The Effect of Monochromatic Light on the Concentration of Large Ions

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Abstract

The divided electrode condenser is used to study the effect of monochromatic light of wave lengths between 4,030 and 6,610 Å (using 10 interference filters of Jena glass), on the concentration of large ions having mobilities below 10×10^{-4} cm/sec: volt/cm.

The number of ions per c.c. is measured with the aid of the characteristics obtained for each wave length, at different group mobilities, both in the presence of light (N_1) and in complete darkness (N_2). The ratio (N_1/N_2) is obtained for each filter and for the four mobility groups, i.e. 6.90×10^{-4}, 2.22×10^{-4}, 1.02×10^{-4} and 0.60×10^{-4} cm/sec. : volt/cm.

The results are discussed on the basis of statistical analysis by applying the correlation and significance tests.

Introduction

The influence of visible light on the mobility spectrum of large atmospheric ions was studied here at Giza by G. ORTNER and A. F. ELNADI (1955). They found that there is an increase in the ion concentration for ions with mobilities greater than about 2.0×10^{-4} both in daylight and in case of light from a tungsten filament lamp. On the other hand, ions with mobilities smaller than 2.0×10^{-4} show a decrease in the ion concentration.

H. ISRAËL, G. FRIES and H. DOLEZALEK (1956) in a report on "Parallelism occurring in the registration of potential gradient and general local brightness", came to the following conclusion:

"When continuously registering the atmospheric potential gradient and the air earth current on one hand and the general local brightness on the other hand, occasional parallelisms and antiparallelisms between the elements were observed.

F. VERZÁR and YVETTE KUNZ (1957) showed that in a closed air mass which has a very low nucleus count, direct sunlight produces, in a few minutes, large numbers of atmospheric condensation nuclei.

S. Williams and W. A. Morgan (Ireland) observed an increase in concentration of condensation nuclei, which are of the same size as large ions, with sunshine near the Atlantic at Valentia. A similar behaviour was found in Basel by M. Bider (POLLAK 1955). Later A. F. ELNADI (1958) at Giza, Cairo, showed that ordinary light decreases the concentration of small ions of mobilities ≥ 1.3 while it causes an increase for lower mobilities (≤ 0.045).

In this paper the influence of monochromatic light on the large ion concentration is studied.

Apparatus

The apparatus used in this investigation consisted of a cylindrical condenser composed of two concentric brass tubings. The inner electrode of 4.76 cm external diameter was divided

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into three sections insulated from each other and fixed firmly together by perspex cylinders. The lengths of the sections were 140, 20 and 20 cm respectively in the direction of air flow. The first and third sections were grounded and the second section was connected to an electrometer of the Compton type having a sensitivity of about 1,800 mm/volt. The outer electrode was 160 cm in length and 7.30 cm internal diameter, connected to a variable voltage supply of dry batteries placed inside a shielded box. The cylindrical condenser was well shielded by a third tube of 10.5 cm in diameter.

The air was drawn from a rectangular box of 240 litres volume, through a short tube of galvanised iron of 5.0 cm internal diameter, into the cylindrical condenser. The box has one of its sides (100 × 60 cm) of thin glass covered by a thick black paper.

The upper part of the box was illuminated by a tungsten filament lamp of 500 watts in a projector with glass lenses at a distance of 100 cm from the box. Monochromatic light was obtained by using interference filters of Jena glass which can be attached to the projector lenses allowing light of a certain wave length to fall on the upper part of the box.

The experiments have been carried out in a dark room (9 metres from the ground level) in the Physics Department, Faculty of Science, Cairo University at Giza.

The effective wave lengths and the corresponding frequencies are given in table 1.

Table 1

Filter number	Wave length $\lambda_{(max)}$ Å	Frequency (ν) × 10^{12} cycles/sec.
1	4,030	744
2	4,340	690
3	4,640	648
4	5,120	585
5	5,280	567
6	5,670	528
7	5,840	513
8	6,010	498
9	6,350	474
10	6,610	453

Method and mode of calculation

The divided-electrode method due to ZELENY (1900) was used as it is one of the most satisfactory methods of the blast type for the the mobility groups.

To check the apparatus, some characteristics of large ions with mobilities below 10×10^{-4} were obtained, see fig. 1. In these characteristics the groups 6.90×10^{-4}, 2.22×10^{-4}, 1.02×10^{-4} and 0.60×10^{-4} appeared clearly, in good agreement with results previously obtained by one of the authors (ELNADI 1955).

The study was made on these groups as follows:

The current in the electrometer was measured for each group while the box was completely dark, then it was subjected to monochromatic light from the projector and after a few minutes the current was again measured for each group. Finally the box was again dark and the current was measured. The interval of time between every set of observations was to assure that the effect was complete.

This was done with the ten filters and repeated six times for positive ions and four times for negative ions.

It is clear that the ratio $(C_1+C_2)/C_1 = 1.15$ is less than the ratio k/k', corresponding to two subsequent ion groups, as it must be, in order to assure a high resolving power.

As the ion concentration (N) does not remain constant throughout the series of observations, the current was measured with a standard potential at short intervals, then every reading was corrected relative to the mean of these readings if they were within reasonable limits; otherwise the whole series was repeated.

The mobility of ions was obtained from the formula:

$$K = \varphi / 4\pi V (C_1 + C_2)$$

where φ is the volume of air passing per second, V is the applied potential, C_1 is the capacity of the first section and C_2 is that of the second section.

The concentration of the ions was obtained from the formula:

$$N = E_m\,(C_2 + C_3/C_2)\,(C_1 + C_2)/\varphi e t$$

where E_m is the increase of potential of the electrometer system in time t for the applied voltage V, C_3 is the capacity of the electrometer and its connections and e is the electronic charge. It is assumed that all ions carry a single charge.

Both expressions were derived by HOGG (1939).

Results

In the characteristics of large ions obtained with the apparatus, four peaks corresponding to four groups appeared clearly, namely: k_1 ranging from 6.2 to 6.9×10^{-4}, k_2 from 2.2 to 2.4×10^{-4}, k_3 from 0.95 to 1.03×10^{-4} and k_4 from 0.60 to 0.63×10^{-4}. Two of these characteristics are shown in fig. 1 for both positive and negative ions.

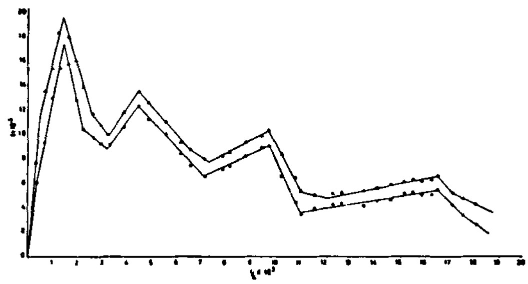

Fig. 1. Large ion characteristics for both positive and negative ions.

△ (—) ve ion
⊙ (+) ve ion

Characteristics were then obtained using monochromatic light. The four groups appeared in the same position as in the case when the box was completely dark. Fig. 2 is an example for positive ions when using monochromatic light of wave length $\lambda_{max} = 4{,}030$ Å.

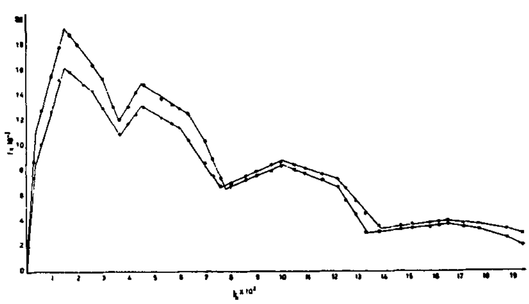

Fig. 2. Large ion characteristics for positive ions:

a) Dark box: The air sample was drawn from the covered box.
b) Box enlighted: The air sample was drawn from the box while it was exposed to monochromatic ligtht of wavelength 4030 A°.

(+) ve ion
× Dark box
⊙ Box irradiated with monochromatic light (4030 Å)

The number of ions N_1 and N_2 and also the ratio (N_1/N_2) for each group are given in table 2.

Table 2

Mobility	Ion concentration (+ *ve*)		Ratio N_1/N_2
	Box subjected to light of 4,030 Å N_1 ions/c.c.	Dark box N_2 ions/c.c.	
6.67×10^{-4}	1249	1034	1.21
2.22	965	792	1.22
1.00	543	548	0.99
0.61	323	340	0.95

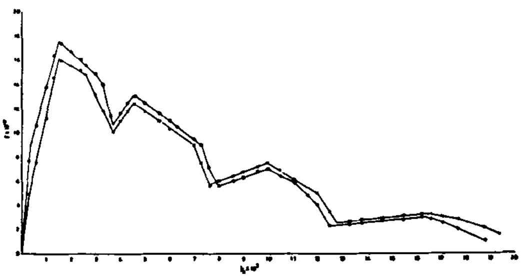

Fig. 3. Large ion characteristics for negative ions:

a) Dark box: The air sample was drawn from the covered box.
b) Box enlighted: The air sample was drawn from the box while it was exposed to monochromatic light of wavelength 6610 A°.

(—) ve ion
× Dark box
⊙ Box irratiated with monochromatic light (6610 Å)

Fig. 3 is an example for negative ions when using monochromatic light of wave length $\lambda_{max.} = 6{,}610$ Å. The number of ions N_1 and N_2 and also the ratio (N_1/N_2) for each group are given in table 3.

Table 3

Mobility	Ion concentration (— *ve*)		Ratio N_1/N_2
	Box subjected to light of 6,610 Å N_1 ions/c.c.	Dark box N_2 ions/c.c.	
6.67×10^{-4}	1,146	1,051	1.09
2.17	861	784	1.10
1.00	448	471	0.95
0.61	265	283	0.94

Table 4

Wave length λ_{max} Å	The ratio (N_1/N_2)							
	k_1		k_2		k_3		k_4	
	+ *ve*	— *ve*	+ *ve*	— *ve*	+ *ve*	— *ve*	+ *ve*	— *ve*
4,030	1.220	1.215	1.194	1.188	0.970	0.968	0.955	0.955
4,340	1.215	1.210	1.185	1.185	.966	.965	.950	.950
4,640	1.210	1.208	1.185	1.180	.965	.960	.946	.945
5,120	1.210	1.205	1.180	1.180	.960	.960	.940	.945
5,280	1.200	1.200	1.180	1.175	.960	.956	.940	.940
5,670	1.200	1.195	1.160	1.160	.970	.965	.950	.955
5,840	1.170	1.168	1.140	1.136	.970	.960	.955	.955
6,010	1.130	1.127	1.130	1.130	.980	.985	.960	.960
6,350	1.110	1.108	1.110	1.110	.985	.985	.975	.965
6,610	1.100	1.085	1.100	1.100	.990	.990	.980	.980

It appears from the above results that there is a slight increase in the ion concentration in case of the group mobilities k_1 and k_2, whereas a slight decrease in the ion concentration in case of the other two mobilities k_3 and k_4 can be observed.

When this effect was tested several times for both positive and negative ions using the ten filters, the same conclusion was reached but in different ratios. In table 4a summary is given for the observations obtained during the period from October 1957 to July 1958.

By analyzing these results statistically, the following deductions were obtained.

a) The correlation test showed a very strong connection between the wave length λ, or the frequency ν, and the ratio (N_1/N_2) for the first two groups k_1 and k_2. This can be shown clearly from the graph relating the frequency ν and the ratio (N_1/N_2) (fig. 4).

b) When applying the significance test on the ratios (N_1/N_2) obtained with 4,030 Å and those obtained with 6,610 Å, for the groups k_1 and k_2, it appeared to be highly significant. Also the ratios (N_1/N_2) obtained with 5,670 Å and those obtained with 6,610 Å were highly significant. On the other hand the ratios (N_1/N_2) obtained with 4,030 Å and those obtained with 5,670 Å were not significant.

c) In case of the other two groups k_3 and k_4, the correlation test showed a significant connection between the wave length λ, or the frequency ν, and the ratio (N_1/N_2). This is shown graphically in fig. 5 relating the frequency ν and the ratio (N_1/N_2).

d) The significance test showed, in case of the groups k_3 and k_4, that the ratios (N_1/N_2) obtained with 4,030 Å and those obtained with 5,280 Å, and also the ratios obtained with

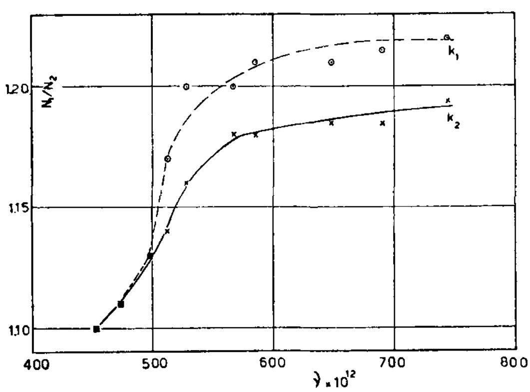

Fig. 4. The relation between N_1/N_2 and the frequency ν of the incident light for the two mobilities k_1 and k_2.

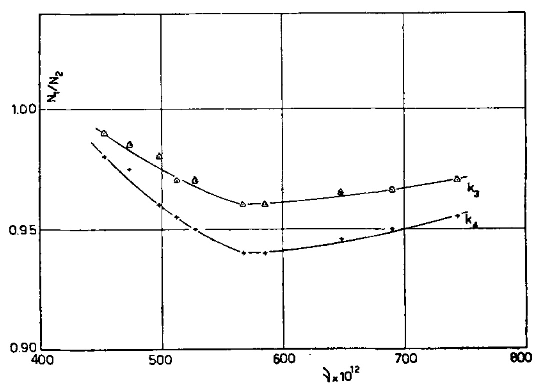

Fig. 5. The relation between N_1/N_2 and the frequency ν of the incident light for the two mobilites k_3 and k_4.

4,030 Å and those obtained with 6,610 Å, were not significant, while the ratios obtained with 5,280 Å and those obtained with 6,610 Å were almost insignificant.

The above discussions can be summarized in the following:

1. There is a slight increase in the ion concentration in the presence of monochromatic light in case of the group mobilities k_1 and k_2. This increase is more clear within the range 4,030—5,670 Å (i.e. from violet to green), and it decreases gradually from 5,670 to 6,610 Å (i.e. from green to red).

This increase in the ion concentration may be explained as due to an increase in the number of nuclei formed from the constituents of air (mainly oxygen and nitrogen) as a result of photo effect.

2. There is a slight decrease in the ion concentration in the presence of monochromatic light in case of the group mobilities k_3 and k_4. This decrease is clear in the range 4,030—5,840 Å and is less clear in the range 6,010—6,610 Å.

This decrease in the ion concentration may be due to coagulation of particles as a result of chance collisions between the nuclei, which leads to an increase in their size and hence a decrease in their concentration.

3. In general the increase in the ion concentration in case of the groups k_1 and k_2 is small, and also the decrease in the ion concentration in case of the groups k_3 and k_4 is very small, as the transmitted light from the interference filters was ≤ 57 %.

4. The ratios (N_1/N_2) obtained in case of positive ions were approximately the same as those obtained in case of negative ions but sometimes they are slightly higher.

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