RELATION BETWEEN INTERMEDIATE IONS
AND METEOROLOGICAL FACTORS

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Abstract. In order to obtain the knowledge on the formation mechanism of aerosols, mobility distributions of intermediate ions were measured. The data of intermediate ions, together with some meteorological factors, Aitken and Mie particles, were used for a multiple regression analysis and main contributors to the time variation of intermediate ions were calculated. From the calculation, it was concluded that solar radiation and relative humidity were pronounced contributors in measurements during summer. Furthermore, the results were compared with a theory about the formation of secondary sulfuric acid particles.

1. Introduction

It is well known that Aitken particles in the atmosphere are mainly produced by a gas-to-particle conversion process. The fact has been confirmed by several authors. Based on laboratory experiments, some authors reported that very fine particles in the size range of 10^{-7} cm in radius were newly produced by the process (e.g. Bricard et.al 1972). Moreover, Whitby et.al (1972) carried out the measurements of aerosol size distributions in a heavily polluted atmosphere and also, Bigg and Turvey (1978) measured the variation of the size distributions and chemical composition of aerosols along the movement of plume. Based on these measurements, they concluded that most of Aitken particles were produced by the gas-to-particle conversion process. However, there are a few conclusive reports on whether or not most of Aitken particles are produced by this process in case of not so heavily polluted environments. For this reason, we measured the aerosols in the restricted size range to aerosol formation in moderately polluted environment and attempted to get the information on the formation mechanism of Aitken particles.

In order to measure Aitken particles, commonly used instruments are ion analyzers for atmospheric ions and condensation nuclei counters such as Pollak counter. To measure fine aerosols which are newly produced by the gas-to-particle conversion, we use an ion analyzer for intermediate ions which consist of smaller parts of Aitken particle in size. The measurements of the ions have an advantage of specially rapid response for the aerosol formation. The reason is that the ions have so high mobility that they have very short life. Accordingly, they are intensely influenced by environmental conditions of places where they are produced. Therefore, the data on the ions become free from the complication caused by transport from the origin of aerosols. On

the other hand, in the size range of intermediate ions, 10 percents or less of the aerosols are charged, even though the charge distribution on aerosols is in equilibrium. This brings some ambiguity in estimating concentration of very fine particles by that of intermediate ions. For this reason, the data has to be interpreted with care.

2. Measurements

For the measurements of intermediate ions, we constructed an ion analyzer of first differential type (Whipple 1960, Misaki 1961). The ion analyzer consisted of double electrodes of concentric cylinders; the outer electrode was 92 mm in inner diameter and 75 cm in length. The inner electrode was 30 mm in diameter and it was divided into two parts; first and second electrodes from the air entrance were 53 and 22 cm in length respectively. This analyzer was available for intermediate ions in the size range of 1.4 to $8 \cdot 10^{-7}$ cm in radius under the operating condition used here. The concentrations of Aitken and Mie particles, together with the intermediate ions, were measured by a Pollak and an optical particle counter respectively.

Five series of measurements were carried out during three seasons from summer 1983 to spring 1984, at the campus of Science University of Tokyo at Noda, which is located in the north-eastern suburban area of Tokyo. One series was a period from 7 to 10 days and the hourly data were used for calculation.

In Fig.1, we show examples of mobility distributions for intermediate ions; each of these distributions is the average of 24 hourly data in a fine day. From the figure, we can easily see

Fig.1. Examples of ion mobility distributions for intermediate ion in fine days.

that even the limited mobility range, the shape of mobility distribution is changeable. The results may show the fact that the influencing factors on intermediate ions have dependence on the particle radius (or mobility). In order to apply the data of ions to a multiple regression analysis, we divided the ion mobility distribution into three ion groups according to the mobility interval; these were denoted III for ions from 0.24 to 0.062 cm^2/Vsec , II2, from 0.062 to 0.023 cm^2/Vsec and II3, from 0.023 to 0.0085 cm^2/Vsec .

3. Results and discussion

The multiple regression analysis was applied for the determination of the main influencing factors on intermediate ions.

Fig.2. The results of regression analysis on a series of measurement during summer.

In the analysis, we took III1, III2 and III3 as dependent variables, and wind velocity(WV), temperature(TEM), relative humidity(HUM), water vapor pressure(VP), solar radiation(SR), Aitken(AP) and Mie particles(MP) as independent variables. In Fig.2, we show the results of calculation of regression analysis on a series of measurement during summer. The figure includes multiple correlation coefficients and standard partial regression coefficients which reveal an extent of contribution to each independent variable; the values of hatched parts show negative ones.

From Fig.2, we can see that relative humidity is the most dominant contributor to III1 and III2; it plays more important role in III1 than in III2. The subsequent contributor to III1 and III2 is solar radiation. Effect of relative humidity and solar radiation becomes remarkable with decreasing the size of intermediate ions. Aitken and Mie particles of pre-existing aerosols is not so remarkable as in the above parameters, but the followings should be benoted. The effect of Aitken particles is the most dominant for III3 and that of Mie particles, for III1. However, we should pay our attention to the fact that aerosols have positive contribution for the variation of intermediate ions.

In Fig.3, we show summary of regression analysis for three measurements during summer. In the figure, circles, triangles and blanks indicate the degrees of contribution, dominant, weak and insignificant, respectively. From Fig.3, we see that common main contributors for every measurements may be relative humidity and solar radiation. On the other hand, Aitken is main contributor for III3. The other factors become main contributor on the occasion, but they seem to be uncommon contributors.

In Fig.4, the results in winter and spring are shown. The tendency remarkably differs from that in Fig.3. The common factor is wind velocity over the whole size range of intermediate ions. The wind velocity has positive contribution to the ions, although the fact is not represented on the table.

These experimental results were compared with a theoretical one(Middleton and Kiang 1978). They developed a numerical kinetic

aerosol model which incorporated the mechanisms of photo-chemical reactions, heteromolecular nucleation, heteromolecular condensa

	W V	TEM	HUM	V P	S R	A P	M P
JUN. 1983							
II 1	●	●	●		●		
II 2	●	●	●	▲	●	▲	▲
II 3		▲	▲		●	●	●
JUL. 1983							
II 1		●	●		●		●
II 2			●				
II 3			▲			●	
AUG. 1983							
II 1	●		▲		●	▲	●
II 2			●		●	●	●
II 3	▲	●	●	●	●	●	●

Fig.3. Summary of regression analysis for three measurements during summer.

	W V	TEM	HUM	V P	S R	A P	M P
JAN. 1984							
II 1	●					●	
II 2	●						
II 3	●			▲			
MAR. 1984							
II 1	▲		●	●	●		▲
II 2	●				●		
II 3	●				▲	●	●

Fig.4. Results of regression analysis for measurements during winter and spring.

tion and thermal coagulation, and obtained the optimum conditions for formation of secondary acid aerosols.

We compared our experimental results with a formation theory of secondary acid aerosol. There was no direct evidence that intermediate ions are secondary acid aerosols. However, taking into account the similarity of the size range of intermediate ions and theoretically predicted sizes of newly formed particles, it seems reasonable to perform the comparison with the theory by Middleton and Kiang(1978). From the theory, they concluded that the optimum conditions for aerosol formation were high relative humidity, low temperature, low concentration of pre-existing particles and high rates of sulfuric acid vapor production.

From measurements in summer, our experimental results approxi-

mately agree with the theory in the fact that main contributors are relative humidity and solar radiation; the solar radiation is related to the high rates of sulfuric acid vapor production. However, the temperature and pre-existing aerosols, which correspond to Aitken and Mie particles, can not be regarded as significant in our experiments.

In the measurements in winter and spring, the main influencing factor is wind velocity. It is difficult to explain it theoretically because the increase of wind velocity contributed to the enhancement of intermediate ions. For the reason, this may be due to unappropriateness in selection of dependent variables. It may be possible that wind velocity covers the other effective parameters.

4. Conclusions

From our preliminary experiments, the following conclusions may be obtained.

- 1) Main contributors to the variation of intermediate ions were relative humidity and solar radiation in the measurements during summer, and wind velocity during winter and spring.
- 2) Our experimental results during summer agreed approximately with theoretical ones on formation of secondary acid aerosols.

Our experimental results include some facts which can not be fully explained by the theory. We should take conclusive results with more sufficient data.

References

- Big, E.K., and D.E. Turvey, Sources of atmospheric particles over Australia, *Atmos. Environ.*, 12, 1143-1155, 1978.
- Bricard, J., M. Cabane, G. Madelaine, and D. Vigla, Formation and properties of neutral ultrafine particles and small ions conditions by gaseous impurity of the air, *J. Coll. Interf. Sci.* 39, 42-58, 1972.
- Middleton, P. and C.S. Kiang, The formation and growth of secondary sulfuric acid particles, "Atmospheric Aerosol and Nuclei", 172-176, edited by A.F. Roddy and T.C. O'Connor, Galway Univ., 1978.
- Misaki, M. Studies on the atmospheric ion spectrum (1), *Pap. Meteor. Geophys.*, 12, 261-276, 1961.
- Whipple, E.C., An improved technique for obtaining atmospheric ion mobility distribution, *J. Geophys. Res.*, 65, 3679-3684, 1960.
- Whitby, K.T., R.B. Husar, and B.Y.H. Liu, The aerosol size distribution of Los Angeles Smog, "Aerosol and Atmospheric Chemistry", 237-264, edited by G.M. Hidy, 1972.

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