Hygroscopicity and Chemical Composition of Silver Iodide Smoke Used in Cloud Seeding Experiments[1]

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(Manuscript received 3 May 1966, in revised form 13 April 1967)

ABSTRACT

The aerosol produced by a commercial device used for cloud seeding experiments was studied by electron microscopy, electron diffraction, chemical analysis and a replica method to test the hygroscopicity of the particles. The electron micrographs obtained from the aerosol when applying the replica method showed the hygroscopic nature of the aerosol particles.

We deduced from chemical analysis that the aerosol is composed of silver and potassium iodides in the ratio of approximately 2:1.

From an electron diffraction pattern and other considerations, the formation of a double salt or a solid solution is indicated; its nature should be considered in further work.

1. Introduction

In planning a cloud seeding experiment where the Bergeron-Findeisen process takes place, it is important to make sure that the particles employed act as ice nuclei within the cloud.

An aerosol with hygroscopic properties might be used if it were placed directly in a proper zone within cloud, but if it were seeded at ground level or at the base of a cloud which had above freezing temperature, the aerosol particles could form droplets. The freezing temperature of these droplets does not need to coincide with the activation temperature of the nuclei as determined in a cold chamber.

All we know about aerosols produced by different devices used in cloud seeding experiments is that when they are introduced in a cold chamber they have ice nucleating properties. However, their properties regarding hygroscopicity, action as ice nuclei or sublimation nuclei, or their chemical composition and crystalline nature, are unknown.

Fletcher (1959), in a theoretical work, deduced that for the sizes of silver iodides smokes the solid insoluble particles act principally as sublimation nuclei, although Edwards and Evans (1960) claim that silver iodide particles act as freezing nuclei after colliding with water droplets. Mason and van den Heuvel (1959) also established that silver iodide particles act as freezing nuclei at temperatures higher than −12C.

Koenig (1964) has studied several silver iodide smokes and from the fact that the particles were flattened when observed in an electron microscope he deduced that they have a volatile substance which may be water.

We have undertaken the study of a silver iodide smoke in order to obtain information on its chemical and physical properties and especially to establish its hygroscopic character.

2. Experimental studies

To produce the aerosol we employed a Meteorology Research, Inc., generator described by Fuquay and Wells (1957). This generator burns an acetonic solution of silver iodide in a propane flame. This solution was prepared according to Vonnegut's (1951) instructions by refluxing a mixture of acetone, potassium iodide, iodine, and an excess of silver until the liquid takes a yellowish transparent color. The solution is filtered and diluted with acetone until a 3.5% silver iodide solution is obtained. When the acetone evaporates, the solid residue remaining consists of silver and potassium iodides in the molar ratio of about 2:1.

The generator output was put into a vertical pipe 150 cm long and 35 cm diameter. The aerosol particles were sampled at the higher end by simple deposition on different surfaces like glass slides, and glass slides or grids covered with a Formvar film.

The aerosol was subjected to chemical analysis, electron microscope examination, electron diffraction and hygroscopicity tests.

[1] This work was partly supported by the Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires, República Argentina.

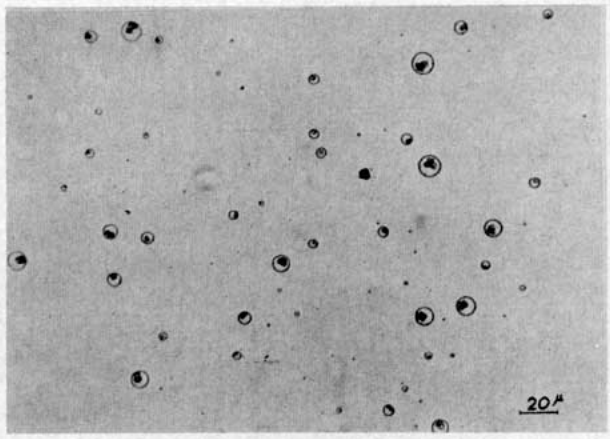


FIG. 1. Replicas obtained with droplets of water solution of sodium chloride.

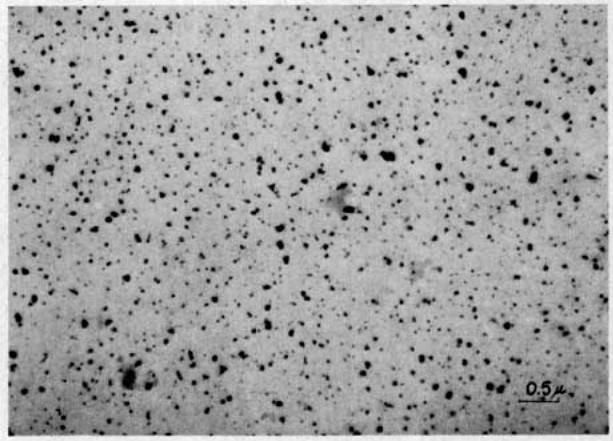


FIG. 3. Electron micrograph of Sample No. 2.

a. Hygroscopic tests. In studying the hygroscopicity of the aerosol particles we used the following replica technique based on Koenig's (1960) method.

The aerosol sampled on a Formvar covered slide (by immersion in a 0.3% chloroform solution) is placed in a closed chamber over a sodium chloride solution to obtain a constant humidity of approximately 95%. If the particles are hygroscopic they adsorb water vapor and form drops. After a certain time and without opening the chamber, a very dilute Formvar solution (0.05%) is poured over the slide through a small hole. This procedure developes another Formvar film which covers the drops. To evaporate the chloroform and the water of the droplets a soft air current at about 40C was blown over the slide for about 10 min. In Fig. 1 we can see replicas of drops of a water solution of sodium chloride obtained with this technique.

We shall call Sample No. 1 that obtained by this method, while Sample No. 2 was obtained by drying the aerosol sampled on the Formvar film with a soft air current at 40C for about 10 min, and then pouring a dilute (0.05%) Formvar solution over the sample to form a second protective film.

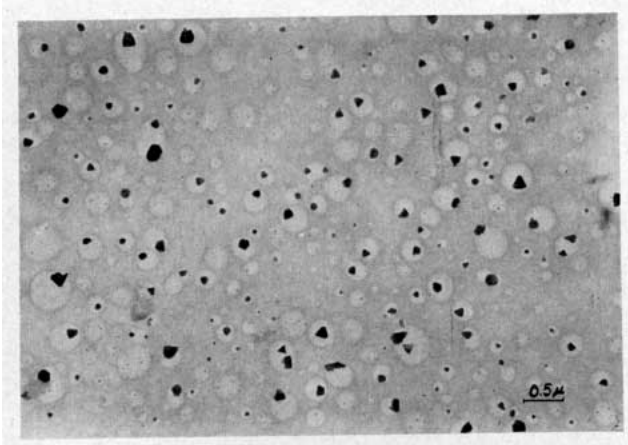


FIG. 2. Electron micrograph of Sample No. 1.

Both samples (No. 1 and No. 2) were kept in a desiccator over silica gel until they were placed in the electron microscope. Fig. 2 is an example of the electron micrographs obtained with sample No. 1. All particles, including the smallest observed (0.0025 μ diameter), appear surrounded by a halo or replica of the droplets around them. We find the same behavior for all particles with respect to hygroscopicity.

Fig. 3 represents an electron micrograph obtained with sample No. 2 in which replicas of water droplets are not observed.

We have measured the diameter of the particles and replicas by chosing ten equal surface areas at random

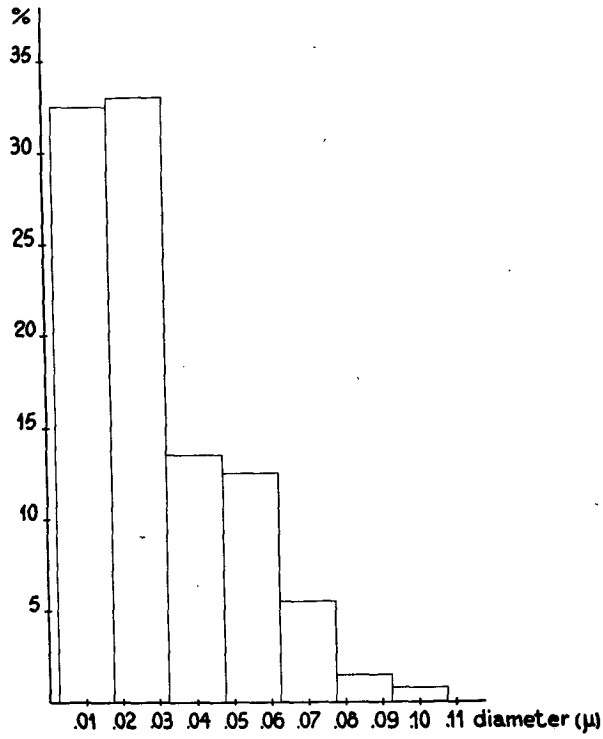
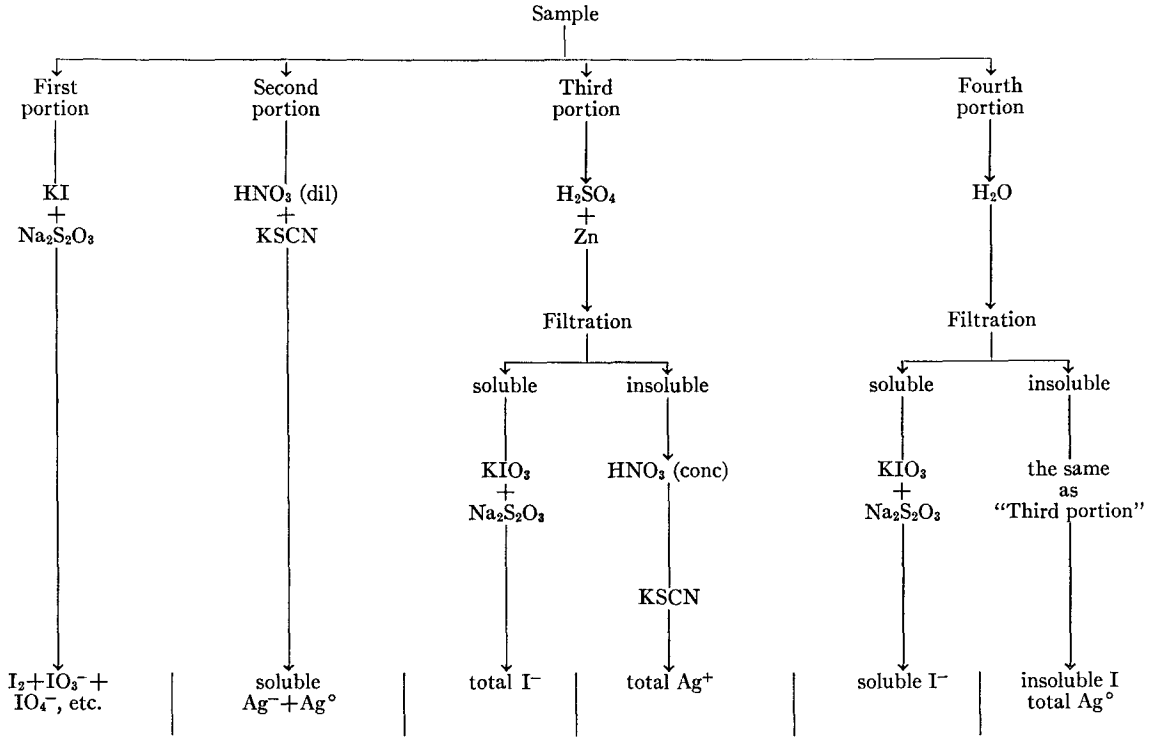


FIG. 4. Distribution of aerosol particle sizes.

TABLE 1. Procedure used in the chemical analysis of silver iodide aerosols.



on micrographs obtained from different samples of one type, i.e., the diameter of the particles on ten micrographs similar to Fig. 3 were measured. The results can be seen on the histogram of Fig. 4. We used ten micrographs similar to No. 2 for measuring the diameter of the replicas. By measuring 448 particles we obtained a value of 0.0030 μ for the mean diameter, whereas it was 0.1880 μ for 121 replicas.

b. Chemical analysis. The aerosol was chemically analyzed by the method of Naito and Sugawara (1954), using samples with masses between 200–300 mg. We obtained these samples by deposition of the aerosol on the outside surface of a glass container continually cooled on the inside by a cold water current. Two such samples were each divided into four portions for analysis.

In the first portion, the presence of free iodine and its oxides were investigated; in the second, metallic silver and the soluble silver ion; in the third, total iodide ion and silver ion; and in the fourth only the soluble iodide ion.

Table 1 is a flow diagram of our procedure.

Potassium ion was obtained from the difference between the total iodide ion and the soluble iodide ion.

The results obtained are summarized in Table 2.

c. Electron diffraction. We also obtained electron diffraction patterns of the aerosol which were compared with those of silver iodide and potassium iodide powders.

The aerosol presents a diffraction pattern, reproducible with different samples, with the lattice spacing: 4.15, 3.73, 3.18, 2.93, 2.79, 2.23, and 2.17. The pattern does not correspond to silver iodide, to potassium iodide, or to any other known silver or iodide compounds. While interpretations of the diagram are still continuing, the aerosol certainly contains a compound different from silver iodide. On the other hand Mason and Hallet (1956) reported the formation of a double salt obtained from the combination of silver and potassium iodides.

3. Discussion

The aerosol produced by the generator used in these studies has more iodide than that corresponding to

TABLE 2. Results of the chemical analysis of silver iodide aerosols.

Sample	Total I^- (%)	I_2 (%)	Total Ag^+ (%)	K^+ (%)	Undetermined (%)	$\frac{AgI}{KI}$
A	55.4	<0.5	29.0	6.6	9.0	1.7
B	52.0	<0.5	29.1	5.5	13.4	1.9
Input solution	55.9	—	31.3	5.8	7.1	1.9

silver iodide. The excess iodide is soluble and it is quite probably potassium iodide. Through chemical analysis we deduce a formula which is approximately 2AgI.KI.

Consider the following facts:

1) We obtained a diffraction pattern from the aerosol which is due neither to silver nor to potassium iodide.

2) In the micrographs obtained with the replica method all particles are surrounded by replicas of drops, showing a homogeneous hygroscopic feature. We then deduced that the aerosol is not a simple mixture of both salts. It may be a double salt or a solid solution of silver and potassium iodide or a combination thereof. Other compounds may be present, as for instance I_4Ag_3K as reported by Burley and Kissinger (1960).

Whatever it is, we are certain that it is a hygroscopic compound, at least at the saturation point, and that the drops formed contain suspended silver iodide.

In planning cloud seeding experiments the freezing temperature of these droplets must be taken into account.

Acknowledgments. We are very much indebted to Ing. E. E. Galloni and his assistants for their help in obtaining and calculating the electron diffraction patterns.

We also wish to thank Ing. J. Valencia for having generously put at our disposal the electron microscope and the technical help of his staff.

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