CONDENSATION AND ICING NUCLEI

Spontaneous Nature of Vaporization and Melting: When a surface of ice is exposed to the free atmosphere, gross vaporization (sublimation) automatically takes place. No initiating element or event is necessary. It simply occurs. Moreover, you can't stop it. As long as the ice surface is exposed to the free atmosphere, gross vaporization ***will*** take place.

Similarly, when a surface of water is exposed to the free atmosphere, gross vaporization also automatically takes place. No initiating element or event is necessary. It simply occurs. Moreover, you can't stop it. As long as the water surface is exposed to the free atmosphere, gross vaporization ***will*** take place.

In somewhat the same fashion, when the temperature of atmospheric ice is raised above the melting point, melting automatically takes place. Again, no initiating element or other initiating event is necessary. It simply occurs. Moreover, you can't stop it. As long as the ice remains at a temperature higher than 0°C, gross liquification ***will*** take place.

Lack of Spontaneity in Condensation and Freezing: In a symmetrical universe, condensation and freezing would be similarly spontaneous and automatic. Unfortunately, this is rarely the case. Clean water vapor, free of impurities, can be cooled far below the dew point without net condensation taking place. Relative humidities of several hundred percent can be reached without any net condensation occurring.

Similarly, clean liquid water can be cooled to temperatures as low as -42°C before freezing starts to occur. Most winter clouds are made up of water droplets at temperatures considerably below 0°C. These supercooled droplets form, vaporize, grow, collide, coalesce, and fragment all without any apparent freezing.

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Essential Presence of Condensation and Freezing Nuclei: For some time now, we have known that exotic condensation nuclei and icing nuclei are necessary to initiate both condensation of water and freezing of ice. Exotic here means apart from the water molecules itself.

There are an enormous number of different aerosols that have been shown to be able to act as either cloud condensation nuclei (CCN) or icing nuclei (IN). These range from simple sea salt and ordinary dust particles to complex organic particulates, and even to living bacteria. Bacteria (both living and dead) are believed to play a very significant role in the initiation of snowflakes.

The concentration of such nuclei in the troposphere ranges from less than a hundred to more than a million per cubic meter of atmosphere. The closer you get to the Earth's surface, the more abundant they become. On the surface itself, they are so abundant that condensation usually occurs at temperatures several degrees above the dew point and at relative humidities as low as 75%.

Icing nuclei are also so abundant on the surface that ice normally forms as soon as the temperature drops below the "freezing point". This factor has given rise to the common (but fallacious) belief that water automatically freezes when this freezing point is reached.

Hygroscopic Nuclei: Some nuclei exert a positive attractive force on approaching water vapor molecules. This force may be chemical (such as exist in deliquescent salts) or physical (the hydrogen bonding of water molecules to silica surfaces) or both. Such nuclei are referred to as hygroscopic. Nuclei are considered to be hygroscopic if measurable condensation occurs at relative humidities below 100%. In the case of common sea salt, condensation may occur with relative humidities as low as 78%. Some industrial particulates have even stronger hygroscopic properties.

In the absence of hygroscopicity, vapor molecules colliding with the nuclei simply rebound and continue on as vapor molecules. When the surface is hygroscopic, however, the vapor molecule is very likely to be either adsorbed or absorbed. Either result starts the condensation process, since water molecules so bonded have enhanced attractiveness to other water molecules. Hydrogen bonding can form clusters, and surface tension (or its equivalent in small clusters) can both restrict molecular escapes and attract passing vapor molecules (forced inflow).

In a similar fashion, liquid water molecules bond to the icing nuclei, initiating the freezing process. While not as apparent or as well documented as the initiation of condensation at temperatures above the dew point, it appears that under some circumstances, the freezing of water can take place at temperatures above the so-called "freezing point". This is attested to by the occurrence of frost damage in plant tissue at temperatures as high as 4°C, and by the formation of clathrates (under pressure) in gas pipelines at temperatures as high as 18°C.

Summary: The presence of condensation nuclei and icing nuclei appear to be necessary to initiate condensation and freezing in the free atmosphere. Simple cooling of water vapor does not by itself initiate condensation. Similarly, simple cooling of liquid water doe not by itself initiate freezing. In both cases, an initiating element (the nuclei) is necessary in addition to the initiating event (the cooling).

For condensation, at any rate, the abundance of such nuclei commonly initiates condensation at temperatures well above the dew point and at relative humidities well below "saturation" levels.

Under very narrow circumstances, the abundance of icing nuclei can have a similar effect on icing temperatures.

