Geek Trivia: The ice is right

Remember the old days when science only expected you to know about three states of matter: Solid, liquid, and gas? Then they started in with the fourth state — plasma — which looks suspiciously like a gas except that the electrons are misbehaving under the guise of ionization. The majority of known matter in the universe is plasma, so we were willing to put up with the change, but those pesky physicists are really getting out of hand now.

Bose-Einstein condensates? String-net liquid? Electron-degenerate matter? There are roughly 20 known or theorized states of matter in the lexicon these days, and most of them display mind-boggling characteristics and occur only under extraordinary conditions — like, say, in the heart of a neutron star.

This, of course, makes no mention of phases of matter, which are different than (but not unrelated to) states of matter. Phases are in some respects subsets of states, and the proverbial example of this relationship is the difference between diamond and graphite.

Both diamond and graphite are pure carbon — solid crystalline carbon, in fact — but they are different phases of the same element. Diamonds and graphite have different crystalline structures — each boasting significantly different physical characteristics — but both are still the same state of carbon.

Now, if you think the difference between phases and states of matter is no concern to the average Joe, let me introduce you to the late Kurt Vonnegut's novel *Cat's Cradle*, which supposes a new form of water called *Ice Nine*. Ice Nine, you see, is solid at room temperature and forces all other water to align to its crystalline structure on contact. Drop it in the ocean, and it's adios life on Earth.

Thankfully, the real ninth type of dihydrogen monoxide crystal (i.e., water ice) isn't quite so grey gooey, but it's a little different than the everyday ice that coats the inside of your household freezer. Moreover, there are more than just nine known kinds of ice crystal out there, though none of them quite match up to Vonnegut's lethal phase of water crystal.

HOW MANY DIFFERENT TYPES OF WATER ICE CRYSTAL ARE KNOWN TO EXIST?

How many different types of water ice crystal exist?

As of today, there are 15 different types of crystalline water ice, each with different crystalline structures and/or physical characteristics. There are 14 major types, each denoted with a roman numeral. So Ice Nine is actually Ice IX. We get our 15th type because the first type, Ice I, has two subsets: Ice I_h and Ice I_c.

Ice I_h is your proverbial everyday ice, which makes up snowflakes and ice cubes and contributes to several varieties of tasty frozen desserts. The *h* stands for *hexagonal*, which describes the crystal structure and explains why snowflakes have six points.

Ice I_c has a different crystalline structure — the *c* stands for *cubic*. Ice I_c forms at extremely low temperatures — between 130 and 200 degrees Kelvin (-226 to -100 degrees Fahrenheit). However, you can find it in nature — as long as your definition of "nature" includes the upper bounds of Earth's atmosphere.

We can't apply the same "naturally occurring" label to most other variants of ice, as almost all of them are products of laboratory experiments involving extreme temperatures and pressures. For example, the aforementioned Ice IX exists only under pressures between 200 and 400 megapascals (between 2,000 and 4,000 times Earth's sea-level atmospheric pressure) and temperatures below 140 degrees Kelvin (-208 degrees Fahrenheit).

That said, these 15 types of ice crystal do not represent the entire range of possible forms for frozen water. Ice, generally speaking, is a crystal, with a regular and repetitious molecular structure. On Earth, this is the form that water typically takes when frozen solid.

In space, it's another story. Enter amorphous ice, the frozen-water equivalent of glass. Unlike crystal ice, amorphous ice has no regular molecular structure. Amorphous ice occurs when water freezes so quickly that a crystal lattice can't form.

Scientists generate low-density amorphous ice by spraying water vapor slowly onto extremely cold metal plating, which is why astrophysicists and astronomers theorize that amorphous ice is the prevalent form of frozen water in outer space. Water vapor ejected into the vacuum would flash-freeze into an amorphous mass, rather than form orderly crystals as ice does in the friendly confines of a human-habitable atmosphere. "Normal" ice is actually rather rare.

That's not just an abrupt phase transition — it's ice-cold Geek Trivia.