The Extent of Inactivation of Atmospheric Aerosol Particles as Condensation Nuclei in an Urban Area

By T. Ohtani and A. Ono

*Water Research Institute, Nagoya University, Nagoya 464, Japan
(Manuscript received 16 January 1981, in revised form 11 June 1981)*

Abstract

In order to make clear how much extent urban aerosol particles are inactivated as condensation nuclei, possibly by the effect of organic materials, an experimental study was made using a vertical thermal diffusion chamber and an impactor. Inactive particles, which grew slowly or not at all under the supersaturation less than about 1%, were collected separated from active particles, and the concentration of inactive particles was compared with that of atmospheric aerosol particles by means of a transmission electron microscope. It was found that inactive particles scarcely existed. This result indicates that most of the atmospheric aerosol particles are not greatly inactivated as condensation nuclei even in the possible presence of organic materials in the urban area.

1. Introduction

Activity of aerosol particles as condensation nuclei is closely related to their chemical composition (Fletcher, 1962; Junge and McLaren, 1971), hence will be lowered by the effect of hydrophobic materials or surface active materials (Silaev *et al.*, 1972; Derjaguin *et al.*, 1971). In urban area many kinds of anthropogenic contaminants are emitted into the atmosphere, and chemical composition in the aerosol, including gases and particles or droplets, will become more complicated as a result of coagulation between particles, absorption or adsorption of gases, and chemical reaction. There is some evidence that organic materials make up a substantial amount of urban particulate matter (Ketseridis *et al.*, 1976). Therefore, some of the urban aerosol particles may be inactivated as condensation nuclei in the following two fashions. Firstly, the whole surface of a particle is covered with hydrophobic materials of a large contact angle and the critical supersaturation of the particle becomes high. Secondly, this being in the case when a particle nucleates to a droplet, surface active materials contained in the original particle are transferred to the droplet surface and form a closely-packed surface film on it. As a result, the condensation coefficient decreases and the

growth rate of the droplet becomes slow.

Chodes *et al.* (1974) and Sinnarwalla *et al.* (1975) measured the growth rate of droplets which were formed on natural cloud condensation nuclei (CCN) and obtained the condensation coefficient value approximately 0.03. This value is almost as same as that obtained by the laboratory experiment measuring the evaporation rate of pure water drops (Alty and Mackay, 1935). It seems accordingly that natural CCN are not greatly inactivated by the effect of organic materials. However, the experimental methods used by Chodes *et al.* (1974) and Sinnarwalla *et al.* (1975) are applicable only to active particles which can grow easily and not to inactive particles which grow slowly or not at all. For example the condensation coefficient value was decreased to 3.5×10^{-5} when the surface of droplets was coated with cetyl alcohol (Derjaguin *et al.*, 1966, 1971). Therefore, at the present stage it still remains in an open question about how much extent atmospheric aerosol particles are inactivated as condensation nuclei by the effect of organic materials.

In order to clear this point, we made an experiment in an urban area. The key point of our experiment is to catch the inactive particles, which grow slowly or not at all, separated from active particles. Using a transmission electron

microscope, concentration data of inactive particles are obtained and compared with that of atmospheric aerosol particles. Application of the BaCl_2 thin film test (Bigg *et al.*, 1974; Ayers, 1977, 1978) enables us to detect sulfates as water-soluble materials, and to examine the possibility of existence of the particles which contain a sufficient amount of water-soluble materials to function as CCN but inactivated.

2. Experimental

Fig. 1 shows the schematic diagram of the apparatus used to collect inactive particles separate from active particles. The following is the experimental procedure. Out door air is continuously sucked into this apparatus and divided into two channels. For both channels air is sucked at a rate of 1.6 l/min. In the left channel, without any separation procedure, air is directly introduced into the electrostatic aerosol sampler, where particles are collected as reference. In the right channel, inactive particles are collected separate from active particles as follows. Air is firstly introduced into the vertical thermal diffusion chamber (Sinnarwalla and Alofs, 1973) kept at a supersaturation less than about 1%.

Here, most of the particles possessing enough potentiality as condensation nuclei (active particles) can grow up to large droplets, while particles not possessing enough potentiality (inactive particles) can not become large droplets. Immediately after passing through the vertical thermal diffusion chamber, air is brought into an impactor, where well grown droplets larger than the cut-off size of the impactor can collide with the glass plate resulting in their removal from the air. On the other hand, inactive particles can pass through the impactor without experiencing considerable removal. In the CaCl_2 water vapor trap, connected just below the impactor, some amount of water vapor is removed for proper operation of the electrostatic aerosol sampler. This trap is a glass bottle with grains of the CaCl_2 desiccant on its bottom. Relative humidity in this trap was measured with a Humicap Hygrometer manufactured by Vaisala Oy to be 40-50%.

The vertical thermal diffusion chamber used in this experiment consists of two copper plates parallel to each other. Its inner space is 60 cm long by 13 cm wide, with a plate spacing d of 1 cm. The two plates are maintained at different temperature and the temperature difference between them can be measured by a copper-constantan thermocouple. For the entire length of the cold plate and the lower 45 cm of the hot plate, the inner surfaces are covered with filter paper wetted with distilled water. The upper 15 cm of the inner hot plate surface is kept dry. The filtered air sheath (Sinnarwalla *et al.*, 1975) is not applied in our experiment for the purpose to collect particles effectively, without any dilution, by means of the electrostatic aerosol sampler. Therefore, the sample air flows through the whole range in the vertical thermal diffusion chamber.

Since the supersaturation distribution achieved in the thermal diffusion chamber is parabolic, it is impossible to avoid the existence of the lower supersaturation range in the vicinity of the inner plate surfaces. Active particles, passing through this lower supersaturation range, will not grow. Accordingly some of the active particles may pass through the impactor without becoming well grown droplets. This hinders the complete separation of the inactive particles from the active particles. However, little amount of the sample air flows through the vicinity of the plate surfaces because of its viscosity. Based on the integration of the velocity profile equation in

Fig. 1. The schematic diagram of the experimental apparatus used for the purpose of collecting inactive particles.

Fig. 2. The supersaturation profile in the vertical thermal diffusion chamber. The upper curve is at $\Delta T=6^\circ\text{C}$, and the lower curve is at $\Delta T=5^\circ\text{C}$.

the vertical thermal diffusion chamber (Sinnarwalla and Alofs, 1973), only 6% of the flowing air passes through the range of $-0.5 \leq y/d \leq -0.4$ and $0.4 \leq y/d \leq 0.5$, where y is the position measured from the midplane between two plates, positive toward the cold plate, d the plate spacing. Hence, if sufficiently high supersaturation is maintained in the range of $-0.4 \leq y/d \leq 0.4$, the difficulty due to the lower supersaturation range can be suppressed.

In this experiment the cold plate temperature T_c , the hot plate temperature T_h and the temperature difference between the two plates ΔT were maintained at about 30°C ($\approx$ room temperature), 36°C and $5\text{--}6^\circ\text{C}$, respectively. Under this condition the supersaturation profiles achieved in the vertical thermal diffusion chamber are as shown in Fig. 2. The supersaturation within the range of $-0.4 \leq y/d \leq 0.4$ is held at about 0.4–1%. This value is so large that particles having enough potentiality as CCN can grow easily. The residence time of the sample air in the supersaturation region is approximately 20 sec. The centerline velocity V_c is 3 cm/sec. This value satisfies the following relation (Sinnarwalla and Alofs, 1973) which determines the lower limit of the centerline velocity to avoid the backflow caused by the temperature difference between the two plates:

$$V_c > 0.43(T_h - T_c). \quad (1)$$

The cut-off radius of the impactor must be chosen small enough to catch the well grown droplets effectively. But it should not be too

small, because inactive particles might be also collected. In order to estimate the grown droplet radius, a condensation growth equation (Twomey, 1967):

$$r \frac{dr}{dt} = \beta S \quad (\beta = 1.2 \times 10^{-8} \text{ cm}^2 \text{ sec}^{-1}) \quad (2)$$

was solved. Eq. (2) gives a $4.4 \mu\text{m}$ radius droplet for $S=0.4\%$ and $t=20$ sec. An impactor of 2.5 mm orifice diameter was chosen as a separator. The value of 0, 50 and 100% cut-off radii are 1.2, 2.2 and $3.6 \mu\text{m}$, respectively, based on the experimental $E-\sqrt{\psi}$ relation (Ranz and Wong, 1952). These cut-off radii guarantee the complete capture of the $4.4 \mu\text{m}$ radius droplets.

However, based upon the above consideration alone, it is not sure whether complete removal of active particles is actually achieved or not. To make clear this point, an automatic CCN counter (Model 130, Mee Industries Inc.), kept at 0.5% supersaturation, was connected below the impactor to check the CCN concentration (Fig. 1). When the reading of the CCN counter was kept below 10 cm^{-3} (This value can be actually regarded as 0 level of the CCN counter.), both electrostatic aerosol samplers were operated. Under this condition removal of the active particles is sufficient, and the right side electrostatic aerosol sampler can collect only inactive particles.

Particles were collected on EM screens which had been prepared in the usual manner: covering EM grids with a thin layer of collodion and with vacuum-evaporated carbon. After particle collection the Au/Pd shadowing was applied to the EM screens to clearly detect reference aerosol particles and inactive aerosol particles. In order to check the background, *i.e.*, contamination on the EM screens not due to the particle collection procedure, the Au/Pd shadowing was also applied simultaneously to EM screens free from the particle collection procedure. For the purpose to detect individual particles containing water-soluble materials, the BaCl_2 thin film test was applied to some other EM screens. The BaCl_2 thin film test makes it possible to detect sulfates contained in individual aerosol particles down to approximately 10^{-17} g (Ayers, 1978). In our experiment the BaCl_2 thin film test was applied in the following manners.

(i) In a vacuum evaporator $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ of special grade reagent was evaporated to the surface of EM screens depositing a $27 \text{ \AA}$ thick thin

layer on them.

(ii) The EM screens were put in the atmosphere saturated with octanol for 24 hrs.

(iii) During the time, SO_4^{2-} contained in the particles reacted with Ba^{2+} to give concentric-circular reaction products which are selective to SO_4^{2-} .

To obtain particle concentration data, five photographs were taken for each of samples by means of a transmission electron microscope by 3,000 magnification.

3. Results

Aerosol particle sampling was carried out during July to August, 1979, in Nagoya. Nagoya, located in Central Japan, is an industrial city having a population of two million. The sampling station is in the fifth floor of our laboratory on the campus of Nagoya University placed at the

east edge of Nagoya. Although the station is situated approximately 10 km apart from the polluted industrial area, some anthropogenic contamination may probably influence the results.

Fig. 3 shows the concentration data of sulfate containing particles (SCP) obtained by the BaCl_2 thin film test. Figs. 4 and 5 show the concentration data of whole aerosol particles, which could be collected by electrostatic precipitation and counted on the EM screens shadowed with Au/Pd, in two size range of $d \geq 0.07 \mu\text{m}$ and $d \leq 0.07 \mu\text{m}$, respectively, where d is the apparent diameter of particles on EM screens, not the actual diameter of particles when they are airborne. Fig. 6 shows the one set of electron micrographs of long period samples obtained from August 6 to 11.

The size separation boundary of $d \approx 0.07 \mu\text{m}$

Fig. 3. Concentration of sulfate containing particles. The left datum of a date shows the reference, and the right the inactive particles.

Fig. 4. Concentration of $d \geq 0.07 \mu\text{m}$ atmospheric aerosol particles. The left datum of a date shows the reference, and the right the inactive particles.

Fig. 5. Concentration of $d \leq 0.07 \mu\text{m}$ atmospheric aerosol particles. The left datum of a date shows the reference, and the right the inactive particles.

Fig. 6. Electron micrographs of 8/6-11 samples. Left to right—Top: Reference of sulfate containing particles, inactive sulfate containing particles. Bottom: Reference of atmospheric aerosol particles, inactive atmospheric aerosol particles.

is setted only for the convenience to count the particles in separated size range and to examine the dependence of number ratio of inactive particles to reference particles on particle size. On the other hand, it is expected that $d \geq 0.07 \mu\text{m}$ particles (Probably their radius will be larger than a few hundredths of a micron.) may be

active in our chamber where most of the sample air experiences the supersaturation about 0.4 to 1%. For example, the nucleation theory shows that the dry critical radius of pure ammonium sulfate particles at 0.4% supersaturation is $0.027 \mu\text{m}$.

It is noted from Figs. 3-6 that inactive particles

Table 1 The concentration ratio of inactive particles to reference for $d \geq 0.07 \mu\text{m}$ and $d \leq 0.07 \mu\text{m}$ size range

Date	7/10	7/11	7/12	7/10-12	8/6	8/7	8/8	8/9	8/10	8/11	8/6-11	average
Ratio for $d \geq 0.07 \mu\text{m}$	0.042	0.115	0.059	0.078	0.078	0.060	0.060	0.036	0.065	0.014	0.057	0.062
Ratio for $d \leq 0.07 \mu\text{m}$	0.190	0.481	0.348	0.317	0.257	0.143	0.209	0.288	0.315	—	0.175	0.272

are scarcely found not only for SCP but also for atmospheric aerosol particles without any exception. Particularly, inactive particle concentration of SCP is 0 or as same as the background level. The concentration of inactive atmospheric aerosol particles of $d \geq 0.07 \mu\text{m}$ is also very low compared with that of reference particles. It is, however, larger than the background level by about one order of magnitude. For $d \leq 0.07 \mu\text{m}$, inactive particle concentration is not so small as for $d \geq 0.07 \mu\text{m}$ and SCP. Table 1 shows the concentration ratio of inactive particles to reference for $d \geq 0.07 \mu\text{m}$ and $d \leq 0.07 \mu\text{m}$. In all cases the concentration ratio is larger for $d \leq 0.07 \mu\text{m}$ than for $d \geq 0.07 \mu\text{m}$.

4. Discussion

The results (Figs. 3 and 4) show that most of the particles including SCP are removed by this experimental procedure. Ideally, it is preferable that no particle loss takes place in this experimental apparatus other than the droplet-capture by the impactor. Based on the estimation described in Appendix, the particle loss other than the droplet-capture by the impactor is 3-28%. Enhancement of supersaturation in the tube, which connects the impactor to the chamber, or at the orifice of the impactor can not occur. Clearly the particle decrease shown in our results can not be explained by the particle loss other than the droplet-capture by the impactor or by the enhancement of supersaturation. In addition, it was checked that the difference in collection efficiency between the two electrostatic aerosol samplers was sufficiently small (20-30%). Thus, these results suggest that most of aerosol particles including SCP were active, growing up to droplets easily under the low supersaturation less than about 1%, and removed by the impactor. This conclusion implies that these active particles will not be inactivated by the perfect cover of hydrophobic materials but contain a sufficient amount of water-soluble materials so as to nucleate at the supersaturation less than about 1%.

Next, the condensation coefficient value of the droplets which grew on these active particles is

estimated. Fig. 7 shows the 100% cut-off radius of the impactor and condensation growth curves, obtained by the calculation of the condensation growth equation used by Fitzgerald (1972, 1974), for various condensation coefficient values at 0.4 or 1% supersaturation. In all cases, the following simplifications are adopted: the initial droplet radius is set at $0.1 \mu\text{m}$, the equilibrium droplet radius of a pure ammonium sulfate particle of 0.4% critical supersaturation at 100% RH; and the solution effect term and the surface tension term are excluded from the equation. But these simplifications will not give significant error for order estimation of the condensation coefficient value. As shown in Fig. 7, the condensation coefficient value of the droplets must be greater than of the order of 10^{-2} so as to exceed the cut-off radius of the impactor in the available growth time of 20-30 sec. This estimation indicates that most of the atmospheric aerosol particles are not greatly inactivated by the effect of surface active materials in their condensation growth process.

Fig. 5 shows that appreciable numbers of

Fig. 7. The cut-off radius of the impactor and condensation growth curves for various condensation coefficient at 0.4% (lower) or 1% (upper) supersaturation. The initial droplet radius is $0.1 \mu\text{m}$, and the accommodation coefficient is assumed to be unity.

inactive particles are detected in $d \leq 0.07 \mu\text{m}$ size range. The ratio of inactive particles to the reference particles is approximately 0.3 and is larger than that of $d \geq 0.07 \mu\text{m}$ particles (Table 1). It is difficult to clear why these particles are inactive. However, it is unlikely that these particles are inactive due to the effect of surface active materials. It is because surface active materials are considered to have a greater advantage to exert their effect on the larger particles than on the smaller particles: in the case of the larger particles, the ratio of surface area to volume is small and it becomes easy for specific substance contained in particles to cover their surface. Hence, if one takes only one assumption, *i.e.*, constant surface active materials content in each of aerosol particles, it is expected that inactive particles would exist in larger ratio when their size becomes large. But the fact shows the reverse (Table 1). Probably these inactive particles may be inactive due to the small amount of water-soluble materials contained in them.

Since Twomey (1971, 1972), it has been generally accepted that the radius of most of the CCN is a few hundredths of a micron and ammonium sulfate particles are one of the most likely CCN. However, our results (Figs. 3 and 4) show that most of the atmospheric aerosol particles, which range in radius more than a few hundredths of a micron and reach in concentration about 10-fold of SCP, can function as CCN.

5. Conclusion

It has been considered that anthropogenic pollution would give some influence on the function of atmospheric aerosol particles as condensation nuclei more or less. However, the results obtained in our study indicate that most of the atmospheric aerosol particles are not inactivated as condensation nuclei to a great extent by the influence of organic materials, but they will contain water-soluble materials causing them to grow easily.

Acknowledgements

The authors would like to acknowledge the kindness of Mr. T. Tanaka and Mr. T. Ito, Meteorological Research Institute, for lending them one of the electrostatic aerosol samplers. The authors also would like to express their appreciation to Miss Y. Suzuki, Nagoya University, for typing of the manuscript.

This work forming part of "Special Research

Project on Environmental Science" was supported financially by Ministry of Education, Science and Culture.

Appendix

In this section, some examinations are made about the particle removal processes in our experimental procedure other than the droplet-capture by the impactor.

In the vertical thermal diffusion chamber, the following four processes may reduce the concentration of inactive particles.

(1) Adhesion to the plate surfaces due to Brownian motion.

(2) Adhesion to the plate surfaces due to thermophoretic or diffusiothermophoretic motion.

(3) Adhesion to the growing droplet surface due to diffusiothermophoretic motion.

(4) Coagulation between growing droplets or inactive particles, and inactive particles.

If these processes reduce inactive particles considerably, this experimental method is not applicable to the purpose of this study.

Theoretically, these four effects can be estimated by calculating the following equations, respectively.

$$(1) \quad \bar{n}/n_0 = 0.9149 \exp(-1.885\mu) + 0.0592 \exp(-22.3\mu) + 0.0258 \exp(-151.8\mu), \quad (A1)$$

$$\mu = Dx/h^2\bar{U}, \quad (A2)$$

$$D = \frac{kT}{6\pi\eta r} \left(1 + A \frac{l}{r} \exp\left(-\frac{br}{l}\right) \right), \quad (A3)$$

where n_0 is the initial aerosol particle concentration, $\bar{n}$ the mean aerosol particle concentration that has passed through a channel with parallel plane walls separated by a distance $2h$ and length x , $\bar{U}$ the mean flow velocity in the channel, D the diffusion coefficient of a particle of radius r , k the Boltzmann's constant, T the absolute temperature, η the viscosity of air, $A = 1.246$, $Q = 0.42$, $b = 0.87$, $l = 0.653 \times 10^{-5}$ (cm) (Fuchs, 1964).

Under the condition of $\bar{U} = 2$ cm/sec, $h = 0.5$ cm, and $x = 80$ cm, Eq. (A1) was calculated. The values of $\bar{n}/n_0$ are listed in Table A1 for the particle size range collected dominantly by the electrostatic aerosol sampler.

$$(2) \quad \bar{n}/n_0 = \frac{2h - |dl|}{2h} \quad (A4)$$

$$dl = V_p \tau \quad (A5)$$

$$V_p = -5.8 \times 10^{-4} dT/dy \quad (A6)$$

(Sinnarwalla and Alofs, 1973)

Table A1. Particle decrease by adhesion to the plate surface due to Brownian motion

1×10^{-1}	0.997
5×10^{-2}	0.993
4×10^{-2}	0.989
3×10^{-2}	0.983
2×10^{-2}	0.968
1×10^{-2}	0.915

where Δl is the distance of diffusio and thermophoretic movement of particles, V_p the diffusio and thermophoretic velocity of particles, τ the residence time of particles in the vertical thermal diffusion chamber, dT/dy the temperature gradient. Under the condition of $\tau=30$ sec and $dT/dy=6^\circ\text{C}/\text{cm}$, $\bar{n}/n_0$ becomes 0.9.

$$(3) \quad \bar{n}/n_0 = \exp\left(-\frac{4\pi K' s r^3 \rho}{3D}\right) \quad (\text{A7})$$

where s is the droplet concentration, r the droplet radius, ρ the density of droplets, D the diffusion coefficient of water vapor in air, $K'=2.6 \times 10^2$ at s.t.p. (Davies, 1966). Under the condition of $s=20,000 \text{ cm}^{-3}$ and $r=7 \times 10^{-4} \text{ cm}$, $\bar{n}/n_0$ becomes 0.97.

$$(4) \quad \frac{dn(m, t)}{dt} = \frac{1}{2} \int_0^m K(m_1, m-m_1) n(m_1, t) n(m-m_1, t) dm_1 - n(m, t) \int_0^\infty K(m, m_1) n(m_1, t) dm_1, \quad (\text{A8})$$

where $n(m, n)dm$ is the concentration of particles having mass between m and $m+dm$ at time t , $K(m, m_1)$ is the coagulation constant for particles of mass m and m_1 (Fuchs, 1964). Calculation result of this equation, simulating likely condition attained in the vertical thermal diffusion chamber, is shown in Fig. A1. The number ratio of inactive particles at $t=20$ sec to initial inactive particles is 0.88.

As shown in above, these four processes hardly decrease inactive particles.

Particle loss was also examined experimentally about the experimental system without the impactor (Fig. A2). The vertical thermal diffusion chamber was kept at the usual supersaturation less than about 1%. But the automatic CCN counter was kept at 3.5% supersaturation so as to mainly detect inactive particles which could not grow in the vertical thermal diffusion chamber. Particle concentration of the left channel was used as reference. As shown in Table A2, concentration ratio of the right channel

Fig. A1. Size distribution change of particles and droplets due to coagulation process. Solid line: Initial size distribution curve of inactive particles (the left curve) and well grown droplets (the right curve). Broken line: Size distribution curve at $t=20$ sec. The size distribution of well grown droplets does not change appreciably, therefore it overlaps that of $t=0$ sec.

Fig. A2. The schematic diagram of the experimental apparatus used for the purpose of checking particle loss in the experimental system without the impactor.

to the left channel varies from 0.72 to 0.97, and its average value is 0.86.

Out of the chamber the following two processes may increase the supersaturation thereby decrease the inactive particles.

- (1) Supersaturation change in the circular tube

Table A2. Concentration data of experimentally measured particle loss and the ratio of concentration of the right channel to the left. Particle concentration of the left channel (reference) and the right channel was measured alternately. Each concentration ratio of the right channel to the left was obtained as $2R_i/(L_{i-1}+L_{i+1})$ or $(R_{i-1}+R_{i+1})/2L_i$, where subscript means the measuring number, and R and L mean particle concentration of the right channel and the left, respectively.

	L_1	R_2	L_3	R_4	L_5	R_6	L_7	R_8	L_9	R_{10}	L_{11}	R_{12}
Concentration (cm ⁻³)	11,160	8,160	11,420	9,970	10,380	10,170	10,600	8,770	10,030	8,320	9,990	8,070
Ratio		0.72	0.79	0.92	0.97	0.97	0.89	0.85	0.85	0.83	0.82	

which connects the chamber to the impactor.

(2) Supersaturation change at the nozzle of the impactor.

These two processes can not be estimated experimentally, but only theoretically, because it is almost impossible to measure supersaturation (temperature and water vapor pressure) exactly in such small space.

The first process is caused by the difference between water vapor diffusion and thermal diffusion. Similar transient occurrence has been examined as for the static type cloud chamber (Fitzgerald, 1970; Saxena *et al.*, 1970). Solution of a differential equation of diffusion in a circular tube (Schneider, 1957) enables us to estimate the supersaturation change in it. If the inner wall of the tube is assumed to be wetted, then the wall temperature T_w and the initial air temperature T_0 determine the supersaturation change pattern. When $T_w > T_0$, supersaturation increases initially and then gradually decreases to 0%. When $T_w < T_0$, supersaturation decreases down to subsaturation and then gradually increases to 0%. Since the experimental condition belongs to the latter case, the first process will not reduce inactive particles.

The second process can be estimated on Bernoulli's theorem and Poisson's law. Adiabatic expansion, caused by the high air velocity at the nozzle, exerts two opposite effects on supersaturation: decrease in supersaturation due to pressure decrease; and increase due to temperature decrease. In this experiment the air velocity is only about 5 m/sec, under which pressure and temperature of air change scarcely. The supersaturation, hence, changes negligibly: ΔS is only about -0.01% , in some what decreasing trend. Accordingly, the second process can not reduce inactive particles.

Taking above considerations all in together, it is confirmed that the inactive particle loss other than droplet-capture by the impactor does

not occur to a great extent in this experimental apparatus.

References

- Alty, Y., and C. A. Mackay, 1935: The accommodation coefficient and the evaporation coefficient of water. *Proc. Roy. Soc. London*, **A149**, 104-116.
- Ayers, G. P., 1977: An improved thin-film sulphate test for submicron particles. *Atmospheric Environment*, **11**, 391-395.
- , 1978: Quantitative determination of sulphate in individual aerosol particles. *Atmospheric Environment*, **12**, 1613-1621.
- Bigg, E. K., A. Ono, and J. A. Williams, 1974: Chemical tests for individual submicron aerosol particles. *Atmospheric Environment*, **8**, 1-13.
- Chodes, N., J. Warner, and A. Gagin, 1974: A determination of the condensation coefficient of water from the growth rate of small cloud droplets. *J. Atmos. Sci.*, **31**, 1351-1357.
- Davies, C. N. (ed.), 1966: *Aerosol Science*. Academic Press 468 pp.
- Derjaguin, B. V., V. A. Fedoseyev, and L. A. Rosenzweig, 1966: Investigation of the adsorption of cetyl alcohol vapor and the effect of this phenomenon on the evaporation of water drops. *J. Colloid Interface Sci.*, **22**, 45-50.
- , Iu. S. Kurghin, L. A. Rosenzweig, and V. A. Fedoseyev, 1971: Study of passivation of condensation growth of drops of water and salt solutions. *J. Colloid Interface Sci.*, **37**, 484-494.
- Fitzgerald, J. W., 1970: Non-steady-state supersaturation in thermal diffusion chamber. *J. Atmos. Sci.*, **27**, 70-72.
- , 1972: A study of the initial phase of cloud droplet growth by condensation: Comparison between theory and observation. Tech. Note. No. 44, Cloud Physics Lab., The University of Chicago, 144 pp.
- , 1974: Effect of aerosol composition on cloud droplet size distribution: a numerical study. *J. Atmos. Sci.*, **31**, 1358-1367.
- Fletcher, N., 1962: *The physics of rainclouds*. Cambridge University Press, 386 pp.
- Fuchs, N. A., 1964: *The mechanics of aerosols*. Per-

- gamon Press, Oxford. 408 pp.
- Junge, C., and E. McLaren, 1971: Relationships of cloud nuclei spectra to aerosol size distribution and composition. *J. Atmos. Sci.*, **28**, 382-390.
- Ketseridis, G., J. Hahn, R. Jaenicke, and C. Junge, 1976: The organic constituents of atmospheric particulate matter. *Atmospheric Environment*, **10**, 603-610.
- Ranz, W. E., and J. B. Wong, 1952: Impaction of dust and smoke particles on surface and body collectors. *Ind. Engng. Chem.*, **44**, 1371-1380.
- Saxena, V. K., J. N. Burford, and J. L. Kassner, Jr., 1970: Operation of a thermal diffusion chamber for measurements of cloud condensation nuclei. *J. Atmos. Sci.*, **27**, 73-80.
- Schneider, P. J., 1957: Effect of axial fluid conduction on heat transfer in entrance regions of parallel plates and tubes. *Trans. ASME*, **79**, 765-773.
- Silaev, A. V., L. V. Ivanchenko, and R. A. Bakhanova, 1972: Passivation of ammonium chloride nuclei by cetyl alcohol vapor in *Advances in Aerosol Physics*, No. 2 (Israel Program for Scientific Translations, Jerusalem 1972), pp. 59-65.
- Sinnarwalla, A. M., and D. J. Alofs, 1973: A cloud nucleus counter with long available growth time. *J. Appl. Meteor.*, **12**, 831-835.
- , D. J. Alofs, and J. C. Carstens, 1975: Measurement of growth rate to determine condensation coefficients for water drops grown on natural cloud nuclei. *J. Atmos. Sci.*, **32**, 592-599.
- Twomey, S., 1967: Remarks on the photographic counting of cloud nuclei. *J. Rech. Atmos.*, **3**, 85-90.
- , 1971: The composition of cloud nuclei. *J. Atmos. Sci.*, **28**, 377-381.
- , 1972: Measurements of the size of natural cloud nuclei by means of nuclepore filters. *J. Atmos. Sci.*, **29**, 318-321.

都市域における大気中のエアロゾル粒子の凝結核としての不活性度

大 谷 健・小 野 晃

名古屋大学水圏科学研究所

都市のエアロゾル粒子が、有機物の効果により、凝結核としてどの程度不活性化されているかを明らかにするために、縦型熱拡散チャンバーとインパクターを用いて実験的研究を行なった。約1%以下の過飽和度下でゆっくり成長するか、あるいは全く成長しない不活発な粒子を、活発な粒子から分離して捕集した。そして透過電子顕微鏡を用いて、これら不活発な粒子の濃度を参照試料の粒子の濃度と対比させた。ところが、不活発な粒子はほとんど見いだされなかった。この結果は、有機物の汚染がかなりあると考えられている都市においてさえも、ほとんどの大気中のエアロゾル粒子は凝結核として極度には不活性化されていないことを示している。