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ISOTHERMAL CLOUD CHAMBER FOR STUDYING THE ICE CRYSTAL NUCLEATION

M. ŽIVANOVIĆ, M. HUTER, D. GRUJIĆ and Ž. DIMITRIJEVIĆ*

»Boris Kidrič« Institute of Nuclear Sciences, Laboratory of Solid State Physics and Radiation Chemistry, Vinča, 11001 Belgrade, P. O. Box 522, Yugoslavia

**Teachers' Technical College, University of Novi Sad*

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The isothermal cloud chamber has been constructed for investigation of atmospheric conditions for ice crystals formation and the influence of aerosols. The cloud chamber is suitable for simulation of atmospheric conditions where the introduced aerosols of active substances serve as activators. They transform supercooled water aerosols into crystals at temperatures higher that the spontaneous water aerosol crystallization temperature. By counting the formed ice crystals, with the estimation per 1 g of the reagent, ice nucleating properties of some substances (pyrotechnic mixture) have been determined. Determined was also the initial maximum waterness of the supercooled cloud in the chamber and measured the axial temperature gradient.

1. Isothermal cloud chamber

In our Laboratory, the »Soulage« type isothermal cloud chamber has been designed and constructed[1,2]. The chamber is both automatically and manually adjustable, in the temperature range from +20 to −30° C. The chamber is of cylindrical shape, volume 0.12 m^3, 500 mm in diameter and 600 mm high. It is cooled by the classic refrigeration system. The refrigeration medium is freon-12, which flows through copper tubing spirally wound around the cylinder between the refrigeration system tubes. On the exterior wall of the chamber there is a thermistor through which the electronic regulator directs the work of both compressor and the heater. In the centre of the chamber, the temperature stability is ± 0.01 °C, which is a necessary experimental condition. The axial temperature gradient in the working region of the chamber is 10^{-2} grad. cm^{-1}, and is shown in Fig. 1.

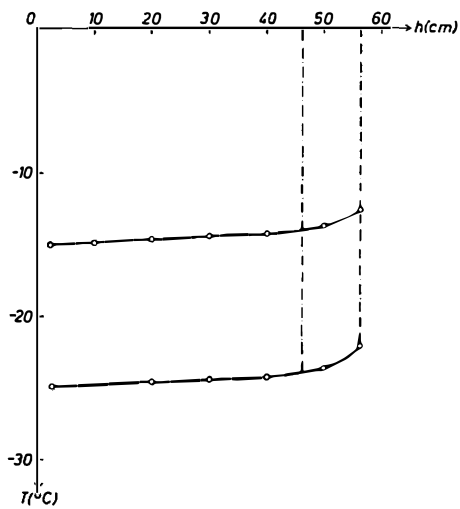

Fig. 1.

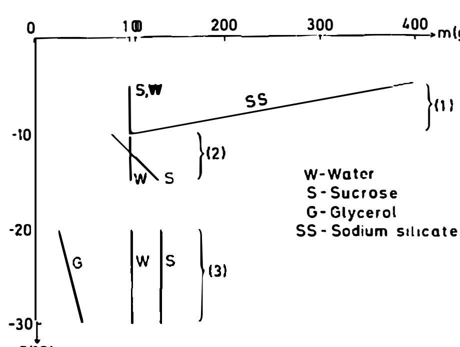

Fig. 2.

(1) Aqueous solution of sucrose and sodium silicate.
(2) Aqueous solution of sucrose.
(3) Aqueous solution of sucrose and glycerol.

The gradient toward the top of the chamber is the higher one due to the window for observations. At the top of the chamber, above the window, a camera is mounted for photographing the crystals in eutectic sugar solution. The chamber microatmosphere is enriched by water vapour from the outer generator. The duration of the cloud in the chamber is about 3 minutes. The amount of water which is to be introduced in that way into the chamber is conditioned by a number of ice nuclei present in the chamber. The eutectic sugar solution or a formware film on the microscope glass is used as a detection device in the chamber. The eutectic sugar solution is used in studying the ice properties of artificial reagents when their aerosols concentration in the chamber is not high, as well as at the automatic regime of work, when the natural ice nuclei are studied. Depending on the temperature at which the investigation of nucleation properties of aerosols is performed, a corresponding composition of eutectic sugar solution is used (Fig. 2). The nucleation detection device by the formware film is used for higher aerosol concentrations of active substances.

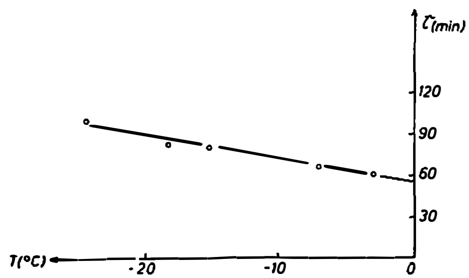

Fig. 3.

Figure 3 presents initial stabilization time of the chamber τ, which is a function of temperature. Duration of the initial time depends on the volume of the chamber. It is obvious that the regime of work at lower temperatures brings about a longer nitial time of stabilization.

Disturbance of stabilization conditions, while introducing the water aerosol, is presented in Fig. 4. Increase of the atmospheric temperature in the chamber and the time of temperature destabilization are caused by the amount of the introduced water aerosol.

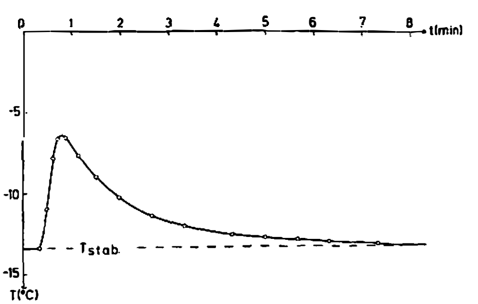

Fig. 4. Determining of the active substance effectiveness in aerosols.

The reproductive capability of the chamber, i. e. the time cycle, is about 60 minutes. Duration of a cycle depends on the refrigerator capacity and the working temperature.

The smallest waterness of the supercooled cloud obtaining the reproductive results, has been determined experimentally — about 1.5 gm^{-3}.

Aerosols of some substances are very effective devices for initiating stimulated nucleations of a supercooled water aerosol. Seeding of their aerosols on the supercooled clouds makes possible formation of a large number of ice nuclei (more than 10^{11} per gram of the substance used). Hence a special interest in investigation of nucleating properties of these substances.

B. Vonnegat[4] has established that aerosols of AgJ and PbJ_2 are very effective as crystallization stimulants when brought into direct contact with a supercooled vapour. They move the temperature threshold of crystallization toward higher temperatures. In that way, the unit of the water mass of the supercooled cloud gets distributed to a large number of crystals by stimulating crystallization, which was the main interest in this investigation.

In order to investigate the ice nucleating power of our active aerosol substance, we have used the method for detecting the number of ice crystals at various temperatures below the zero temperature. The number of ice crystals has been evaluated per one gram of the dispersed reagent in a supercooled water cloud. The method is appropriate for obtaining information on the ice nuclei formation and effectiveness of the polydispersed reagent.

With a purpose to get the aerosol of the active substance, we have done a static burning in a special vessel of the volume 1.5 m^3. After the burning, the mixture was homogenized; then, the »diluted« active aerosol is introduced into the chamber and its effectiveness determined. The effectiveness was calculated by the formula

$$E = \frac{V_I V_{II} S N}{m V_1 V_2 P}$$

where: V_I and V_{II} are the burning bags volumes, S shows the relationship between the chamber bottom surface and the surface of the vessel with the sugar solution, N is the number of crystals in the vessel, m the mass of the burned pyrotechnic mixture, V_1 and V_2 the volumes of the mixture of active substance injected by a syringe and P is the Ag percentage.

In the chamber, the effectiveness measurements of an experimental pyrotechnic mixture have been performed; it was found that approximately $5.5 \cdot 10^{12}$ active nuclei are formed per 1 g AgJ at $-10\,°C$.

2. *Conclusion*

The constructed isothermal cloud chamber for investigation of ice nucleating properties of some substances serves in obtaining the data on the effectiveness of polydispersed reagents. The chamber is both automatically and manually adjustable in the temperature interval from 20 to $-30\,°C$. The temperature stability measured in the centre of the chamber is $\pm$ 0.01 °C, while the axial temperature gradient in the working region of the chamber is 10^{-2} K · cm^{-1}. The smallest waterness of the supercooled cloud providing the reproductive results is about 1.5 gm^{-3}. The operating cycle of the chamber lasts 60 minutes.

The activity measurements of the experimental pyrotechnic mixture were performed by the method for counting ice crystals evaluated per 1 g AgJ, in the eutectic sugar solution. The measured activity of the mixture at — 10 °C is 5.5 · · 10^{12} nuclei per 1 g AgJ.

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IZOTERMALNA KOMORA ZA IZUČAVANJE MEHANIZMA NUKLEACIJE KRISTALA LEDA

M. ŽIVANOVIĆ, M. HUTER, D. GRUJIĆ i Ž. DIMITRIJEVIĆ*

Laboratorija za fiziku čvrstog stanja i radijacionu hemiju Instituta za nuklearne nauke »Boris Kidrič«, Vinča, Beograd

**Pedagoško-tehnički fakultet Univerziteta u Novom Sadu, Zrenjanin*

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U cilju izučavanja ledničkih osobina atmosfere i uticaja supstancija u aerosolnom stanju na njih, izgrađena je izotermalna maglena komora. Komora je pogodna za simuliranje atmosferskih uslova, pri čemu uvedeni aerosoli aktivnih supstancija služe kao aktivatori. Oni prevode prehlađene vodene aerosole u kristalno stanje na temperaturama višim od temperature spontane kristalizacije vodenog aerosola. Brojanjem formiranih kristala leda i obračunavanjem po 1 g reagensa, određena su lednička svojstva nekih supstancija (pirotehničkih smeša). Pored toga, određena je početna maksimalna vodnost prehlađenog oblaka u komori i izmeren aksijalni temperaturski gradijent u njoj.