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AIR IONS AND ELECTRICAL AEROSOL ANALYSIS

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THE DEPENDENCE OF SMALL AIR ION MOBILITY SPECTRA IN THE GROUND LAYER OF THE ATMOSPHERE ON TEMPERATURE AND PRESSURE

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First, we will consider the theoretical side of the problem of dependence of mobility on temperature and pressure. In the formula of ion mobility in the first approximation of the Chapman-Enskog theory which in our conditions is sufficiently exact, the inverse proportionality of mobility and gas density is clearly expressed [1]. This relation is easy to prove if the gas is sufficiently rarefied, so that the processes of transport are determined only by paired collisions of particles, and the strength of the electric field is sufficiently weak. Therefore it is generally accepted to reduce the mobility to standard conditions with the equation

$$k = k' \frac{p}{101325} \frac{273.15}{T} , \qquad (1)$$

where k' is the natural mobility,
p is the pressure in Pa ,
T is the absolute temperature in K.

In addition to that, mobility depends on temperature also at constant gas density. This dependence is determined by the character of the interaction of ions and neutral particles. Unfortunately, for our conditions the character of this interaction is not sufficiently investigated. Indirectly it can be estimated that for ions of stable structure the dependence of the reduced mobility on temperature can be characterized by a power with the absolute value below 1/2. The experimental data show that this dependence is considerably weaker. Proceeding from the data in the range 300-500 K, we obtain the relative change of the reduced mobility which does not exceed ±2% for 10% change of the absolute temperature [1,2].

We have carried out a systematic recording of the mobility spectra of small air ions (together with the small fraction of intermediate ions) in natural air [3]. Temperature, pressure, and relative humidity of the air were recorded at the same observation point. Below we will analyze the dependence of the mobility spectrum of small air ions on temperature and pressure during a one-year observation period (10.06.1985 - 02.06.1986), and the dependence of the same on humidity during a three-month period (10.06.1985 - 15.09.1985).

Fig. 1 presents average spectra for different temperature ranges. The spectra have been created by plotting the fraction concentrations on a graph and connecting the respective points with a smooth curve. As spectral change at temperatures below -4°C is relatively weaker, we present an average spectrum for these temperatures, above these temperatures the intervals are 6°C.

As can be seen in Fig. 1 the rise of temperature is generally accompanied by the increase in the concentration of small air ions, whereas the mobility decreases. The form of the spectrum of negative air ions undergoes considerable changes. To clarify these conclusions Fig. 2 graphically presents the dependencies of the concentrations of n_- and n_+, average mobilities of small ions $\bar{k}_-$ and $\bar{k}_+$ and also the relative widths of the respective spectra s_- and s_+ on temperature. At first concentrations increase together with temperature and then, achieving a maximum at about 10-12°C, they start to decrease. The average mobilities are initially almost stable, later they start to decrease with temperature. The respective estimates of the coefficients of linear correlation are $r_{\bar{k}_-t}$ = -51%, $r_{\bar{k}_+t}$ = -46%. According to Fig. 2 the average mobility of air ions decreases about 14% for the growth of temperature by 10%. This can be explained only by the rise of air ion clusters in proportion with the growth of temperature. The relative width of the spectrum of negative ions grows about 10% for the rise of temperature by 10%, in the case of positive ions it is almost stable.

The statistic correlation between the relative width of the spectrum and the average mobility is similarly asymmetrical ($r_{s_-\bar{k}_-}$ = -70%), in the case of positive ions there is no correlation ($r_{s_+\bar{k}_+}$ = -4%).

A partial justification for reducing the mobilities to normal conditions with formula (1) is the fact that the right sides of the spectra on Fig. 1 coincide rather well. A similar justification was found also on the basis of the measurement of spectra of one-second air ions in natural air [4].

A comparison of the present results with the preliminary results of a three-months period of the same observation

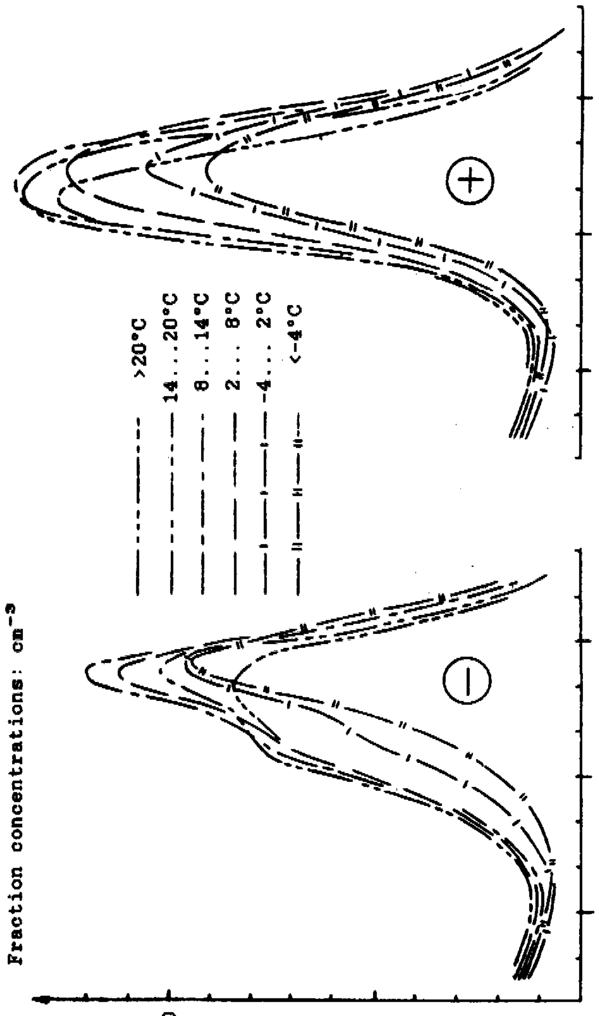

Fig. 1. Mobility spectra of air ions in different temperature ranges. Fraction boundaries are designated at the abscissa axis (10 fractions $k_{j+1}/k_j = \sqrt[3]{2}$).

series [3] shows that in summer in the temperature range of 0-30°C the reduced average mobility falls even more sharply with the growth of temperature, especially in the range of 0-15°C (see Fig. 2).

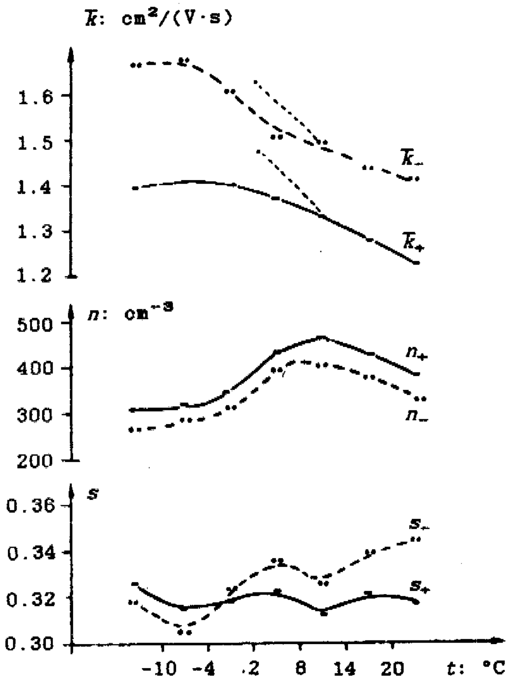

Fig. 2. The dependence of the parameters of air ion spectra on temperature. The dotted line designates the values of $\bar{k}$ in summer.

On the basis of the above material it can be concluded that air ion clusters grow in accordance with temperature. growth accelerates when temperatures above 0°C are achieved, for negative air ions it happens sooner, for positive ions later. The reasons for this phenomenon have not yet been proposed. The role of air humidity seems negligible here. The coefficients of correlation with absolute humidity for average mobilities are $r_{\bar{k}_-A} = -16\%$ and $r_{\bar{k}_+A} = -11\%$. If to eliminate the influence of temperature in linear regressions, the correlation coefficients will be positive $r_{\bar{k}_-A/t} = 0.15$, $r_{\bar{k}_+A/t} = 0.25$. The coefficients of correlation for relative humidity are also positive ($r_{\bar{k}_-R} = 0.39$, $r_{\bar{k}_+R} = 0.49$) which can easily be explained by the indirect influence of temperature.

It is likely that some kind of trace gases, the content of which in the air is correlated with temperature, may also play a role in cluster formation. Temperature, in its turn, is correlated with the intensity of solar radiation, and also with various biological processes and with the activity of man. *These factors can hypothetically be viewed as supplementary* in the change of the composition of the air. On the one hand, temperature is closely connected with the hours of the day, on the other hand, biological processes and human *activity are also correlated with the hours of the day.* It is known that the concentration of ozone and many other small components in the atmosphere have a strong daily variation which is correlated with temperature [5, 6].

During a one-year period temperature varied between 257.5 K and 296 K in 95% of the cases, i.e . ±7% in relation to the average. The variability of pressure is weaker: 985.5-1035.5 mbar, i.e. ±2.5%. The dependence of the mobility spectrum of small ions on pressure was studied with similar procedures as were applied in the case of temperature and it was found that the dependence was noticeably unmonotonous. Fig. 3 presents the dependence of the parameters of the spectra and averaged temperature on pressure.

The highest concentrations and the lowest average mobilities are located in the region of average values of pressure (about 1017 mbar). The concentration decreases and the average mobility increases almost symmetrically in accordance with the distance from the extreme. This dependence does not havw a direct physical explanation. However, during the considered one-year period there was a strong non-linear statistical dependence between pressure and temperature which can be a peculiarity of this particular period of observation. The average temperatures for the fixed pressure values are also presented in Fig. 3. It seems that the observed statistical dependence can be explained as a secondary effect due to a physical dependence of mobility on temperature and a statistical dependence of temperature on pressure.

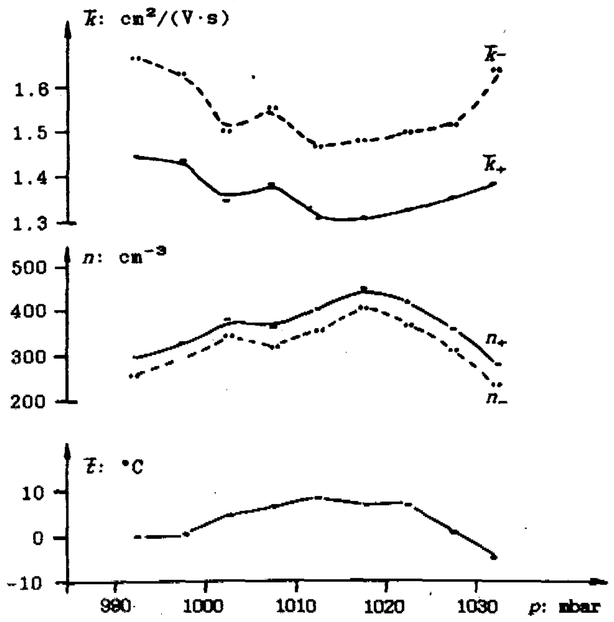

Fig. 3. The dependence of the parameters of the spectra and averaged temperature on pressure during the period of observations.

We can draw the following conclusions. The results of the observations coincide with the acknowledged statement that natural mobility of small air ions with stable structure is inversely proportional to the density of the air and the mobility reduced to normal conditions is independent of pressure and almost independent of the temperature of the air.

The spectrum of small air ions created on the basis of mobilities reduced to standard conditions is significantly dependent on the temperature of the air which can be explained by the dependence of the structure of air ions on temperature and on factors statistically dependent on temperature.

The average reduced mobility of small air ions decreases together with the rise of temperature which indicates the growth of clusters together with temperature. The dependence of the concentration of small air ions on temperature is unmonotonous with a maximum at the temperature 10-12°C.

The dependence of average reduced mobility of air ions on temperature cannot be explained by the effect of air humidity. It can be assumed that the rise of temperature leads to the growth in the concentration of some kind of trace gases in the air, and this in its turn causes the formation of larger clusters.

The quantitative dependencies of the mobility spectra on temperature are significantly different for negative and positive ions.

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