A NON-SILVER IODIDE CLOUD SEEDING NUCLEUS– Al_2O_3

William G. Finnegan[1] and Lee Ates[2]
[1] Division of Atmospheric Sciences, Desert Research Institute
Nevada Systems of Higher Education, Reno Nevada
[2] Concho Cartridge Company Inc., San Angelo, Texas

Forward (by Steven Chai)

Dr. William G. Finnegan, a chemist, devoted most of his research career to advancing our understanding of ice nucleation mechanisms and searching for new ice nucleus formulas as an aid to weather modification operations (especially directed toward enhancement of precipitation from cloud systems). This paper describes his final piece of research related to the development of a non-silver ice nucleus for weather modification applications in order to lighten the financial burden of weather modification programs impacted by the escalating price of silver. Mr. Lee Ates of Concho Cartridge in San Angelo, TX helped Bill on running the necessary experiments of this research project. Bill surely appreciated Lee's help. Bill said to me several times that without Lee nothing could be accomplished.

Bill and Lee started this research in early 2008. Bill would come up with a formula and Lee would run it in the cold box at Concho Cartridge. Since the acidity and the solubility of the ice nucleus is important in ice nucleation, Bill would calculate and recalculate the compositions of each chemical in a formula in order to have the right acidity and solubility. He once said "I was working on my new, hopefully effective, solution combustion mixture for ice nuclei generation. It's interesting chemistry, but whether or not it works is an unknown quantity. I'm working on that supposition that one should do something, even if it's wrong." The lack of a cloud chamber sometimes discouraged him. He said "I really wish the CSU cloud chamber was functioning." Not to be discouraged, he would then think and speculate that a cold box could establish various threshold temperatures and some idea concerning the density of ice crystal formation at cold temperatures could be ascertained. That's good enough for the new formula development. It still needed in-cloud testing to determine utility. When the news that there were plenty of ice crystals formed in an experiment executed by Lee, Bill would break out in a smile and said "Chemistry is really fun, when you get it to work." However, when an experiment failed, he would say "This is the way research goes. I will give Lee some new instructions and maybe we'll succeed next time." From these interactions we could see Bill's joy in working with chemistry. He thought about chemistry to his last day on earth. He was a genuine scientist and I deem it a privilege to know Bill and to discuss chemistry with him.

1. INTRODUCTION

Condensation-freezing ice nucleation has been proved to be a fast functioning winter cloud seeding mechanism (Feng and Finnegan, 1989, DeMott, 1995). The advantage of condensation-freezing nucleation (through use of silver iodide based hygroscopic ice nuclei) compared to contact nucleation (using pure silver iodide nuclei) is that the efficiency of ice nucleation does not depend on the slow collection rates between the ice nuclei and the super-cooled cloud droplets. Therefore, silver iodide based hygroscopic ice nuclei, e.g., AgI- 0.5 NaI or AgI-AgCl-4NaCl, are usually used in winter cloud seeding projects. Given the recent increase in the price of silver, the cost of silver iodide based seeding agents has become a large financial burden to weather modification projects. Therefore, there is impetus to develop a non-silver iodide based condensation-freezing ice nuclei. Based on research results of Finnegan and Chai (2003), the mode of adsorption and the hydrogen bonding of water molecules are the primary drivers for ice nucleation, not the structural match of silver iodide to ice crystals. Along this line of thinking we have recently identified an efficient ice nucleus and demonstrated its efficiency as a seeding agent.

2. THE CLOUD CHAMBER

Due to the absence of a functioning cloud chamber in the U.S. cloud physics community, a Sears and Roebuck 0.14m^3 deep freezer was used as a cloud chamber for testing the efficiencies of nucleation following the above-mentioned formulae. One of the authors, Lee Ates, set up the chamber in San Angelo, TX. The chamber uses an R134a refrigerant, with a precisely tuned thermostat. The temperature was verified with a National Institute of Standards and Technology (N.I.S.T.) certified thermometer. The chamber was operated at ambient pressure and a selected constant temperature during each execution of the experiments. A super-cooled water cloud was introduced by an ultrasonic nebulizer. A 2400 c.c. gas syringe was used to collect a Al_2O_3 nuclei sample from a burning pyrotechnic and followed by injection into the chamber. Observations were made through a glass window on top of the cold box. The box was illuminated by a light beam which shined across the box. Observations indicated how fast and efficient ice crystals form after injection of the nuclei sample into the chamber.

3. THE ICE NUCLEI FORMULA

Following the work of Finnegan and Chai (2003), it was hypothesized that hydrates, as a class, promote nucleation. A variety of non-silver iodide formulas were tested and it was found that AlF_3 formed abundant ice crystals in the chamber at -6^{o}C as well as formation of ice crystals at -4^{o}C. However, this formula only worked in pyrotechnics systems – it failed to work in acetone solution combustion systems. Further investigation identified Al_2O_3 as an excellent ice nucleus in the pyrotechnic system. Experimental replicates at temperatures -8, -7, -6 and -5^{o}C in our chamber were all successful with many ice crystals formed in less than a minute after the sample was injected. The NS-1 (non-silver-1) pyrotechnic was commercially produced and further testing of the NS-1 flare is currently underway by a weather modification group in Texas to determine if the formula gives positive results at altitude.

This formula is also compatible with acetone solution combustion systems. Mr. Arlen Huggins of the Desert Research Institute tested the acetone-water solution of aluminum nitrate-9 hydrate ($Al(NO_3)_3$-9H_2O) that leads to the generation Al_2O_3 ice nuclei. Initial testing showed that ice crystals were formed after dipping a rod twice in solution and burned with a propane torch. Additional testing continues.

4. CONCLUSIONS

Although the cloud chamber used in these tests was less than ideal, results showed that large numbers of ice crystals were formed within a short time after the nuclei smoke was introduced into the super-cooled water cloud at the set stabilized temperature. The pending altitude tests of the NS-1 pyrotechnics are a necessary step to determine if this formula is effective for seeding.

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