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Combining Kelvin's Equation with Jennings' Equation for Snow Formation

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Abstract
Winter snow is necessary for countries to maintain their crops. Here we combine two equations, one the Kelvin equation (Young, 1993, page 30) [1], and an equation derived by (Jennings, 2025) [2], by eliminating kT between them. T is the temperature of supercooling in the cloud. Here is the Kelvin equation for prssure of a raindrop over a curved surface.

$$\ln (P / P_{sat}) = (2\ \sigma) / (N_L\ k\ T\ r)$$

Then we present the Jennings equation for undercooling in snow formation.

$$T = (D\ (7.14 \times 10^7)) / (k\ ns\ a\ (To - T)^{0.69})$$

By taking kT out of both the result becomes.

$$(2\ \sigma) / (\ln (P / P_{sat})\ r) = (D\ (7.785 \times 10^7)) / (a\ (To - T)^{0.69})$$

To > T and D is a function of T and P. D, the self-diffusion coefficient, is obtained by consulting Krynicki, *et al* (1978) [3]. Since a snow forming cloud can form at 0°C, it is instructive to get D near there. For σ, water surface tension, this is found in (Hacker, 1951) [4].

Keywords: Kelvin's Equation, Jennings' Equation, Nomenclature

Introduction

The question arises, Why is it mathematically sound to eliminate kT between the Kelvin equation and the Jennings equation? In (Young, 1993, pages 30 to 40) [1] we see that the nucleation expression (3.36) follows from the Kelvin equation and the Boltzmann distribution (3.16). The T in the nucleation expression is the temperature inside the cloud, which corresponds to the T in Jennings' undercooling equation. Thus, we can eliminate kT between the two equations.

Results

Now it is necessary to put the numbers into the desired equation in the ABSTRACT. Again, we have.

$$(2\ \sigma) / (\ln (P / P_{sat})\ r) = (D\ (7.785 \times 10^7)) / (a\ (To - T)^{0.69}) \quad (1)$$

The values are given in NOMENCLATURE. We get T, the undercooling temperature, by putting all the numbers in for temperature at 0°C. Another reference is required (Jennings, 2023) [5]. (1) shows that T, the undercooling temperature, depends on P, the pressure inside the cloud.

Nomenclature

a: atomic spacing of ice = 2.76×10^{-10} m
D: Self-diffusion coefficient of water = 1.2×10^{-9} m^2-s^{-1}
k: Boltzmann constant (Joules/Kelvin) = 1.380649 × 10-23 m2 kg s-2 K-1
N_L: number density of water at 0°C, 3.3425×10^{22} molecules/cm^3
n_s: number density of ice at 0°C, 3.0656×10^{22} molecules/cm^3
P: water vapor pressure in cloud over spherically curved water surface (bar)
P_{sat}: saturated vapor pressure over plane water surface (bar)

r: critical drop radius = 0.7663×10^{-7} cm
T: supercooling temperature in cloud (Kelvin)
T_o: freezing temperature of water (Kelvin) = 273.15 Kelvin
σ: surface tension of water at 0°C = 75.6 dyne/cm

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