ON THE CHARGING OF ALPHA-ACTIVE AEROSOLS BY SECONDARY ELECTRON EMISSION

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For radioactive aerosols, in addition to the usual mechanism of charging by capture of gas ions, there is the possibility that particles acquire charges as a result of secondary electron emission accompanying alpha- and beta-decay ([1]). Even in the case of alpha-decay the particle must become positively charged, since the number of secondary electrons may reach 10-20 ([2]). This phenomenon was first observed as early as 1910 by Ehrenhaft ([3], [4]), who showed that aerosol particles of mercury, silver, and selenium activated by radon-222 decay products or by polonium can, in a single alpha-decay, acquire a charge reaching 10 electron charges. Ehrenhaft' s work was not further developed, since it was believed that the charging mechanism under consideration in radioactive aerosols is suppressed by the capture of gas ions. However, this is true only for particles of low activity.

At the present time interest has arisen in highly active, so-called "hot," aerosol particles as a factor specifically harmful to health ([5], [6]). Simple estimates show that, for such particles, the contribution of secondary emission to the charging mechanism becomes substantial, and they should become positively charged. Study of this phenomenon will perhaps make it possible to develop selective methods for collecting highly active particles and to simplify considerably their detection and analysis.

The extensive information available in the literature on secondary electron emission concerns the surfaces of pure substances in vacuum and cannot be used in the case of an undefined chemical composition of the surface of aerosol particles in the atmosphere.

In the present work we present the results of experimental observation of charge changes on aerosol particles as a consequence of the emission of secondary electrons accompanying alpha-decay. The possibility of unipolar charging of particles is also studied.

Fig. 1. Schematic of the apparatus. 1 —aerosol generator, 2 —ion source, 3 — activation column, 4 —ultramicroscope cuvette, 5 —obturator, 6 —vacuum gauge, 7 —rheometers, 8 —air-purification filter, 9 —SI6-40 lamp.

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Fig. 2. Particle trajectories in the ultramicroscope cuvette

Figure 2: Fig. 2. Particle trajectories in the ultramicroscope cuvette

Method. The known method was used for measuring the charges and sizes of aerosol particles by photographing and analyzing their trajectories in a horizontal electric field ([7]).

The arrangement of the apparatus is shown in Fig. 1. A monodisperse aerosol of dibutyl phthalate with a concentration of 10^3-10^4 particles/cm^3 was obtained in a generator-

of a heat-exchange type, the source of ions for which was a heated platinum spiral *2*. No less than 90% of the particles had radii from 0.3 to 1.1 μ. In a glass flask *3* of 1-liter capacity the aerosol was mixed with radon-222 and activated by the products of its decay, which settled on the particles by diffusion. The average activation time did not exceed 8-10 min, in order to exclude significant accumulation in the volume and on the particles of beta-active daughter products. The aerosol and radon were introduced into flask *3* by means of the rarefaction produced in it by a vacuum pump. The radon concentration in the activation flask was 10^{-5}—10^{-6} C/liter and was measured with a scintillation detector. The alpha activity of the aerosol particles was estimated by a radiographic method.

Fig. 2. Particle trajectories in the ultramicroscope cuvette

From flask *3* the activated particles were introduced into the ultramicroscope cuvette *4*, consisting of two massive copper electrodes placed in an airtight copper casing with glass windows for illumination and observation. The distance between the electrodes was 0.252 cm, and the electric-field strength in the gap was 120 V/cm.

The light source was a spectrometric lamp with a ribbon filament, type SI6-40. The light flux illuminating the interelectrode space could be interrupted twice per second by means of a rotating shutter *5*, which made it possible to obtain the time mark necessary for calculating the charge and size of the particles from their trajectories. The shutter was switched on simultaneously with the application of voltage to the electrodes. The particle trajectories in the cuvette were observed and recorded on photographic film by means of a mirror camera.

The use, for activation of the particles, of short-lived daughter products of radon-

Figure 3 and Figure 4: charge-distribution graphs

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222 decay made it possible to exclude significant radioactive contamination of the apparatus.

Results. Figure 2a presents a typical pattern observed in the ultramicroscope cuvette in the case of particle activity up to 10^{-12} C. After the electric field was applied, the particles began to deviate toward the positive or negative electrode. Having determined, for each particle, the rate of fall and the drift velocity in the electric field, one can calculate its charge. On the particle trajectories sharp breaks toward the negative electrode are visible; we attributed these to rechargings of the particles due to the emission of secondary electrons during alpha decay.

Figure 3 presents the integral curve *1* of the distribution of charges acquired by 150 particles and the corresponding differential curve *2*. Only changes of charge greater than 3 electron charges were taken into account; however, the satisfactory agreement of the frequency of rechargings recorded by us with the alpha activity of the particles permits one to consider that the contribution of small-charge changes to the total number of rechargings is small. Therefore the actual mean value of the positive charge acquired during alpha decay by an aerosol particle is, apparently, close to that found from the curve in Fig. 3— namely, 12 electron charges.

To study the possibility of unipolar charging of the aerosol, the alpha activity of the individual particles was increased to 10^{-11} C. In this case—

in the cuvette the pattern shown in Fig. 2b was observed. It is seen that immediately after the electric field was applied all particles moved toward the negative electrode, i.e., they possessed positive charges. Figure 4 gives the integral curve 1 of the distribution of these charges for 100 particles and the corresponding differential curve 2. It is seen that

Fig. 3. Distribution of charges acquired by particles in a single alpha decay

Fig. 4. Distribution of charges on particles with an individual alpha activity of 10^{-11} C

in contrast to the charge distribution symmetric with respect to zero, characteristic of a bipolar ionic atmosphere, in the present case the distribution curve has a steep rising front in the positive region, a maximum at 9, and a slow fall all the way to 40 elementary charges.

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Note: Figure translations are in progress. See original paper for figures.