Freezing of Supercooled Water-droplets (II)*

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Abstract

Many supercooled water-droplets were frozen on a cooling brass plate to find the effects of artificial rainmaking. The water-droplets were contaminated with silver iodide smoke and some soil and mineral powder. As shown in Tables 1 and 2 the freezing temperature was found for each contaminated substance. Freezing temperature of melted snow crystals was observed.

1. Introduction

In the previous paper [1] were reported the results of the experiment in which supercooled waterdroplets were frozen one by one. But in the present report the results of a new device will be published, the apparatus of which was improved with a view increasing efficiency so that 30 supercooled water-droplets might be frozen at a time. The powders of various soil and mineral substances were suspended in pure water-droplets and then frozen. In such a process, quartz, talc and feldspar, second to silver iodide, were effective for raising the freezing temperature.

2. Experiment Apparatus

The experiment apparatus is shown in Fig. 1. A brass cooling rod is set into Dewar's vessel and a cooling plate (4.7 cm × 3.4 cm × 1.0 cm) is fixed on the top of the rod. As shown in Fig. 2 there are 30 hollows on the upper surface of the plate. Each hollow is 4 mm in diameter and 2 mm in depth. Dewar's vessel is full of cooled alcohol

Fig. 1. Cooling chamber installed in Dewar's vessel.

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Fig. 2. Cooling plate.

alcohol. The flow of electric current in the heater should be controlled so as to keep cooling rate at $1^{\circ}\text{C}/3\text{ min}$.

As for soil and mineral substances, the powders of talc, quartz, kaolin, amphibole, angite, chalcopyrite, mica, calcite, fluor-spar and feldspar were employed.

Pure water-droplets contaminated with silver iodide powder was used for comparison, and at the same time the freezing temperature of distilled water-droplets was observed. Its temperature was, as given in Fig. 1, measured with the copper-constantan thermojunction. Within $1^{\circ}\text{C}/3\text{ min}$ of the cooling rate, the gradient of temperature was not recognized in the cooling plate.

With the same apparatus, water-droplets were frozen in which snow crystals were melted, and their freezing temperature was observed. The snow crystals were collected at a mountain cottage of Mt. Zaō (the summit 1841 m and the cottage 1240 m above the

with dry ice. The cooling rod is 20 cm in length and 1 cm in diameter. Its upper part is coiled with manganin wire which is heated with electric current. The cooling plate is covered with silicon varnish and all the hollows are filled with silicon oil.*

3. Experiment method

One water-droplet is put into each of the 30 hollows, and the cooling rod is immersed into -60°C

Fig. 3. Observed snow crystals.

Upper: Soft hail. Lower: Dendritic crystal.

* Shinetsu Silicon KF 90L.

Fig. 4. View of Mt. Zaō.

sea-level) on January 27th, 30th and 31st, 1956 (Fig. 4).^{*} Their forms were mostly dendritic crystal and soft hail (Fig. 3), and the number of the collected crystals was 510 in all.

4. Results of observation

Fig. 5 shows the distribution frequency of the freezing temperature of contaminated water-droplets with silver iodide smoke. The concentration of silver iodide smoke was of arbitrary value, because it was found to be hard to measure. The concentration (a) is such that the droplets are tinged with yellow to a degree that they are visible to the naked eye; (b) is one-tenth of (a); (c) is one-hundredth of (a); (d) is the value of the top water-droplets of contaminated water. No difference is recognized in the distributions of (a) and (b), while the variance is distinctly large in (c) and (d).

Fig. 5. Frequency of the freezing temperature of contaminated water-droplets with silver iodide smoke.

- (a) Arbitrary concentration C. (b) 1/10 C.
(c) 1/100 C. (d) Top water.

^{*} As shown in Fig. 4 the upper part of Mt. Zaō is covered with mountain cloud almost every day.

Fig. 6. Relation between the size of water-droplets contaminated with silver iodide smoke and its freezing temperature.

In Fig. 6 is shown the relation between the size of water-drops contaminated with silver iodide smoke and its freezing temperature. The larger the size of droplets, the higher the freezing temperature rises showing smaller variance.

The freezing temperature of pure water-droplets of 1.2 mm in diameter is shown in Fig. 7. The tendency of the freezing temperature to rise with the size of the droplet was already found and explained in the previous paper, but only a question-marked point is against this tendency. Though it is difficult to specify the reason, a phenomenon is observable which cannot be treated on the same basis as the values of other droplets.

In this case the mean freezing temperature is

$$\bar{t} = 15.2^{\circ}\text{C} \pm 3.1^{\circ}\text{C}.$$

and its variance indicates the following value:

$$\sigma^2 = 2.4.$$

The reason why the variance is so large is not obvious. It is conceivable that it is caused either by the

Fig. 7. (a) Relation between the size of pure water-droplet and freezing temperature. (b) Frequency of freezing temperature.

nature of the distilled water used or by the experimental apparatus and its method. The latter cause, it seems, is much more plausible.

In Tables 1, 2 and Figs. 8, 9 is shown the freezing temperature of water-droplets contaminated with the powder of soil or mineral substances.

Table 1 and Fig. 8 indicate the value in the case where silicon oil is used, while Table 2 and Fig. 9 in the case where silicon oil is not used. Silver iodide used in this case is powdered and suspended in water-droplets. As seen in the two tables, the freezing temperature varies with the substances used, i.e., the

Table 1. Freezing temperature of water-droplets contaminated with various substances (in silicon oil).

Substances	Freezing temperature
Silver iodide	- 6.8°C
Quartz	- 8.2
Kaolin	- 9.7
Amphibole	- 9.7
Augite	-10.6
Chalcopyrite	-11.3
Distilled water	-14.4

Table 2. Freezing temperature of water-droplets contaminated with various substances (not in silicon oil).

Substances	Freezing temperature
Silver iodide	-2.6°C
Talc	-5.1
Feldspar	-5.1
Quartz	-5.7
Fluorspar	-7.1
Calcite	-7.2
Mica	-7.4
Distilled water	-7.4

Fig. 8. Freezing temperature of water-droplets contaminated with soil and mineral powder (observed in silicon oil).

lower the freezing temperature, the larger is the variance of the freezing temperature. Such variance is not so plain in Fig. 8, but the effects of the soil or mineral substances on the freezing temperature are more clearly graded in Fig. 9. Silver iodide is the most effective; talc, feldspar and quartz are almost of the same effect; fluorspar, calcite and mica are almost the same with distilled water.

The considerable difference between the value in Table 1 and that in Table 2 is due to the difference in the method of the experiment.

Fig. 10 shows the frequency of the freezing temperature of melted snow crystals. The results express only those of soft hail and dendritic crystal, eliminat-

Fig. 9. Freezing temperature of water-droplets contaminated with soil and mineral powder (non silicon oil).

Fig. 10. Frequency of freezing temperature of melted snow crystals.

ing other crystals such as star-like, hexagonal plate and prism because of their very small number.

The pictures of snow crystals and freezing droplets are shown in Fig. 11.

Fig. 11. Observing water-droplets in silicon oil.

Fig. 12 shows the diameter of the ice ball which frozen the melted snow crystals.

Fig. 12. Frequency of diameter of frozen melted snow crystals.

Generally, the size of the crystals observed at the mountain is very small. The freezing temperature varies with days, which might be caused by the kind of the supplied air pollution substances to act as nuclei in the upper atmosphere.

5. Conclusion

The following results are obtained from the above-mentioned observation :

- 1) When soil and mineral substances act as nuclei, talc, feldspar and quartz are more effective, but those are distinguishable from the value of silver iodide.
- 2) Even in case of water-droplets contaminated with silver iodide smoke, their freezing temperature rises with the increase in size of the water-droplets.
- 3) The weaker the concentration of water-droplets contaminated with silver iodide smoke, the larger is the variance of the freezing temperature.
- 4) The freezing temperature of water-droplets of melted snow crystals varies with days. It may be supposed this fact is due to the different kinds of the substances acting as nuclei.

Reference

- [1] ITOO, K. and HAMA, K., 1956: Freezing of Supercooled Water-droplets (I). Pap. Met. Geophys., 6, p. 247.