water, —that is, turn it into tiny droplets—and spray out a long plume of the fine mist, which hopefully freezes before hitting the ground.

In 1980, the Olympics held in Lake Placid, N.Y., became the first Winter Games to use machine-made snow, but they weren't the last.

During the 2018 Olympics in South Korea, snow guns coated the slopes at the Jeongseon Alpine Centre, the site of the games' alpine speed events, according to the website of Michigan-based SMI Snowmakers. And the 2022 Winter Olympics in Beijing will have to rely almost entirely on snowmaking to offset the region's minimal precipitation.

As long as the temperature remains below about –8 °C (18 °F), snow guns can readily produce as much snow as needed. When the thermometer reads higher, the water needs a little help to freeze.



Under the microscope, tiny, irregular blobs of artificial snow (left) don't come close to mimicking the real thing. The artificial snow image containing many bits of ice is about 4 millimeters (mm) across. A single, real snowflake can range in size from about 1 mm to 5 mm on average. Monster snowflakes can be 10 mm from tip to tip!

KENNETH LIBBRECHT, PH.D.; SHUTTERSTOCK

The main article was adapted from "What's Artificial Snow, and How Is It Made?" which first appeared in *Chemical & Engineering News* on Feb. 5, 2018.

But first, how real snow forms

To understand how snow guns work, it might help to take a look at how snow forms without the help of technology. Natural snow forms when warm, moist air rises from Earth's warm surface and runs into colder layers of the atmosphere. **The drop in temperature lowers the kinetic energy of the water molecules, and the attraction between them starts pulling the molecules together, forming water droplets.**

Natural snow forms in clouds when water molecules organize around a nucleator, a particle that acts as a scaffolding to "kick-start" ice-crystal formation, says Daniel Cziczo, an atmospheric chemist at Massachusetts Institute of Technology. These nucleators often have a hexagonal binding structure that mimics that of water, although scientists aren't certain the hexagonal structure is required (Fig. 1). Once the binding gets started, the rest of the water molecules begin to knit together as ice, Cziczo says. Mineral dust, clay particles, and even bacteria can all serve as nucleation sites.

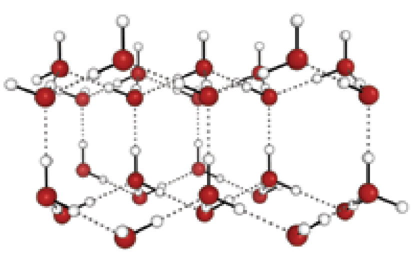


Figure 1. In this hexagonal crystal structure of ice (H_2O), red balls represent oxygen, and the white spheres represent hydrogen.

Earthbound snow guns, however, don't always have the benefit of the atmosphere's cold temperatures. Thus, artificial snowmakers have borrowed some nucleation ideas from on high to help water freeze more rapidly at temperatures closer to –5 °C (23 °F) or higher.

One such product is Snomax, a freeze-dried protein powder sold by Snomax International in Denver that gets mixed into the water pumped uphill to snow guns. Snomax derives its nucleating ability from *Pseudomonas syringae*, a bacterium commonly found on agricultural crops and other plants, as well as in the atmosphere. *P. syringae* has a powerful nucleating protein on its cell surface, with which it creates an icy spear to pierce plant cells and then feast upon their contents.

Surfactants: Beyond Snowmaking

SURFACTANTS HAVE MANY USES BEYOND HELPING SKI RESORTS make snow. They are also used in the formulation of pharmaceuticals and other applications. But their largest use is in soaps and detergents. Here's why:

Some substances just refuse to get wet. You may have noticed how water beads up on the surface of a greasy rag. The surface (the rag) does not attract the water droplets, so the water remains in small globular beads.

Beading happens when attractive forces within a substance are stronger than the substance's attraction to the surface it's on. The substance will tend to remain clustered by itself.

Polar molecules, such as water, have relatively strong intermolecular or cohesive attractions. Nonpolar compounds, such as wax or grease, aren't really attracted to polar water molecules. So using water to rinse out grease from a rag won't do much good since the water and the grease aren't attracted to each other.

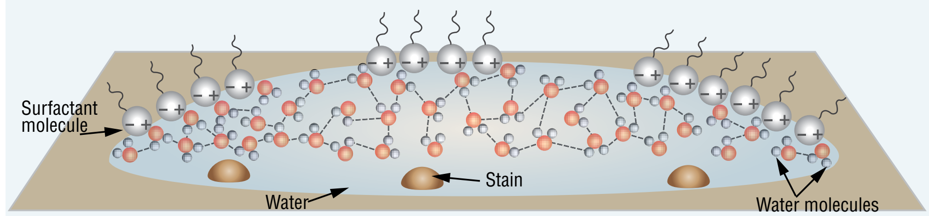
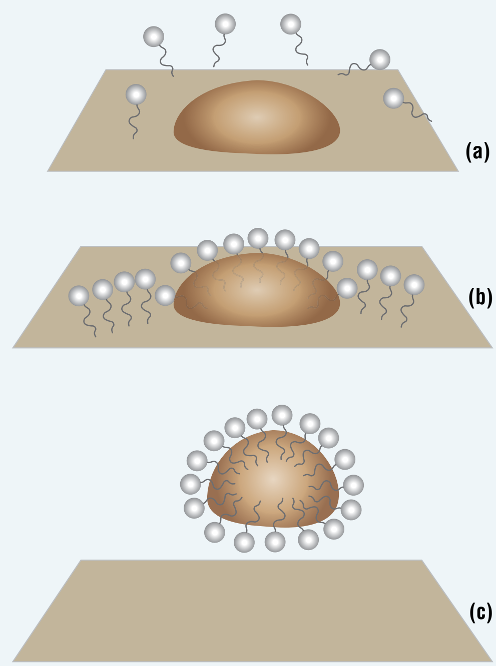


Figure 2. Surfactant molecules decrease the surface tension of a drop of water on a surface by spreading it on the surface.

Surfactants, or wetting agents, help overcome this standoffish behavior. The molecules of surfactants contain both polar and nonpolar components that interrupt the attractions among the water molecules and allows the nonpolar molecules to integrate with the water (Fig. 2). This interference encourages attractions between a polar liquid (water) and a nonpolar surface (greasy rag). The nonpolar portion of the surfactant molecules surround the grease stains, and dislodge them from the rag (Fig. 3). The stains rinse away because the polar end of the surfactant enveloping the stains is attracted to water.

Here is an easy, quick demonstration you can try. Wearing your safety goggles, use a dropping pipette to add drops of water to the surface of a penny. Count how many drops fit on the penny. Then dry the penny off and coat it with a thin film of dish soap, a surfactant. How many drops do you think will fit on the penny now? Try it to find out.

—Michael Tinnesand



ANTHONY FERNANDEZ

Figure 3. A stain on a piece of fabric is removed by surfactant molecules: (a) The nonpolar side of the surfactant molecules (their tails) are attracted to nonpolar oil molecules in the stain; (b) the surfactant molecules surround the stain; and (c) the surfactant molecules lift the stain out of the fabric.

We Can Make Snowy Slopes. Can We Make Rain on Demand?

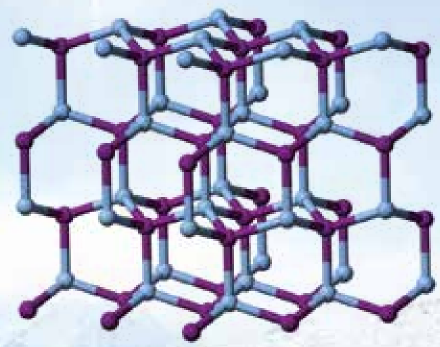
CREATING ARTIFICIAL SNOW FOR SKI RESORTS gives winter sports a huge boost, but this is just a small piece of a much larger picture.

Human efforts to coax the skies to produce precipitation started in earnest in the 1940s. The primary method for inducing rain was—and continues to be—cloud seeding. Natural rainstorms occur when water vapor in clouds cools and begins to condense into liquid. But we can have cloudy skies that don't yield a single snowflake or rain drop. In periods of drought or in arid locations, this means severe water shortages for millions of people.

Copying Nature

Condensation of water vapor appears to be more likely if water molecules can condense on a "seed." In natural rain, the seed is usually a solid speck of dust, pollen, or even airborne bacteria.

In 1946, Bernard Vonnegut, a researcher at General Electric, discovered that fine crystals of silver iodide (AgI) could be used as seed crystals to encourage rain to form and fall. Other substances, such as potassium iodide (KI) and dry ice (CO_2), have also been used, as has table salt (NaCl). Table salt has the advantage of being hygroscopic—it attracts and holds water vapor molecules. These seeding substances are either released from aircraft or shot into the sky.



Efforts to make it rain or snow often involve spraying fine crystals of silver iodide (AgI).

Cloudy Results

The final effects of these and other techniques are difficult to measure. The atmospheric conditions that occur in cloud systems are complex, and measuring all the variables is very difficult.

Still, cloud-seeding projects continue today. And one day, we might develop technology that will finally allow us to make rain where it's needed most. Then the question will be: Should we use it?

—Michael Tinnesand

Drift, a snowmaking additive launched in 2001 by Aquatrols in Paulsboro, N.J., is an organic compound that acts as a surfactant (Fig. 4). By reducing the surface tension of the water sprayed out of snow guns, this surfactant helps the droplets freeze more rapidly rather than clump together, says Andy Moore, the sales director for Drift. This ability helps increase the high-temperature window for snowmaking by about 1 °C (1.8 °F) and can improve snow quality at lower temperatures, he says.

"What we do is real snow," Moore points out. "We're just helping to make it."

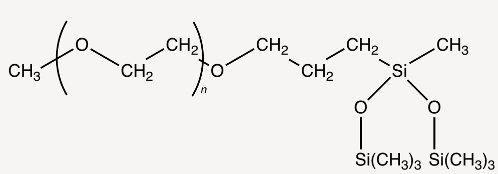


Figure 4. Structure of the major component of Drift. The OCH_2CH_2 polymer in parentheses is hydrophilic; and the silicon-containing end is hydrophobic.

Technicians use dry foam to create snowfall during a video shoot.

Faux snow on the silver screen

For snowscapes that require a higher degree of control, like movie and television sets, an array of truly artificial snow products is available. Most of those in use today, according to Roland Hathaway of Snow Business Hollywood, are paper based, though that wasn't always the case.

Cornflakes, painted white, are an early example of a faux film snow, Hathaway says, but that crunchy snow stand-in faded quickly with the advent of audio recording. Firefighting foam, instant potato flakes, and flour have also graced the silver screen. Marble dust was famously used in filming "Doctor Zhivago," and gypsum ($CaSO_4 \cdot 2H_2O$) is another alternative still in use today.

Paper, however, is the most popular, due to the variety of thicknesses, textures, and grain sizes—some almost as fine as flour—available to create gentle dustings or knee-deep drifts. Paper snow comes packaged in bales, which are then blown through a specialized hose that lightly dampens the paper to help it stick to the surfaces it lands on. This technique can cover up to 37 m^2 (398 ft^2) per minute, including structures and trees, Hathaway says.

Best of all, it doesn't melt. CM

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