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Boiling Point Elevation and AgI Cloud-Seeding

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Abstract
Jennings, in 2020, proposed an equation for rise in superheat by adding electrolyte. Expanding that equation (letting the limiting slope be the true slope) produces one which is quadratic in To, the limit of superheat. The temperature of the solution is T and T - To is small and positive. The surface tension be taken as constant because ΔT is so small, thus the quadratic is solved for To. All of the variables are found and a simple formula, To = T - 3 ε T*2* emerges using the binomial theorem where T is set at 288.2K, a typical temperature for a cloud producing rain. The meaning of this simple formula is unclear, but it echoes boiling point elevation in that 3 ε T*2* is roughly 2 millidegrees. This relates to cloud-seeding, putting w2 at approximately 2 nanograms/cc, according to Standler and Vonnegut's estimate. A 2021 paper by Jennings provides the rationale for linking this all to rainfall.

Keywords: Boiling Point, Cloud-Seeding, Electrolyte

1. Introduction
The formula for rise in superheat by adding electrolyte is:

$$\lim c\rightarrow 0\ (dT/dc)s,\ \text{electrolyte} = (3\ k\ To2\ \ MWo\ i) / (\ \rho_o\ \sigma o\ ao\ MW2(e)) \quad (1)$$

Then,

$$\lim c\rightarrow 0\ (dT/dw2) = (3\ k\ To2\ MWo\ i)\ ((dc/dw2) / (\rho_o)) / (\sigma o\ ao\ MW2(e)) \quad (2)$$

From Jennings, 2020, we have

$$dc/dw2 = m_o/v \text{ and } \rho_o = m_o/v \quad (3)$$

So, using (3) and expanding in w2, we further have. This assumes the slope can be treated the same way as in Jennings 2014: the limiting slope is the true slope.

$$T\text{-}To = (3\ k\ To2\ MWo\ i\ w2) / (\sigma o\ ao\ MW2(e)) \quad (4)$$

(4) is quadratic in To, the Dew Point, and w2 is got from Standler/Vonnegut's estimate
for silver in snow from seeded clouds. Because it turns out that T-To is about 2 millidegrees, then the surface tension, σo, can be taken as a constant to allow the following.

Expanding it out to power of 3 we have, from the binomial expansion.

$$(1 + x\ )1/2 = 1 + (1/2)\ x - (1/8)\ x2 + (1/16)\ x3$$
$$= 1 + (1/2)\ 12\ \varepsilon\ T - (1/8)\ (12\ \varepsilon\ T)2 + (1/16)(12\ \varepsilon\ T)3 \quad (5)$$

Notice 12 ε T = 3.5 x 10-5 so the term in power 3 is negligible
Now we have to examine ε which is a collection of terms

w2 and σo are hard to determine, especially w2.

$$\varepsilon = (k\ MWo\ i\ w_2) / (\sigma o\ ao\ MW_2(e)) \qquad (6)$$

The resulting equation is still To = T - 3 ε T2 so maybe the equation could be used to adjust the AgI cloud-seeding agent weight fraction w2 to the proper value.
If To and T are actually as close as this indicates, the surface tension of the water, σo, will be taken as constant.

I boiled it down to (solution of quadratic equation).

$$To = (- 1 + (1+ 12\ \varepsilon\ T\ )1/2) / (6\ \varepsilon) \qquad (7)$$

Then I found out I could neglect the higher cubic term because x is minuscule. x = 3.5 x 10-5

$$(1 + x\ )1/2 = 1 + (1/2)\ x - (1/8)\ x2+ (1/16)\ x3 \qquad (8)$$

$\varepsilon = 1.00 \times 10^{-8}$ deg^{-1} T = 288.2K x = 12 ε T cubic term negligible

And then, with some algebra

$$To = (- 1 + 1+ (1/2)\ 12\ \varepsilon\ T - (1/8)\ (12\ \varepsilon\ T)2) / (6\ \varepsilon) \qquad (9)$$

$$To = (6\ \varepsilon\ T - (144/8)\ (\varepsilon\ T)2) / (6\ \varepsilon)$$

$$To = T - (18)\ (\varepsilon\ T)2/\ 6\ \varepsilon$$

Finally, To = T - 3 ε T2. (10)

T - To is minuscule, so I don't know what that means.

We are taking 288.2K as the temperature of the raincloud and w2 = gm/cc (AgI) / gm/cc (air).
gm/cc (AgI) = 2 nanograms/cc and gm/cc (air) = 0.00123 gm/cc. So, w2 = 0.00163. This is from Standler and Vonnegut p. 1389 and the Internet.

2. Discussion

The Nomenclature section has a full outlay of the data used to get $\varepsilon = 1.00 \times 10^{-8}\ deg^{-1}$. It is interesting to note that this harks back to boiling point elevation in that BPE is also measured in millidegrees.

$$T – To = 3\ \varepsilon\ T2 = 0.002492 \text{ degrees Centigrade} \qquad (11)$$

This is an exploratory study and the author doesn't know the scientific meaning of (9). Possibly this sheds light on how much AgI to use during cloud-seeding. Solving the quadratic and making the approximation gives (11).

3. Conclusion

What the author has presented here is an odd new equation he is linking to creation of rainfall. Cloud-seeding by silver iodide appears to be most common, so conceivably there is value in this paper.

4. Acknowledgments

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Table 1: Nomenclature

Ag	silver
a_o	Surface area of H2O molecule
c	Concentration of AgI in cloud
I	Iodine
i	Van't Hoff factor = 2
k	Boltzmann constant = 1.3805×10^{-16} erg/deg
m_o	Mass of water
MWo	Molecular weight of water
MW_2 (e)	Molecular weight of AgI
T	Temperature of cloud
To	Temperature at onset of raincloud
v	Characteristic volume
w2	Weight fraction AgI in cloud vapor after cloud-seeding (in text)
x	Unknown
ε	Variable
ρ_o	Density of water at To
σo	Surface tension of water at 15 degrees Centigrade = 74 erg/cm

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