Chemistry of Changing Seasons: Snow

Snow is a precipitation from the atmospheric water vapor in the form of crystalline ice falling from the cloud in horde of light white flakes. Since it is composed of small ice particles, it is granular material with soft structure unless lightly packed by the force of external pressure. When temperature reaches 32^0F ($0\ ^0$C) or lower, water changes from the liquid state to the solid state (ice):

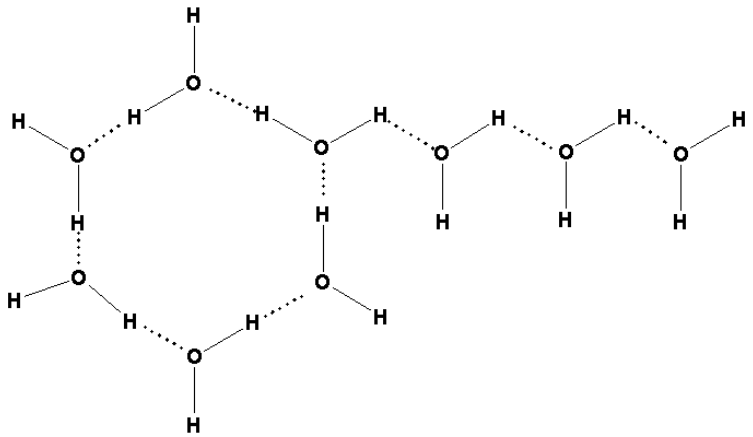
$$H_2O\ (l) \rightarrow H_2O(s) \qquad \Delta H = -6.01\ kJ/mol$$

Under this condition, **snowflakes** are born in clouds in variety of shapes and sizes influenced by several factors like, temperature, air currents, and humidity. Dirt and dust particles, if present in water, can affect crystal weight and durability, making snowflakes heavier and susceptible to cracks and breaks in crystals thereby subjecting to easy melt. The process of snowflake (solid water) formation is an exothermic reaction, meaning, heat is released to the surrounding. That is why the air feels warmer when snow it is snowing. From the above equation it is evident that one mole of water (18 g) releases about 6.01 kJ of heat into the atmosphere or about 334 kJ of heat per liter of water or about 1260 kJ of heat per gal of water.

The process of precipitating snow is known as **snowfall**. Snow on the ground can be categorized as either powdery when fluffy or granular. When it goes through cycles of melting and refreezing and eventually ice, it packs into a dense mass known as **snowpack.** If the snow remains on the ground for years uninterrupted, the snowpack develops into a mass of ice called **glacier** or **iceberg**.

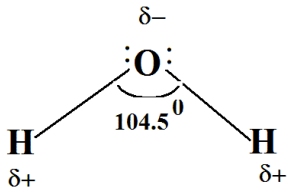
Snowflakes are generally hexagonal (six-sided) crystals that are formed in high clouds when the temperature is suitable; flat hexagonal crystals or needles are synthesized in middle height clouds, and a range of hexagonal shapes is formed in low clouds. Lower temperature produces snowflakes with sharper tips on the sides of the crystal and may lead to branching of the snowflake arms (dendrites). For example, hexagonal plates are formed when the temperature falls between 32^0 and 25^0 F, needles between 25^0 and 21^0 F, hollow columns between 21^0 and14^0 F, hexagons with indentations (sector plates) between 14^0 and10^0 F, and lacy hexagonal shapes (dendrites) between 10^0 and 3^0 F. There are, of course, numerous websites about the snowflakes. Among them, SnowCrystals.com, displays beautiful colored pictures of variety of snowflakes.

Not all the snowflakes are symmetrical due to uneven temperature, presence of dirt, and influence of other factors. In spite of that, it is true that many snowflakes are symmetrical and complex in nature reflecting on the arrangement of water molecules (a typical snowflake consists of roughly 10^{18}(quintillion) water molecules) when they are transformed from liquid state to solid state (ice, snowflakes). The water molecules form a special kind of bond known as "**hydrogen bond"** (a weak bond between oxygen atom (O) and hydrogen atom (H), the dotted line in the following diagram) with one another and when frozen lead towards symmetrical hexagonal shape of the snowflakes.



Compared to any other liquids on this planet, water has very unusual property, that is, upon freezing solid water (ice) becomes less dense than liquid water due to the formation of hydrogen bonds between water molecules (intermolecular forces) creating hexagonal crystals and making solid less dense than water (ice floats on liquid water) that is an important factor in manipulating Earth's climate as well as protecting aquatic and marine lives in the winter time. This is the way the nature protects its assets. Without this property, the ice would sink to the bottom annihilating aquatic and marine lives in the winter time that is devastating to the ecosystem. In addition, the loss of wild life and vegetation is also eminent

Now the question is why the formation of hydrogen bonds makes the ice float on water? In order to understand this, we have to examine the structure of water and the manner in which one water molecule hydrogen bonds to another molecule. To start with, water is formed by two hydrogen atoms (H) covalently bonded to one oxygen atom (O):



The oxygen atom being more electronegative (electronegativity of O-atom is 3.5) than hydrogen atoms (electronegativity of H-atom is 2.1), the electrons are drawn from hydrogen atoms to oxygen atom making the water molecule as a polar molecule leading towards formation of hydrogen bonds between water molecules. Water molecule is a planar bent-type of molecule with bond angle of 104.5^0 and with O-H bond length of 96 pm (9.6×10^{-11} m). Since it is a bent-type of molecule, it creates lots of empty space between molecules when hydrogen bonds are formed. Consequently, fewer number of water molecules are packed in a unit volume of ice than water leading towards lower density (the density is defined as the ratio of mass to volume) than water. That is the reason why ice is less dense than water making it to float on water.

The water and ice are clear, yet the **snow is white**. This is because snowflakes have many light-reflecting surfaces for scattering the light into all of its colors resulting in a white color (white color is composed of all the colors). Light reflecting from ice, especially, glaciers and icebergs appear blue due to absorption of the red frequencies than blue ones. Also, icebergs containing impurities, such as, sediments, algae, air bubbles, can appear brown, grey or green.

When about 10-inch depth of snow melts, it becomes about 1-inch depth of water (approximate 10:1 ratio). Newly fallen snow acts a sound-absorbing material minimizing sound over its surface due to trapped air between individual flakes that trap sound waves and diminish vibrations. Snowfall can be beneficial to agriculture acting as a thermal insulator, conserving the heat of the earth and protecting crops from subfreezing conditions. Many winter sports like skiing, ice hockey, and snowboarding depend on snow.

Mahadev Kumbar, Chemistry Department, NCC