Studies on the Atmospheric Ion Spectrum (I)

—Procedures of Experiments and Data Analysis—

by

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Abstract

A newly designed apparatus for measuring the mobility spectrum of atmospheric ions was constructed in 1959, on the basis of the method previously developed by the author. After the examination of the air flow pattern through the aspiration cylinder, measurements of the mobility spectrum have been resumed since 1960.

Two ion probes were used in the present studies with different diameters and with the same length to scan the mobility ranges of 3–0.1 and 0.1–0.005 cm²/volt sec, respectively.

Details on the experimental set-up, procedures of experiments and practical treatments of data analysis are described in this paper.

1. Introduction

Previously the author (MISAKI: 1950) introduced a new method of measuring the mobility spectrum of atmospheric ions, together with an example of actual measurement by this method. The observations of ion concentration, especially the measurements of the mobility spectrum, involve many difficulties. They are apt to be disturbed by various factors which are out of our control. First of all, the air stream going through the ion chamber is required to be laminar. This is, in general, very difficult to realize practically, though it is the first necessary condition to improve accuracy of measurement.

Recently I have newly designed and constructed an aspiration chamber (MISAKI: 1960), and examined the air flow pattern going through it. From the result of this examination, the appropriate air flow rate was determined at which the air stream is kept laminar. With this new apparatus, we have resumed the measurements of the mobility spectrum since 1960.

The main purpose of the present experiment is to determine as exactly as possible the fine structure of the spectrum in the region of the small ion group.

In this paper, the descriptions of the experimental set-up, the procedures and the treatments of observational data are given*.

* Recently E.C. WHIPPLE, Jr. (1960) has improved this method. The characteristics of his method are normalized with reference to the applied voltage before being differentiated. Though the procedure of Whipple's analysis is almost the same with the present author's, it has a sure advantage in experimental procedure, since in his method only the current to the second electrode needs to be measured. The experiments hereafter shall be tried with his modified method.

2. Experimental set-up

1) Description of the aspiration cylinder

The aspiration cylinder through which the air flow pattern was examined in preliminary investigation, was reconstructed for the present purpose. The schematic diagram of the cylinder is shown in Fig. 1.

Fig. 1. The schematic diagram of the ion mobility spectrometer.

The ion-probe placed along the axis of the cylinder is divided into four portions. The head and the tail portions are grounded, the longer one of the two portions between them serving as the first electrode and the other as the second one. The portions are joined to each other firmly with three insulating spacers between them. Since these brass cylinders and teflon spacers of 6 mm in width have the same radius, the probe has an entirely smooth surface even at these junctures.

This probe is supported and settled in the outer cylinder by the aid of four pin legs implanted at the head and the tail portions. Lead wires connected with the first and the second electrode respectively are passed through the inside of the probe cylinder and drawn out at the tail portion. Thus the probe has neither legs nor lead wires, which might cause undesirable disturbances in the air stream and the electric field, within the electric field between the collecting electrodes. Eddies caused at the head of the probe, or at the pin legs, dissipate before they reach the portion of the collecting electrode, where, then, the air stream is kept laminar. Undesirable effects of a stray flux of the electric field which terminates at the head portion will be discussed later.

Fig. 2. Two types of the ion probes.

Two probes have been constructed in order to scan the different ranges of the

ion mobilities. The slender one, called the small-ion probe, is designed to measure for the mobility range between 3.0 and 0.1 cm²/volt. sec, and has a diameter of 5 cm. The lengths of its first and second electrodes are 45 cm and 15 cm respectively. Another probe, called the intermediate-ion probe, is used in order to scan for the range between 0.1 and 0.005 cm²/volt. sec, and has a diameter of 12 cm. The lengths of both electrodes of it are the same with those of the small-ion probe. They are shown in Fig. 2.

The aspiration cylinder has a wide opening of 30 cm diameter. Two sheets of saran net (synthetic fiber) were placed at this entrance to prevent the inflowing of eddies from outside. The air stream from this wide opening is squeezed as it goes into the chamber, the diameter of which is 15 cm. The squeezing curve of this portion has been drawn by the following formula :

$$\left(\frac{r_1}{r}\right)^2 = \left(\frac{r_1}{r_0}\right)^2 \left[1 - \left\{ 1 - \left(\frac{r_0}{r_1}\right)^2 \cdot \frac{\left(1 - \frac{x^2}{l^2}\right)^2}{\left(1 + \frac{x^2}{3l^2}\right)^2} \right\} \right]$$

where r_1 and r_0 denote the radius of the opening and of the inner radius of the outer cylinder, and r is the radius at x which is the co-ordinate along the axis. Squeezing begins at $x=0$ and ends at $x=l$.

The portion of the outer cylinder which faces the inner electrodes is insulated by bakelite spacers and serves as the outer electrode of the condenser. The potential from a D.C. voltage source is applied to this electrode. The whole picture of the equipment assembled for the experiments is shown in Fig. 3.

Fig. 3. Experimental set-up for obtaining the ion spectrum.

2) Description of the electrometer system

The current i_1 , and i_2 , consisting of ions collected by the first and the second electrode, flow to the ground through the high resistors R_1 and R_2 respectively, and develop the voltages v_1 and v_2 across each of them. A Lindemann electrometer is used to measure the potential difference $v_1 - v_2$. The case of the electrometer is insulated by three teflon bosses and connected with the first electrode, whereas its needle is connected with the second electrode. Therefore, the deflection of the needle is proportional to $v_1 - v_2$.

Since the experimental procedure based upon the author's method requires to

plot the value $\frac{i_1}{a_1} - \frac{i_2^*}{a_2}$ against the potential applied to the outer electrode, it is convenient if $v_1 - v_2$ is proportional to $\frac{i_1}{a_1} - \frac{i_2}{a_2}$.

Since $v_1 = i_1 R_1$ and $v_2 = i_2 R_2$,

$$(1) \quad \frac{i_1}{a_1} - \frac{i_2}{a_2} = \frac{v_1}{a_1 R_1} - \frac{v_2}{a_2 R_2}.$$

Now, if we choose the values R_1 and R_2 so as to make $\frac{R_1}{R_2} = \frac{a_2}{a_1}$, the above formula becomes equal to $\frac{1}{a_1 R_1} (v_1 - v_2)$.

Considering that the Lindemann electrometer used has the voltage sensibility of about 0.02 volt/scale div. and that the current to the electrode is of the order of 10^{-13} amp, R_1 has been decided to be $1 \times 10^{12} \Omega$, and consequently R_2 be $3 \times 10^{12} \Omega$ since $\frac{R_1}{R_2} = \frac{a_2}{a_1} = \frac{l_2}{l_1} = \frac{1}{3}$.

The time constants of the two systems must be equal, because it is necessary for the two systems to be dynamically balanced. If C_1 denotes the capacity** of the first electrode system and C_2 that of the second one, the relation

$$(2) \quad C_1 R_1 = C_2 R_2,$$

must hold. For this purpose, C_1 was adjusted by adding suitable capacity. The values of C_1 , C_2 etc. are shown in Table 1.

Table 1. Constants of the electrometer system.

	C_1	C_2	C_3	$C_1 R_1$	$C_2 R_2$	Half-value time
	pF	pF	pF	sec	sec	sec
small-ion probe	76	26	7	79	81	55
intermediate-ion probe	246	82	18	256	257	177

The time constants of both systems are given in the fourth and the fifth column, where $R_1 = 1.04 \times 10^{12} \Omega$ and $R_2 = 3.13 \times 10^{12} \Omega$.

* The constants a_1 and a_2 are calculated from

$$a_j = l_j / 2 \ln \frac{r_0}{r_i} \quad (j=1, 2),$$

where r_i and r_0 represent the radii of the inner and outer electrodes, and l_1 , l_2 are the lengths of them, respectively. Therefore, a_j is the capacity of the cylindrical condenser divided by the dielectric constant of air.

For the small-ion probe, $a_1 = 20.48$ cm and $a_2 = 6.83$ cm, and for the intermediate-ion probe, $a_1 = 100.8$ cm and $a_2 = 33.6$ cm.

** Because the two systems of the first and the second electrode have a certain amount of coupling capacity C_3 between them which can not be neglected, C_1 and C_2 are computed considering the effect of C_3 . Accordingly, when the second electrode system is grounded, as in the case of measuring the ordinary voltage vs current characteristics, C_1 increases slightly.

As readily seen from the values of the time constant, it takes much time before the indication of electrometer attains to the final value. Therefore, reading of electrometer indication is made at the time when it attains to the half value of the final one after it starts from zero potential. These half value times, calculated from the time constants, are shown in the last column.

The insulation resistance of both electrodes of the probe must be kept at least about two orders of magnitude higher than R_1 or R_2 . Teflon insulators have served satisfactorily for this purpose.

3) *D.C. supply to the outer electrode*

Potential of the outer electrode is supplied from a D.C. source which consists of a stabilizer, a rectifier and a potential divider. 500 volt D.C. generated from a rectifier is potentiometrically divided in 20 or 30 steps with an equal interval on the logarithmic scale. In the experiments carried out at Karuizawa, where the fluctuation of A.C. voltage occurred frequently, dry batteries were used.

4) *Stray flux at the entrance of the electrode*

In the preliminary tests of our experiments, it was found that some fractions of ions are removed before they reach the first electrode. Since the grounded metal wall of the outer cylinder, and the head portion of the probe are just in front of the electrodes, a stray flux from the outer electrode terminates on both. Therefore, some of the ions introduced into the chamber are caught before reaching the electrode owing to this stray flux.

In order to reduce this effect as much as possible, a wide spacer of the insulator was first inserted between the head portion of the probe and the first electrode, and another spacer at its opposite position in the outer cylinder, with a view to keeping these grounded metal parts away from the electrodes. A cylinder made of plastics (acrylic acid resin) with a length of 20 cm was used as a spacer in the outer cylinder, and a bakelite pipe of the same length as a spacer in the probe.

This attempt, however, has ended in failure, because observations are seriously disturbed by the fluctuating induction caused perhaps by unsettled distribution of charge on the surface of these insulators, or by alteration of the potential (relaxation) at them. Thus, these insulating spacers were removed finally and the chamber has been restored again.

A detailed description of the effects of the stray flux at the entrance of the electrode will be presented later.

3. Experimental procedure

1) *Scanning range*

Descriptions of the theory on the method of measurements have been given in the previous paper (MISAKI: 1950). In the following, further details regarding the practical procedure of experiments performed with the newly constructed apparatus are given.

There is a well-known relation between the air flow rate Φ , the potential V ap-

plied to the outer electrode and the critical mobility κ_c (e.g. for the first electrode), that is

$$(3) \quad \kappa_c = \frac{\phi}{4\pi a_1} \frac{1}{V},$$

where the constant a_1 is 20.48 cm for the small-ion probe and 100.8 cm for the intermediate-ion probe as already described. The above relation is shown in Fig. 4.

Fig. 4. The relation between air flow rate, applied voltage and critical mobility for the first electrode. (in the case of the small-ion probe)

The appropriate air flow rate at which the air stream is kept laminar, in the case of the small-ion probe, has been found by the previous work to be from about 4 l/sec to 9 l/sec, so that the experiments with the small-ion probe have been carried out at the flow rate of 7.5 l/sec.

Now, the maximum voltage applied to the outer electrode from the D.C. generator is 500 volts. Therefore the lower limit of a mobility range which can be scanned with this arrangement is seen from Fig. 4 to be about 0.1 cm²/volt. sec. Further lower regions, down to 0.005 cm²/volt. sec., can be scanned with the intermediate-ion probe and with the same D.C. supply at the air flow rate of about 5 l/sec.

2) Resolution of the spectrum and steps of applied voltage

From the method upon which the present work is based, the concentration of ions with mobilities between κ_c and κ_d is to be deduced. The relation of κ_c to κ_d is given as follows:

$$(4) \quad \kappa_d = \frac{a_1}{a_1 + a_2} \kappa_c,$$

then,

$$(4') \quad \log \kappa_c - \log \kappa_d = \text{const.}$$

that is to say, ion concentration is given for every section of mobility axis divided at equal interval on the logarithmic scale*. Thus it will be seen that the value of $\frac{a_1}{a_1+a_2}$ gives a measure of resolutions of the spectrum.

Accordingly, plots of the characteristic curve $\frac{i_1}{a_1} - \frac{i_2}{a_2}$ vs V should be taken, at least, at every voltage which corresponds to the particular interval described above.

The voltage interval, with which measurements were made stepwise, was somewhat finer than that. Table 2 shows such a sequence steps of voltage V applied to the outer electrode.

Table 2. Voltages at 20 steps.

(volt)

Step No.	1	2	3	4	5	6	7	8	9	10
Voltage	3.20	4.80	6.3	7.9	9.5	12.7	15.7	22.2	28.5	37.6
Step No.	11	12	13	14	15	16	17	18	19	20
Voltage	51	67	90	116	152	198	270	345	461	610

It takes considerably much time to complete all measurements at every step. Sometimes when the observed characteristic curve is almost flat, measurements at some steps were skipped over.

Since the time required for one reading for one step is fairly long owing to the fact that the electrometer system has rather a large time constant, actual readings were made at the half value time as already mentioned. In spite of this, one series of measurements for scanning the intended mobility range still requires much time. For example, in the case with the small-ion probe, it takes about 20 minutes to scan the range between 3-0.1 cm²/volt. sec. Therefore, conditions of ions in the atmosphere may vary within this time. To ascertain whether conditions have varied or not during the experiment, measurement was repeated at an appropriate step after the scanning was completed. When appreciable difference was found between them, the data of the experiment were not used.

* Chr. JUNGE (1958) has made a proposal as follows:

Considering the wide range of particle sizes and concentrations, it seems advisable to use the logarithmic scale. The log-radius distribution can thus be defined by

$$n(r) = dN/d(\log r).$$

For the same reason, our mobility spectrum should be represented in a similar form. Fortunately, the data obtained by this method gives the ion concentration ΔN in the particular interval $\Delta(\log \kappa)$, where

$$\Delta(\log \kappa) = \log \frac{a_1 + a_2}{a_1} = 0.1249.$$

So that the spectrum will be easily converted into the form

$$n(\kappa) = \Delta N / \Delta(\log \kappa) = \Delta N / 0.1249.$$

The atmospheric conditions in fair weather were so stable that most of the data were available.

4. Procedure of data analysis

1) General description of the procedure of analysis

The potential difference between the first and the second electrode obtained from the electrometer reading is converted to $\frac{i_1}{a_1} - \frac{i_2}{a_2}$ by eq. (1). Then the characteristic curve, V vs $\frac{i_1}{a_1} - \frac{i_2}{a_2}$, is ready to be plotted. Fig. 5 shows an example of the characteristics. Critical mobility for the first electrode, κ_c , is scaled in the abscissa as well as the corresponding V .

Fig. 5. An example of the characteristic curve, $\frac{i_1}{a_1} - \frac{i_2}{a_2}$ vs V .

(Apr. 8 1960, 8 hr. positive ion)

The concentration of ions with mobility between κ_c and κ_d is deduced from

$$(5) \quad \int_{\kappa_d}^{\kappa_c} f(\kappa) d\kappa = \frac{1}{\bar{\kappa}} \frac{a_2}{4\pi e(a_1 + a_2)} \frac{d}{dV} \left(\frac{i_1}{a_1} - \frac{i_2}{a_2} \right),$$

where $\bar{\kappa} = \frac{1}{2}(\kappa_c + \kappa_d)$, and the differentiation in the right hand side of the equation is to be taken at V corresponding to κ_c (eq. (3)). κ_d is related to κ_c by eq. (4), and it follows in our apparatus as $\kappa_d = 0.75 \kappa_c$.

Then, it is necessary to determine the slopes of the curve with appropriate intervals. This was done at every measuring step as follows: denoting

$$\frac{i_1}{a_1} - \frac{i_2}{a_2} = X,$$

then,

$$(6) \quad \left(\frac{dX}{dV} \right)_{V=V_n} = \frac{1}{2} \left[\frac{X_n - X_{n-1}}{V_n - V_{n-1}} - \frac{X_{n+1} - X_n}{V_{n+1} - V_n} \right],$$

where n is the step number of measurements. An example of spectrum thus obtained is shown in Fig. 6, which has been derived from Fig. 5.

Fig. 6. Ion concentration between κ_c and κ_d (Derived from Fig. 5).

The expression of the spectrum in a histogram form, as is shown in Fig. 7, was given by plotting the ordinates of Fig. 6 at the voltages V , $(4/3)V$, $(4/3)^2V$,..... etc.

Fig. 7. An example of the mobility spectrum (derived from Fig. 6).

2) Removal of ions by the stray field at the entrance of the electrode

The undesirable effect of the stray flux of the electric field at the entrance of the electrode in the experiment with the small-ion probe was revealed especially when the air was clean and contained rather a low concentration of ions with larger sizes than those of the small-ion group. In such a case, the characteristic curve often showed a negative slope at voltages greater than about 70 volts as shown by the broken line in Fig. 8.

Fig. 8. Improper decrement in A-curve.

Theoretically speaking, if there is no concentration of ions within certain region of mobilities, the characteristic curve should have no slope in the region of voltage corresponding to it.

Many tests made on such a decrement of the curve with voltage have revealed that it was caused by the stray flux at the entrance. Some of the ions are removed before reaching the first electrode, which reduces, as a result, the amount of ions expected to be collected by the first electrode.

A similar effect was found in the ordinary voltage-current characteristics. When the second electrode is grounded, leaving the connection of the electrometer system unchanged, the reading of the electrometer becomes proportional to i_1 , i.e. the current into the first electrode. Then the i_1 vs V curve is readily plotted. For simplicity we call this characteristic as B-curve hereafter, whereas the $\frac{i_1}{a_1} - \frac{i_2}{a_2}$ vs V characteristic as A-curve. B-curve should be monotonic increasing with the first derivative of monotonic decreasing.

In the case when some portion of A-curve showed improper decrement, B-curve obtained by the successive measurements also frequently showed decrease with increasing voltage, or increase in the first derivative.

An example corresponding to Fig. 8 is shown in Fig. 9 by the broken line.

Fig. 9. Improper decrement in B-curve.

Now, the effect of the reduction in A-curve, caused by a stray field as well as in B-curve, must always exist even when it is not revealed apparently. For instance, when the air contains of the large ions, B-curve will not decrease but only increase, even though the reduction should exist.

It is impossible to give strict corrections for these observed values under the present experimental arrangements. Roughly estimated correction, however, was made, which will be mentioned below.

In the first place, it is assumed that the removal of the small ions may increase proportionally with the applied voltage, until all of the small ions are removed at a certain voltage. The removal must be added to i_1 as a correction. This assumption will roughly hold, because the small ion group can be regarded as a single line spectrum in such a wide range up to the region where the decrement of the characteristics comes to be apparent.

In the experiments carried out at Karulzawa in winter 1960, where the air was fairly clean, B-curve showed an apparent decrement. It was often reduced to zero over the voltage of 600 volts. The broken line in Fig. 9 shows such an example. Thus the critical voltage in this case, at which all small ions are removed before they reach the first electrode, has been estimated to be about 600 volts.

For simplicity we illustrate the procedure of correction by an example. As the first approximation, a provisional value of the small ion content N' was determined from A-curve shown in Fig. 8 by the broken line. $\frac{V}{600}(e\Phi N')$ was then added to

each i_1 corresponding to V . The full line in Fig. 8 shows the plot of the corrected data. B-curve in Fig. 9 determined just before the measurement of A-curve was similarly corrected. This is shown by the full line in the Figure.

Computation was again carried out on the corrected data to deduce the spectrum. This, however, did not differ more than 10 percent from the one derived without corrections. These are shown in Fig. 10. The average of the corrections for the small ion concentration has been found to be 7.5 percent from the results of 24 experiments. This shows that, if we limit the scanning range up to $0.3 \text{ cm}^2/\text{volt. sec.}$ using the small-ion probe, the data without corrections would give the results without appreciable errors.

Fig. 10. Comparison of spectrum with the one derived from the data without corrections. (Broken line shows the latter.)

3) Some effects of improper determinations of constants R_1 , R_2 , etc.

Another cause of errors also may lie in wrong determinations of the constants of the electrometer system, *e.g.* R_1 , R_2 etc. This has been examined as follows.

The currents to both electrodes can be written in the form,

$$(7) \quad i_1 = \Phi e \left[\int_{\kappa_c}^{\infty} f(\kappa) d\kappa + \frac{1}{\kappa_c} \int_0^{\kappa_c} \kappa f(\kappa) d\kappa \right],$$

$$(8) \quad i_2 = \Phi e \left[\int_{\kappa_d}^{\kappa_c} f(\kappa) d\kappa + \frac{1}{\kappa_d} \int_0^{\kappa_d} \kappa f(\kappa) d\kappa - \frac{1}{\kappa_c} \int_0^{\kappa_c} \kappa f(\kappa) d\kappa \right],$$

If the air is free of the small ions, the total concentration of ions can be expressed practically by

$$N = \int_0^{\kappa_g} f(\kappa) d\kappa,$$

where κ_g denotes the greatest mobility of ions which are present. Since measurements are made in the region of the small ions, we can put $\kappa_g \ll \kappa_d$.

Then eqs. (7) and (8) become

$$i_1 = \Phi e N \cdot \frac{1}{\kappa_c}, \quad i_2 = \Phi e N \cdot \left(\frac{1}{\kappa_d} - \frac{1}{\kappa_c} \right),$$

So that there follows

$$(9) \quad \frac{i_1}{a_1} - \frac{i_2}{a_2} = \phi e N \left[\frac{1}{a_1 \kappa_c} - \frac{1}{a_2} \left(\frac{1}{\kappa_d} - \frac{1}{\kappa_c} \right) \right].$$

Inserting the relation of κ_c to κ_d , (4), into (9), the term in the bracket becomes zero.

Now, if $a_1 R_1 \neq a_2 R_2$, we obtain from (1) putting $\frac{a_2 R_2}{a_1 R_1} = p$

$$(10) \quad \frac{i_1}{a_1} - \frac{i_2}{a_2} = \frac{v_1/R_1}{a_1} - \frac{v_2/R_2}{a_2} = \frac{1}{a_2 R_2} (v_1 - v_2) - \frac{v_1}{a_2 R_2} (1-p).$$

We observe the first term in the right hand side of the above equation, and so the second term gives the quantity of the correction for observed values.

Then, even if ions are absent in a scanning range, A-curve, in spite of being expected to be zero at all voltages of scanning, will decrease or increase with V as p is greater than unity or vice versa. If p is known, the correction term can be evaluated from the data of B-curve if obtained simultaneously.

The small ion free air was easily produced in a sealed laboratory by producing abundant large ions with the aid of a Cottrell's discharger. An example of decrease in A-curve is shown in Fig. 11, which was obtained under such a condition using the intermediate-ion probe. The decrease showed good agreement with the amount of the correction estimated as above.

Fig. 11. Decrement in A-curve caused by improper determination of the circuit constant. Full line shows the corrected curve.

Strictly speaking, eq. (3), as well as eq. (4), does not hold good because the

effect of stray field at the edges of the electrodes is neglected. Subsequently the ratio R_1/R_2 , though determined to be exactly equal to $a_2/a_1 (=l_2/l_1)$, is not yet proper. But these effects do not seem to cause any serious errors to the results, considering that the decrease in Fig. 11 has been well explained as described above.

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References

- MISAKI, M., 1950: A method of measuring the ion spectrum, *Pap. Met. Geophys.*, 1, 313-318.
 MISAKI, M., 1960: Determination of air flow in an ion chamber (Preliminary examination for the study of ion spectrum.) *Pap. Met. Geophys.*, 11, 348-355.
 JUNGE, C.E., 1958: *Advances in Geophysics IV, Atmospheric Chemistry*, Academic Press Inc. Publishers, New York.
 WHIPPLE, E.C.J., 1960: An improved technique for obtaining atmospheric ion mobility distributions. *Journ. Geophys. Res.* 65, 3679-3684.

大気イオン・スペクトラムの研究 (I)

— 測定および計算の方法について —

三 崎 方 郎

前報では、1959年に新たに設計製作した大気イオンの移動度スペクトロメーターの内部の気流分布に関する実験結果を述べたが、 $4\sim 9\text{ l/sec}$ が適当な流量であることがわかったので、これに基づき、通気筒の一部を改造して、スペクトロメーター本来の機能をもたせて、測定を開始した。

スペクトラム測定の方法は以前に筆者が考案した原理による。イオン・プローブは等長で、直径の異なる二本を用意したが、それぞれに適当な移動度範囲を受けもたせれば $3\sim 0.005\text{ m}^2/\text{volt. sec}$ の範囲が走査できる。しかし当面の研究範囲は $3\sim 0.1\text{ cm}^2/\text{volt. sec}$ として、いわゆる小イオン群のスペクトラム微細構造を明らかにすることを目的とした。

ここでは装置および実験手順に関する詳細と、装置の特性(分解能等)について述べ、更に、清浄空気および汚濁空気中で行った総合検査の検討から、実験上の組織的誤差とその補正法について述べた。