

Ice Cube Spikes

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Abstract. We answer surely one of the most prominent scientific problems in your life: why ice "spikes" occur jutting out of the top surface of ice cubes.

Naively, you might expect the top surface of an ice cube in your ice cube tray, to be flat. But often it is not. Usually it is convexly curved. Indeed, many years ago, Henry Cejtin pointed out to me that ice cubes in his ice cube tray, often had an ice spike jutting out of their top surface, either vertically, or more commonly diagonally, a bit like an upside-down icicle. In the most spectacular cases the ice spike could be as long as 3 times the sidelength of the ice cube. We decided we had no idea why that happened.

Whether and how often this happens, depends greatly on your ice cube tray (e.g. is it metal or plastic? what size & shape cubes?) and its position relative to everything else in your freezer. In my life, the phenomenon has always been rare (5% or fewer cubes have spikes). However, I recently switched to a translucent plastic ice cube tray with 2 rows of 8 ice cubes, each about 35×57×32(high) mm (not truly rectangular since actually a bit narrower toward the bottom to enable the cubes to be extracted easily), and re-arranged my freezer; and now I get spikes on about 30% of the cubes. In my current setup, it takes about 7 hours for full ice cube tray freezing.

If you freeze olive oil instead of water, you never get spikes.

It then become pretty easy to figure out why spikes happen by looking at the cubes every hour as they froze.

Step 1. The water freezes around the outer boundary of the ice cube, giving you a hollow ice cube with an oval internal region filled with still-liquid water. This is because the water is initially warm, and the heat is lost through the surface, which gets cold hence freezes. The situation has some resemblance to the planet Earth (solid crust, inner liquid).

Step 2. Ice has density 0.9167-0.9168 while water has density 0.9998-0.9999 at 0°C and 1 atm pressure. Olive oil shows that it is essential (for spike formation) that the density of ice is less than liquid water. Therefore, as the internal liquid-filled region freezes, it will try to increase in volume by 9%, but will be prevented by the rigid ice walls of the surrounding cube.

Step 3. The pressure thus built up ultimately will enormously exceed the tensile strength of the ice, so the ice cube will first distort and then something will break. Any hole thus formed on the top surface of the ice cube will therefore be a "volcano."

Step 4. Perhaps some steps in this process are sudden and violent – I do not know since I never witnessed that. But it is, at least mostly, gradual and gentle. We then can get a spike pushed out of the top surface of the cube by the internal pressure, getting continually "welded" by leaking water which freezes when it hits the cold outside air; and the geometry of the spike loses heat, due to conduction and/or air-convection, faster than average, causing freezing all round the bottom of the spike, thus extending it.

Step 5. Those welds get "broken" by the internal pressure since the welds are made of weaker-than-average and thinner-than-average ice. This lifts the spike a bit further. The growing spike is "lubricated" versus the wall of the hole. Steps 4 & 5 occur cyclically and/or continually.

Step 6. Process ends when everything frozen solid.

After doing all this, [wikipedia](#) claimed that basically the same idea, under the name "Bally-Dorsey model," was proposed by Herbert G. Dorsey in 1921 and Oscar Bally in 1935. (Actually, upon examining their papers I do not see any explanation nearly as clear as mine.) I don't know if this can be considered "proof," but the fact several people independently came up with essentially the same hypothesis indicates: probably valid. Obviously, I cannot claim to be the first discoverer.

Oscar Bally: Über eine eigenartige Eiskrystallbildung, Helvetica Chimica Acta 18,1 (1935) 475-476.

Herbert G. Dorsey: Peculiar Ice Formations, Physical Review 18,2 (1921) 162-164.