

[54] METHOD OF CONTROLLING WEATHER

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[58] Field of Search 239/2 R; 149/19, 20, 81

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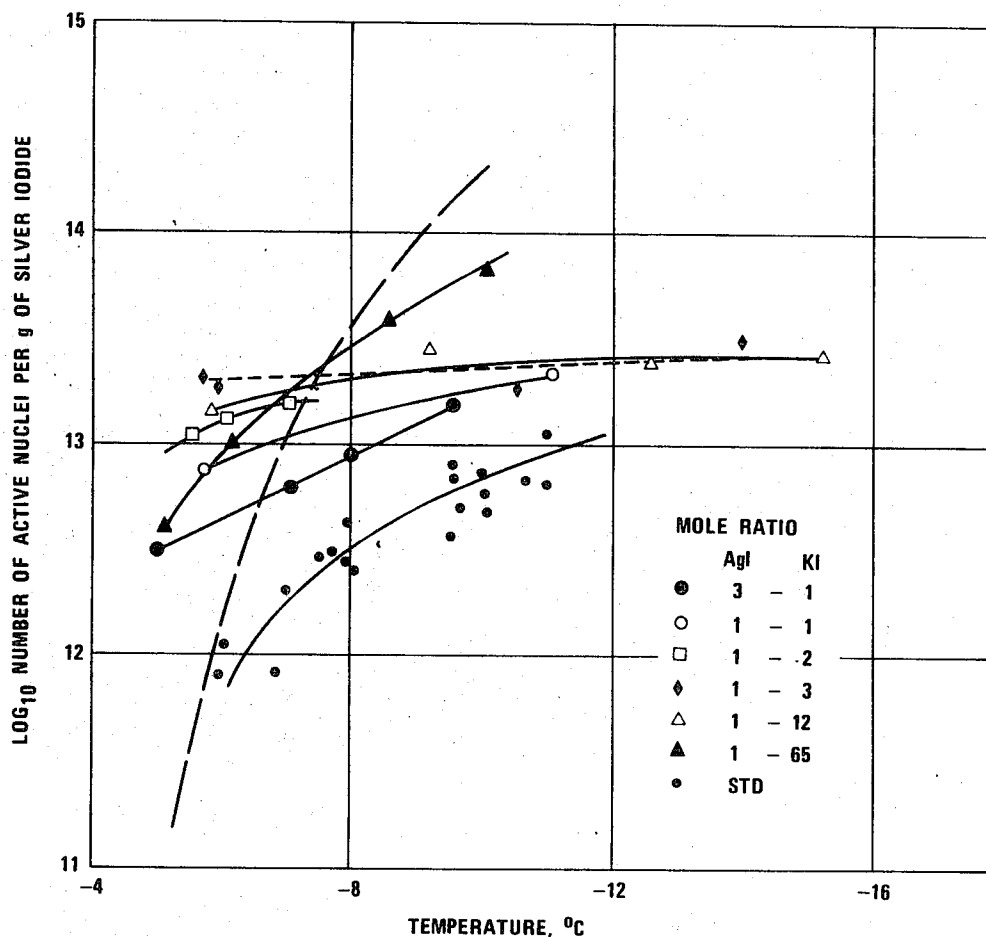
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[57]

ABSTRACT

A pyrotechnic formulation for use in weather modification comprising a fuel and an oxidizer and a mixture of a metal iodate and an alkali iodate. Upon combustion metal iodide and alkali iodide are generated as mixtures and complexes which show ice nuclei activity at from -5° to -20° C. depending on the molar range of metal iodide to alkali iodide.

2 Claims, 3 Drawing Figures



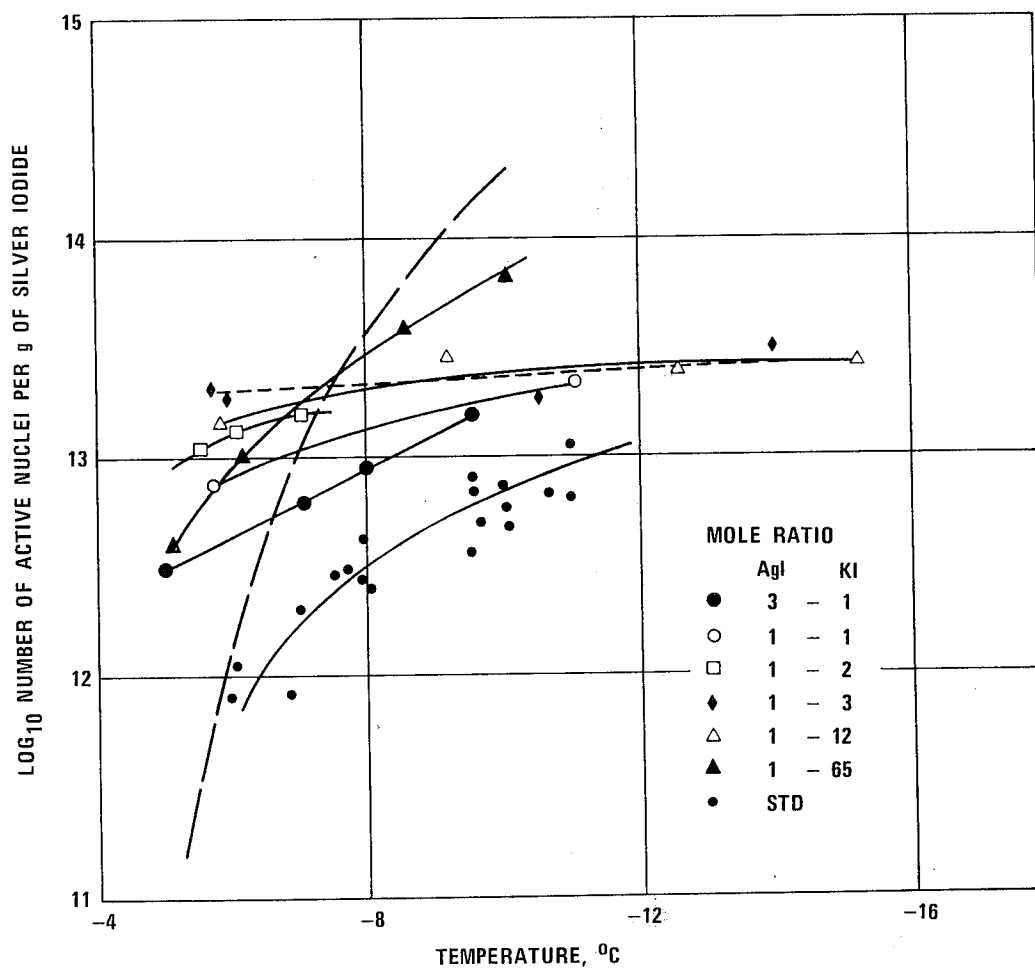


Fig. 1

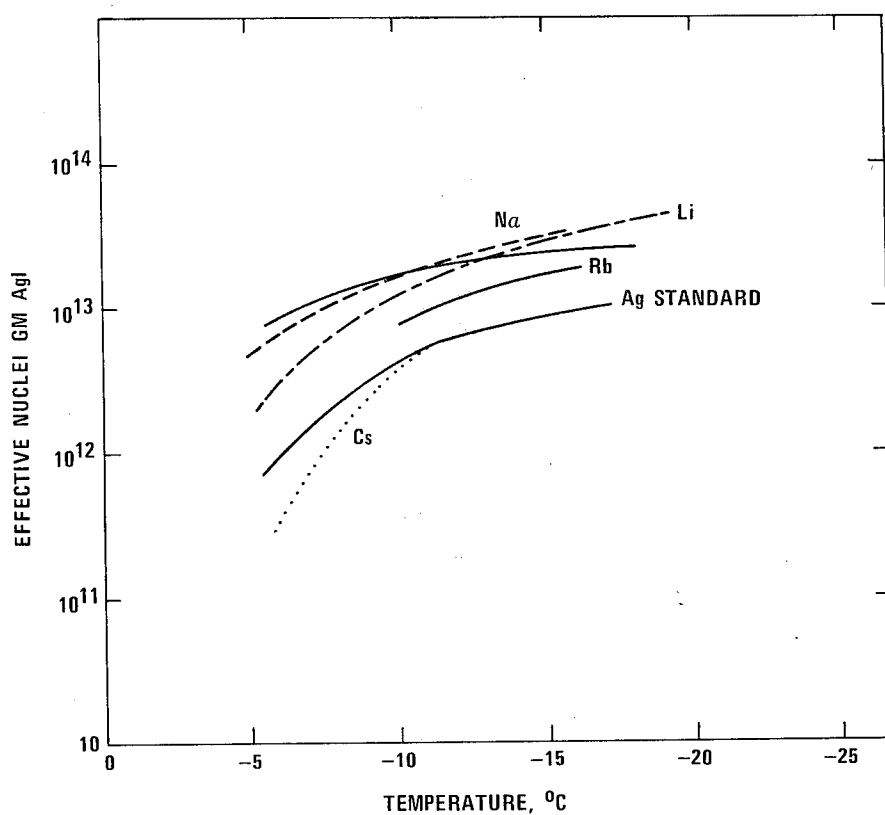


Fig. 2

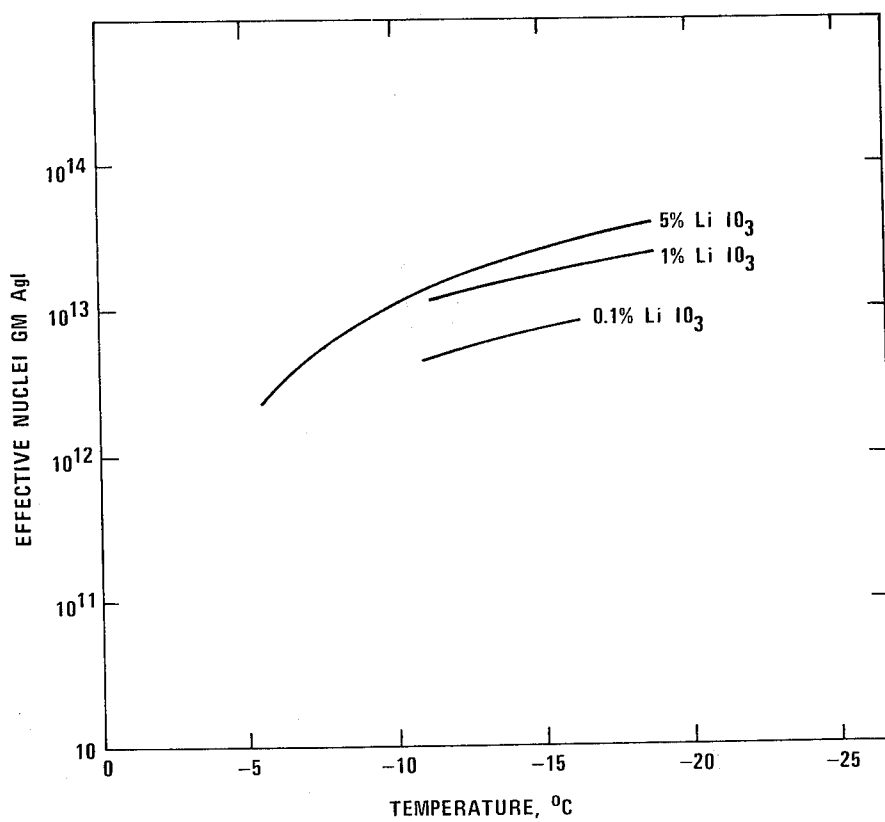


Fig. 3

METHOD OF CONTROLLING WEATHER

GOVERNMENT INTEREST

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention is a division of patent application Ser. No. 767,068, filed Oct. 10, 1968 now U.S. Pat. No. 3,802,971.

Weather modification has been applied in different parts of the world and several methods and means have been used to modify the physical and dynamical conditions of the atmosphere. Particles exist in the atmosphere which have the ability to form ice crystals in supercooled clouds. These are called natural or atmospheric ice nuclei and are responsible primarily for most of the natural ice formation in the cloud and their absence is strongly related to the supercooling of the cloud. When a supercooled cloud is seeded with ice nuclei, ice crystals are formed which start growing by abstracting water vapor from the surrounding atmosphere or by freezing the cloud droplets by accretion. There are two widely used artificial ice nuclei: dry ice (solid carbon dioxide) used successfully for cloud modification by Schaefer in 1946, and silver iodide whose excellent activity was discovered by Vonnegut in 1947. Research has been conducted on the generation of solid particulate matter by pyrotechnic and rocket propulsion techniques and studies made of the nucleating properties of these materials as functions of their chemical and physical properties. The generation of pure silver iodide has been studied in the past to characterize the generation process and to establish ice nuclei characteristics as a function of silver iodate concentration in the pyrotechnic. The present invention provides a number of new pyrotechnic compositions which upon combustion show ice nuclei activity at from -5° to -20° C. and provide more effective cloud seeding.

SUMMARY OF THE INVENTION

This invention is for improved pyrotechnic compositions. The compositions comprise a fuel and oxidizer mixture to which a mixture consisting of a metal iodate and an alkali iodate is added. The products of decomposition are the metal iodide-alkali iodide in varying molar ratios, complexes and other mixtures which induce the freezing of supercooled water droplets in cold clouds and fogs in an effective manner.

The general object of this invention is to provide a composition which upon combustion yields freezing nuclei having greatly increased activity, especially at the higher temperatures approaching 0° C. Another object is to provide pyrotechnic compositions which are inexpensive to formulate and are simple to use in dispelling fog, suppressing hail formation and increasing rainfall.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 shows nuclei activity of the potassium iodide-silver iodide complex wherein the mole ratio of AgI-KI ranges from 3:1 to 1:65;

FIG. 2 shows the ice nuclei activity for the initial series of formulations (Examples 4, 5, 7, 8, and 9) wherein silver iodide is shown as the working standard; and

FIG. 3 shows the nuclei activity of the lithium iodide-silver iodide complex.

DESCRIPTION OF THE INVENTION

In accordance with the present invention formulations comprising a fuel, an oxidizer, a metal iodate selected from the group consisting of silver, lead, copper, and bismuth iodates and an alkali iodate selected from the group consisting of lithium, sodium, potassium, rubidium, cesium and ammonium iodates were blended. The formulations were then pressed, cast, or extruded into the desired shape and cured.

The following examples set forth in Table I will better illustrate the invention but should not be considered as limiting thereof.

TABLE I

Pyrotechnic Compositions (Ingredients % by Weight)					
Sample	Metal Iodate	Alkali Iodate	Oxidizer	Fuel	Nucleation Temp. ° C.
1	AgIO ₃	5% NH ₄ IO ₃	5% NH ₄ NO ₃	40% Nitrosol	50%
2	PbIO ₃	5% NH ₄ IO ₃	5% NH ₄ NO ₃	40% Nitrosol	50%
3	AgIO ₃	15% NaIO ₃	28.73% NH ₄ NO ₃	6.27% PNC	50%
4	AgIO ₃	15% NaIO ₃	15% NH ₄ NO ₃	20% PNC	50%
5	AgIO ₃	5% LiIO ₃	5% NH ₄ NO ₃	40% PNC	50%
6	AgIO ₃	5% NaIO ₃	5.44% NH ₄ NO ₃	39.56% PNC	50%
7	AgIO ₃	5% KIO ₃	5.88% NH ₄ NO ₃	39.12% PNC	50%
8	AgIO ₃	5% CsIO ₃	8.46% NH ₄ NO ₃	36.54% PNC	50%
9	AgIO ₃	5% RbIO ₃	7.16% NH ₄ NO ₃	37.84% PNC	50%
10	AgIO ₃	5% CsIO ₃	1% NH ₄ NO ₃	44% PNC	50%
11	AgIO ₃	5% RbIO ₃	1% NH ₄ NO ₃	44% PNC	50%
12	Pb(10 ₃) ₂	5% LiIO ₃	5% NH ₄ NO ₃	40% PNC	50%
13	AgIO ₃	5% NaIO ₃	1% NH ₄ NO ₃	44% PNC	50%
14	AgIO ₃	5% KIO ₃	1% NH ₄ NO ₃	44% PNC	50%
15	AgIO ₃	5% LiIO ₃	1% NH ₄ NO ₃	44% PNC	50%
16	AgIO ₃	5% LiIO ₃	1% NH ₄ NO ₃	44.9% PNC	50%
17	AgIO ₃	5% KIO ₃	0.1% NH ₄ NO ₃	44.9% PNC	50%
18	AgIO ₃	5% CsIO ₃	0.1% NH ₄ NO ₃	44.9% PNC	50%
19	AgIO ₃	5% KIO ₃	45%	PNC	50%
20	AgIO ₃	5% KIO ₃	1.26% NH ₄ NO ₃	43.74% PNC	50%
21	AgIO ₃	5% KIO ₃	1.89% NH ₄ NO ₃	43.11% PNC	50%
22	AgIO ₃	5% KIO ₃	3.79% NH ₄ NO ₃	41.21% PNC	50%
23	AgIO ₃	5% KIO ₃	7.58% NH ₄ NO ₃	37.42% PNC	50%
24	AgIO ₃	5% KIO ₃	11.35% NH ₄ NO ₃	33.65% PNC	50%
25	AgIO ₃	1% KIO ₃	49%	PNC	50%

TABLE I—Continued

Pyrotechnic Compositions (Ingredients % by Weight)								Nucleation Temp. ° C.
Sample	Metal Iodate	Alkali Iodate		Oxidizer		Fuel		
26	AgIO ₃	5% KIO ₃	5.88%	NH ₄ NO ₃	34.12%	PNC	50%	
27	AgIO ₃	1% LiIO ₃ KIO ₃	10% 39%			Al PNC	5% 50%	
28	AgIO ₃	5% KIO ₃	5.88%	NH ₄ NO ₃	34.12%	Al PETRIN PNC	5% 15% 35%	
29	AgIO ₃	1% NaIO ₃	49%			PNC	50%	
30	AgIO ₃	5% NaIO ₃	1.17%	NH ₄ NO ₃	43.88%	PNC	50%	
31	AgIO ₃	5% NaIO ₃	3.5%	NH ₄ NO ₃	41.5%	PNC	50%	
32	AgIO ₃	5% NaIO ₃	10.5%	NH ₄ NO ₃	34.5%	PNC	50%	
33	AgIO ₃	12.04% LiIO ₃	1.36%	NH ₄ NO ₃	36.6%	Nitrosol	50%	
34	Pb(IO ₃) ₂	10% KIO ₃	11.75%	NH ₄ NO ₃	28.25%	PNC	50%	
35	Pb(IO ₃) ₂	10% KIO ₃	8%	NH ₄ NO ₃	32%	PNC	50%	
36	Pb(IO ₃) ₂	10% KIO ₃	15%	NH ₄ NO ₃	25%	PNC	50%	
37	Pb(IO ₃) ₂	10% KIO ₃	19.4%	NH ₄ NO ₃	20.6%	PNC	50%	
38	Pb(IO ₃) ₂	10% LiIO ₃	6.5%	NH ₄ NO ₃	33.5%	PNC	50%	
39	Pb(IO ₃) ₂	10% LiIO ₃	10%	NH ₄ NO ₃	30%	PNC	50%	
40	Pb(IO ₃) ₂	10% LiIO ₃	13%	NH ₄ NO ₃	27%	PNC	50%	
41	Pb(IO ₃) ₂	10% KIO ₃	1.92%	NH ₄ NO ₃	38.08%	PNC	50%	
42	Pb(IO ₃) ₂	10% KIO ₃	1.28%	NH ₄ NO ₃	38.72%	PNC	50%	
43	Pb(IO ₃) ₂	10% NaIO ₃	1.77%	NH ₄ NO ₃	38.23%	PNC	50%	
44	Pb(IO ₃) ₂	10% NaIO ₃	3.55%	NH ₄ NO ₃	36.45%	PNC	50%	
45	Pb(IO ₃) ₂	10% NaIO ₃	7.06%	NH ₄ NO ₃	32.94%	PNC	50%	
46	AgIO ₃	10% KIO ₃	15.14%	NH ₄ NO ₃	24.36%	PNC	50%	
47	AgIO ₃	10% KIO ₃	22.70%	NH ₄ NO ₃	17.30%	PNC	50%	
48	AgIO ₃	10% KIO ₃	30.27%	NH ₄ NO ₃	9.73%	PNC	50%	
49	CuIO ₃	10%		NH ₄ NO ₃	40%	PNC	50%	
50	CuIO ₃	10% KIO ₃	10.35%	NH ₄ NO ₃	29.65%	PNC	50%	
51	CuIO ₃	10% KIO ₃	15.53%	NH ₄ NO ₃	24.47%	PNC	50%	
52	CuIO ₃	10% KIO ₃	20.71%	NH ₄ NO ₃	19.29%	PNC	50%	
53	Cu(IO ₃) ₂	10% LiIO ₃	8.80%	NH ₄ NO ₃	31.2%	PNC	50%	
54	Cu(IO ₃) ₂	10% LiIO ₃	13.20%	NH ₄ NO ₃	26.80%	PNC	50%	
55	Pb(IO ₃) ₂	10% KIO ₃	26.89%	NH ₄ NO ₃	13.11%	PNC	50%	
56	Pb(IO ₃) ₂	10% KIO ₃	30.74%	NH ₄ NO ₃	9.26%	PNC	50%	
57	Pb(IO ₃) ₂	10% KIO ₃	43.58%	NH ₄ NO ₃	5.42%	PNC	50%	
58	Bi(IO ₃) ₃	10% LiIO ₃	7.43%	NH ₄ NO ₃	32.57%	PNC	50%	
59	PbCO ₃ Pb(OH) ₂	3% KIO ₃	7%	NH ₄ NO ₃	40%	PNC	50%	
60	Bi(IO ₃) ₃	10% NaIO ₃	8.09%	NH ₄ NO ₃	31.91%	PNC	50%	
61	Bi(IO ₃) ₃	10% KIO ₃	8.75%	NH ₄ NO ₃	31.25%	PNC	50%	
62	Pb(IO ₃) ₂	10%		NH ₄ NO ₃	40%	PNC	50%	
63	AgIO ₃	10%		NH ₄ NO ₃	40%	PNC	50%	

AgIO₃ - silver iodate
Pb(IO₃)₂ - lead iodate
Cu(IO₃)₂ - copper iodate
Bi(IO₃)₃ - bismuth iodate
XIO₃ - potassium iodate
NaIO₃ - sodium iodate
LiIO₃ - lithium iodate
CsIO₃ - cesium iodate
RbIO₃ - rubidium iodate
NH₄NO₃ - ammonium nitrate
PNC - plastisol nitrocellulose
Nitrosol - comprises about 30% plastisol
nitrocellulose and about 70%
pentaerythritol trinitrate

Examples were first prepared incorporating silver iodate and lead iodate with an alkali iodate in a nitrosol binder to which the additional oxidizer, ammonium nitrate, was added to ensure proper combustion. Nitrosol comprises about 30% plastisol grade nitrocellulose (PNC) and 70% pentaerythritol trinitrate (PETriN). Other nitrate esters such as nitroglycerin, metriol trinitate, triethylene glycol dinitrate, etc., may be used. The ratio of plastisol nitrocellulose (PNC) to nitrate ester varies with the particular lot of nitrocellulose and ester chosen. The formulations using nitrosol were easily made by first preparing the binder which comprises blending plastisol nitrocellulose and a nitrate ester in a vacuum mixer at room temperature until a homogeneous bubble-free mixture is obtained. The desired amount of metal iodate alkali iodate and ammonium nitrate are added and vacuum mixing continued until a homogeneous bubble-free mixture is obtained. The material is then cast into the desired form and oven cured.

50 The temperature and time of cure depends on the size and shape of the casting. For example, a cylinder about 1 inch in diameter and 2 inches long may be expected to cure in 1 to 2 hours at a temperature ranging from 130° to 180° F. The ratio of nitrosol to solid additives

55 (metal iodate, alkali iodate, ammonium nitrate, aluminum) is determined by the oxygen balance and the particle size of the solids. The particle size should result in a mix viscosity which is castable but which will not permit the solids to settle out.

60 The plastisol nitrocellulose (PNC) used herein is commercially available. It is a dense, spherical nitrocellulose of from 1 to 30 μ median diameter and is not substantially attacked by the plasticizers until cure at elevated temperatures is initiated. Plastisol nitrocellulose

65 is prepared by placing 90 grams of nitrocellulose (12.6% N), 1.2 grams of ethyl centralite and 1.4 liters of nitromethane in a flask and stirring vigorously until dissolution occurs, stirring slowly for an additional 10

minutes to insure homogeneity, adding to the resulting lacquer 19.2 grams of a petroleum sulfonate emulsifying agent for nitrocellulose in about 900 ml of water and circulating through a collard mill for about 10 minutes, draining the resulting emulsion from the mill into about 30 liters of water and stirring about 15 minutes until a nitrocellulose precipitate is formed which is filtered from the liquid, washed in hexane, dried for about 16 hours and sifted through a 200 mesh screen.

The formulations shown in Table I above may be modified as necessary to generate the desired complex nuclei. In place of the plastisol nitrocellulose double base formulations were used. They comprise about 51% by weight nitrocellulose, 43% by weight nitroglycerin, and the remainder diethylphthalate, a plasticizer, and ethyl centralite, a stabilizer. Cast double base comprising nitrocellulose and nitroglycerin in major amount petrin and metriol trinitrate in minor amount also provided a good fuel for the metal iodate-alkali iodate mixture.

The products of combustion of these examples using nitrosol binder were collected, characterized by wet chemical and X-ray diffraction analysis and the results compared with data on known complexes. Ice nuclei activity spectra were measured in a Naval Weapons Center cloud chamber burning small pyrotechnic samples directly in supercooled fog of 1 g/m³ liquid water content. These fogs evaporate in 3-8 minutes, dependent on operating conditions if not nucleated. Each experiment utilized 100 mg of pyrotechnic containing 10% of the heavy metal derivative burned at one point in the chamber. Nucleation temperatures were taken as those where complete icing of the chamber occurred, but do not necessarily represent the true droplet equilibrium threshold values.

The activity spectra for the initial series of formulations were compared with silver iodide as a working standard (see FIG. 2). The spectrum for complex cesium iodide-silver iodide nuclei did not show enhanced activity over that for silver iodide alone. Nevertheless, sufficient cesium iodide was present in the nuclei to complex the silver iodide completely. The rubidium iodide-silver iodide system shows slightly enhanced activity over that of standard silver iodide. The sodium iodide-silver iodide, potassium iodide-silver iodide, and lithium iodide-silver iodide nuclei all show greatly enhanced activity.

The potassium iodide-silver iodide series showed the highest activity at warmer temperatures. Formulations calculated to yield complex nuclei with potassium iodide-silver iodide ratios of 1:3, 2:1, 3:1, 12:1, and 65:1 are shown in FIG. 1. The 3KI - AgI complex shows the highest activity. Although less effective at warmer temperatures, the 65KI - AgI nuclei show excellent activities at lower temperatures.

Nuclei having a molar ratio of 65KI to one AgI (97.87 wt. % KI, 213 st. % AgI) are completely soluble when sufficient water is acquired to yield a composition of 39 wt. % water and 61 wt. % of the nuclei material.

The LiI-2AgI complex follows the behavior of the KI-AgI complex shown in FIG. 3.

Table II gives the nucleation temperature values obtained for silver iodide and several complexes of silver iodide and potassium iodide.

TABLE II

Pyrotechnic Composition	Nucleation Temp., °C.
AgIO ₃	0
AgIO ₃ .2 KIO ₃	-1.0
AgIO ₃ .3 KIO ₃	-1.0
AgIO ₃ .4 KIO ₃	-0.8

Table III shows the temperature of nucleation of the decomposition product of lead iodate and those if its complexes with several alkali iodides.

TABLE III

Ice Nucleation Temperatures	
3 Pb(IO ₃) ₂ .KIO ₃	-1.2
2 Pb(IO ₃) ₂ .KIO ₃	-1.0
Pb(IO ₃) ₂ .KIO ₃	-1.0
Pb(IO ₃) ₂ .2 KIO ₃	-1.5
Pb(IO ₃) ₂ .3 KIO ₃	-1.8
Pb(IO ₃) ₂ .4 KIO ₃	-1.2
Pb(IO ₃) ₂ .5 KIO ₃	-1.5
Pb(IO ₃) ₂ .7 KIO ₃	-1.0
Pb(IO ₃) ₂ .8 KIO ₃	-1.0
Pb(IO ₃) ₂ .9 KIO ₃	-0.5
Pb(IO ₃) ₂ .2 LiIO ₃	-1.0
Pb(IO ₃) ₂ .3 LiIO ₃	-1.5
Pb(IO ₃) ₂ .4 LiIO ₃	-1.0
2 Pb(IO ₃) ₂ .NaIO ₃	-0.8
Pb(IO ₃) ₂ .NaIO ₃	-1.0
Pb(IO ₃) ₂ .2 NaIO ₃	-1.0

Table IV shows the values obtained for nuclei generated by combustion or pyrotechnics containing cupric iodate alone and with added alkali iodates.

TABLE IV

Pyrotechnic Composition	Ice Nucleation Temperatures	Nucleation Temp., °C.
Cu(IO ₃) ₂		-7.0
Cu(IO ₃) ₂ .2 KIO ₃		-6.0
Cu(IO ₃) ₂ .3 KIO ₃		-6.5 ^a
Cu(IO ₃) ₂ .4 KIO ₃		-2.0
Cu(IO ₃) ₂ .2 LiIO ₃		-1.2
Cu(IO ₃) ₂ .3 LiIO ₃		b

^aNo nucleation occurred at -1.0° C.

^bNo nucleation occurred at -5.5° C.

TABLE V

Pyrotechnic Composition	Nucleation Temp., °C.
MoO ₃	-9.8
MoO ₃ .KIO ₃	-10.5
MoO ₃ .2 KIO ₃	-10.0
MoO ₃ .3 KIO ₃	-11.0
MoO ₃ .2 LiIO ₃	-12.0
Bi ₂ O ₃ .2 KIO ₃	—
Bi ₂ O ₃ .4 KIO ₃	—
Bi ₂ O ₃ .6 KIO ₃	—
Bi(IO ₃) ₃ .3 LiIO ₃	—
Bi(IO ₃) ₃ .3 KIO ₃	—

The unexpectedly high threshold temperature values obtained suggest strongly that contact freezing of droplets is the major mechanism of ice crystal formation.

Under the test conditions of an evaporating fog, silver iodide can function as an ice nuclei at measured air temperatures of +0.5° C.

Tentative interpretation of the data in Tables II-V suggests the following:

Heavy metal iodides are more effective nuclei than the corresponding oxides. Molybdenum and bismuth iodides are thermodynamically unstable and are not formed during combustion processes. Complexes of the oxides with alkali iodides are also not active at high temperatures. Lead and copper iodates decompose to give oxyiodides of intermediate activity. Complexing with alkali iodides may enhance activity. Silver iodide shows the highest temperature threshold and is a stable product of combustion of silver iodate. Complexes of silver iodide and alkali iodides are equally effective as ice nuclei.

The new compositions disclosed herein are pyrotechnics which are generally low explosives that have but little explosive value because of their low rates of combustion and the liberation of relatively little gas per unit weight of composition. The combustion by products of the present compositions include the silver iodide-alkali iodide complex, lead iodate and those of its complexes with several alkali iodides, cupric iodate alone and with alkali iodates, complexes of bismuth and molybdenum oxides and alkali iodides. All of the samples are well within the safety requirements of a military pyrotechnic.

Metal such as aluminum is added to raise the flame temperature and additional oxidizer (in addition to the iodates) is added to ensure proper combustion.

Many cloud seeding techniques have been used to introduce the metal iodide-alkali iodide complexes formed upon combustion of these new pyrotechnics into undercooled clouds whereby rainfall was attained and hail suppression was achieved. In several experiments the composition was ignited on a mountain top and the complexes entrained into the range of clouds to be seeded by updraft. The material was also ferried directly into the clouds to be seeded by aircraft provided with special devices for expelling the pyrotechnics which produced the atomized seeding material. Rockets and artillery missiles have also been loaded with the composition and fired into the appropriate cloud.

These new pyrotechnic compositions either seed the cloud and produce rainfall or snow if they reach the cold part of the cloud or they dissolve out. Most of the complexes formed upon combustion of the composition, e.g., AgI-KI, break down with water and silver or lead iodide, as the case may be, is precipitated out. All of the compositions in the dry state nucleate ice but they must be dispersed into the cloud at the right temperatures (-20° to 0° C.). Most of them are quite effective if the complex is dropped into the clouds and overseeding the tops of connective clouds has stopped clouds from raining.

The herein described compositions must be brought into a state of fine dispersion for the seeding of the clouds to successfully suppress hail, increase rainfall or disperse fog. The present invention provides substances which show better capability of forming freezing nuclei as silver iodide alone, and are simple and inexpensive to prepare.

What is claimed is:

- 1. A method for artificially influencing the weather which comprises overseeding the tops of convective clouds with a silver iodide-potassium iodide complex whereby rainfall is suppressed.
- 2. A method for influencing the weather comprising the steps of:
 - a. providing a pyrotechnic formulation containing the following:

Ingredients	Percent by weight
Fuel Binder	50-55
Oxidizer Addition	5-45
Metal Iodate	1-10
Alkali Iodate	0.1-30

- said fuel binder being selected from the group consisting of: plastisol nitrocellulose, nitrosol, double base propellant binder consisting essentially of nitrocellulose and nitroglycerine, cast double base consisting essentially of nitrocellulose, petrin, metriorol trinitrate, and the binder system consisting essentially of a carboxylated linear polybutadiene having a carboxy end group present on both ends of the polymer chain and tris - [1-(2 methyl) aziridinyl] phosphine oxide and trimethylol ethane trinitrate;
- said oxidizer being selected from the group consisting of ammonium iodate, ammonium nitrate, and ammonium perchlorate;
- said metal iodate being selected from the group consisting of the iodates of copper, silver, lead, bismuth and molybdenum; and
- said alkali iodate being selected from the group consisting of the iodates of lithium, sodium, potassium, rubidium, cesium and ammonium;
- b. forming the pyrotechnic formulation into a desired shape and curing it; and
- c. burning the shaped and cured pyrotechnic formulation above a cloud having an air temperature in the range of from -20° to 0°C to form complex metal iodide-alkali iodide ice forming nuclei.

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