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A New Formula for the Rain Dew Point

John H Jennings

Jennings Research & Editing 2530 Hillegass Ave. #307, Berkeley, CA 94704, USA

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Corresponding Author: **John H Jennings**

Abstract
By using the Ostwald-Freundlich [1] equation to simplify the Jennings [2] equation for the dew point of initiation of rain in a cloud, the author has succeeded in eliminating P_{H2O}, the water vapor pressure. The following equation for nucleation is proved here in this paper.

$$To-T=(3kTo^2/\sigma_o a_o)(P^*_{H2O}/Pair)$$

Here T is the undercooling below to the freezing point of water, and P^*_{H2O} is the equilibrium water vapor pressure. The other variables are defined in NOMENCLATURE.

Keywords: Nucleation, Vapor Pressure, Dew Point, Rain Droplets

Introduction

Jennings [2] derived an equation for the dew point through nucleation when a cloud begins to form rain droplets. It is this equation.

$$To–T=(3kTo^2/\sigma_o a_o)(P^*_{H2O}/Pair)RH \quad (1)$$

In (1), RH is the relative humidity ≡ vapor pressure of water/equilibrium (saturated) vapor pressure of water, or P_{H2O}/P^*_{H2O}. Thus, the P^*_{H2O} terms cancel, so we have.

$$To–T=(3kTo^2/\sigma_o a_o)(P_{H2O}/Pair) \quad (2)$$

Then there is the Ostwald-Freundlich [1] equation (3), which was derived after Lord Kelvin's [3] formula (5) for the vapor pressure of a droplet with a curved surface of radius r. The derivation of the Ostwald-Freundlich equation will be presented in Results.

$$p(r) = P + (2\ \sigma_o\ V_{molecule}\ P)/(k\ T\ r) \quad (3)$$

Combining (2) and (3) we are able to eliminate P_{H2O} from (2) to get a new formula for the rain dew point (4).

$$To-T=(3kTo^2/\sigma_o a_o)(P^*_{H2O}/Pair) \quad (4)$$

P^*_{H2O} is known, the equilibrium water vapor pressure, and that makes it possible to calculate T the undercooling for the cloud to produce rain droplets.

Results

In 1871, Lord Kelvin published his first version (5) of the raising of the vapor pressure from radius orthogonal curvatures r_1 and r_2. This derivation is largely taken from Reference [1].

$$p(r_1,r_2)=P-((\sigma_o\ \rho_{vapor})/(\rho_{liquid}-\rho_{vapor})(1/r_1+1/r_2) \quad (5)$$

Because Kelvin took the surface tension as the work performed by the interface rather than *on* the interface, the sign of σ_o is taken to be positive. Also, since $\rho_{liquid}>>\rho_{vapor}$, then $\rho_{liquid}-\rho_{vapor}\approx\rho_{liquid}$. Equation (5) becomes.

$$p(r)=P+2(\sigma_o \rho_{vapor})/((\rho_{liquid})(r)) \quad (6)$$

Where the surface is a sphere with radius r. Since the vapor is an ideal gas, we have.

$$\rho_{vapor}=(MW_{water}P)/(N_AkT) \quad (7)$$

Combing (6) and (7) gives (8).

$$p(r)=P+ 2\sigma_o((MW_{water}P)/(N_AkT))/((\rho_{liquid})(r)) \quad (8)$$

So, we have.

$$(p(r)-P)/P=2\sigma_o((MW_{water})/(N_AkT))/((\rho_{liquid})(r)) \quad (9)$$

Now, p(r)=vapor pressure of the water droplet=P_{H2O} and P=equilibrium vapor pressure of water from droplet with r=∞, or P^*_{H2O}.

Discussion

It is necessary to calculate the following quantity: $2\sigma_o((MW_{water})/(N_AkT))/((\rho_{liquid})(r))=\delta$ for T=273.15 Kelvin. σ_o=75.6 erg/cm^2, MW_{water}=18.015 gram/cm^3, $N_A=6.022x10^{23}$ molecules/mole, k=1.381x10^{-16} erg/K, ρ_{liquid} (water)=1gram/cm^3 and r=(0.002x0.05)$^{1/2}$ millimeters or 0.001 centimeters from GOOGLE [4].

Putting in the numbers, δ=2.4x10^{-8}. So, $P_{H2O}=P^*_{H2O}$ and (2) becomes (10).

$$To–T=(3kTo^2/\sigma_oa_o)(P^*_{H2O}/Pair) \quad (10)$$

This means that it is easier to get T, the undercooling temperature for a cloud, given that this theoretical treatment is correct.

Conclusion

Clouds, rain and snow have always fascinated me and my Chemistry expertise gave me the ability to solve this problem. Atmospheric scientists can get all of these variables needed for equation (10).

Table 1: Nomenclature

a_o	Surface area of water molecule
K	Boltzmann constant
MW_{water}	Molecular weight of water
N_A	Avogadro's number
P	Water vapor pressure at r=∞
p(r)	Water vapor pressure at spherical radius r
$p(r_1,r_2)$	p(r) with differing orthogonal radii
P_{air}	Air pressure around the cloud
PH2O=p(r)	Water vapor pressure
P^*_{H2O}=P	Equilibrium water vapor pressure
r	Radius of spherical rain droplet
RH	Relative Humidity
T	Temperature Kelvin inside the cloud
To	Freezing temperature of water
δ	Parameter in Ostwald-Freundlich derivation
ρ_{liquid}	Density of water
ρ_{vapor}	Density of water vapor
σ_o	Surface tension of water

Acknowledgments

At a certain point the rule of the world will come from the State of Israel after the return of Jesus Christ the Messiah. This is found in a quote from Luke's Book of Acts: "While they were with him they asked, 'Lord, are you going to restore the rule to Israel now?'" (ACTS 1:6) In Romans we are told that: "For if their rejection has meant reconciliation for the world, what will their acceptance mean? Nothing less than life from the dead!" (ROMANS 11:15)

References

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4. GOOGLE: raindrop size within a cloud.