SHORTER CONTRIBUTION

On the influence of the electric field upon the processes in thunderstorms

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During the last decade the interest has been grown greatly concerning the question of the electric field influence upon elementary and electric processes in clouds, and in the first place in cumulo-nimbus ones having the largest electric fields. We can point out the works carried out in this direction by SARTOR (1954), MAGONO and KOENUMA (1958), LEVIN (1961), MAGARVEY and BLANKFORD (1962), BARTLETT, HEUVAL and MASON (1963) and MATTHEWS and MASON (1964). A good many of investigations in this direction has been carried out by Muchnik and Rudko at the Ukrainian Hydrometeorological Research Institute. A short description of these investigations is given below.

ELSTER and GEITEL (1885) were the first to touch upon the problem of the effects of an electric field on the electrification processes in clouds. They considered in particular that in the case of drop breaking in the electric field, electric charges of one sign must arise on the small droplets, whereas those of another sign must arise on the large ones. These ideas were forgotten, however, as a result of SIMPSON's criticism (1913) and in so far as we know, these problems were not dealt with till 1945, the time we began our experimental research of electrification processes in the electric field.

During the process of drops breaking (drop diameter being 5,8 mm) in a vertical air jet in the electric field, an electric charge of one sign was found to arise on large particles, whereas an electric charge of the opposite sign appeared on the water dust (apparently, large ions). In this case the value of electric charges is proportional to the electric potential gradient. The mean value of electric charges arising by drop breaking in the electric field of 200 v/cm was found to be equal to 8 e.s.u. per mass unit (MUCHNIK, 1949, 1952a, 1954). Investigation of the electrification by drop breaking in the electric field has been recently carried out (MAGONO and KOENUMA, 1958, MAGARVEY and BLANKFORD, 1962, MATTHEWS and MASON, 1964), which confirmed the results obtained.

The investigation of drop breaking by collision with metallic balls (hail model) rotating on a pivot, showed the electrification of drops and balls to be rather intensive, but dependent upon a number of circumstances, such as: the drop size, the angle and the velocity of collision between balls and drops. It has been found that the largest charges arose as a result of central collisions. As the point of collision of a drop with a ball transfers from the vertical axis of the balls, the charge value decreases, then becomes equal to zero, and further changes its sign. Within the limits of 25 m/sec one can assume the existence of a linear relationship between the electrification and the collision velocity of drops and balls. As the drops grow, electrification first increases rapidly, then becomes slower and when the diameter reaches 4 mm, it does not change its value any longer. This relationship is influenced by the velocity of collision between drops and balls. The electrification depends linearly upon the electric potential gradient. The mean value of a generated charge in the electric field with a potential gradient of 200 v/cm, when the velocity of central collision between a ball of 3 cm diameter with drops of 3 mm diameter being 10 m/sec, is 15 e.s.u. per mass unit (MUCHNIK, 1952b, 1957, 1958).

Considerable electrification can also be observed by drops tearing from melting ice balls (hail model) in the electric field in a vertical air jet. The electrification has been found to be in a linear dependence upon the electric potential gradient and if the latter is 200 v/cm the mean charge is equal to 4 e.s.u. per mass unit (MUCHNIK, 1949).

The electric field appears to influence not only upon electrification processes in liquid drop destruction but in the destruction of freezing drops as well. A series of studies showed that when freezing, the drops fall to pieces (MALKINA and ZACK, 1952, MASON and MAYBANK, 1960, MUCHNIK and RUDKO, 1961). The studies of KACHURIN and BEKRIAEV (1960) show that this process is accompanied by considerable electrification. These results have been confirmed by Muchnik and Rudko, who investigated the influence of the electric field on electrification in this process. They have found that in the electric field with a potential gradient equal to several hundreds of v/cm, the electrification increased appreciably as compared with electrification in the case when the electric field is absent.

When an ice pellet is in the electric field in the ice crystal environment, ice crystals are precipitating on its surface. This leads to a formation of crystalline ice twigs in the direction of the electric field lines (directed coagulation). The process of the hoar-frost formation on freezing water drops in the electric field as well as the breaking of the crystalline ice twigs, is accompanied by rather intensive electrification (MUCHNIK and RUDKO, 1962). The formation of hoar-frost on the surface of metal pivots in the electric field has been observed by ARABADGY (1961) and BARTLETT, HEUVAL and MASON (1963).

Examining the process of thunderstorm development one can assume that in the initial stage the main role is played by electrification mechanisms, which do not require any external electric field for their realisation. Those are, first of all, the processes of electrification of ice hydrometeors, namely; the formation of soft hail (MASON, 1953), the collision of liquid and solid particles because of their contact potential differences (IMIANITOV, 1958) and as a result of partial freezing of liquid drops on the surface of hail in the process of their collision (WORKMAN and REYNOLDS, 1948). With the thunderstorm development the above processes of the electrification of hydrometeors in the electric field begin playing an ever increasing role.

In the crystalline part of thunderclouds the electrification of ice and soft hail must be observed because of the formation of crystalline twigs on the surface of ice hydrometeors in the electric field. Directly above the freezing level functions the mechanism of electrification by collision of ice pellets and hailstones with drops. It also takes place below the freezing level, but there it must be less effective since the electric field above the freezing level as a rule is larger than that below it. Below the freezing level there is a rapid melting of hailstones and tearing of drops from their surface, which leads to the electrification in the electric field. The electrification by spontaneous breaking of large drops in the electric field seems to occur in the same place. It will be noted that according to IMIANITOV and SHIFRIN (1962) the latter of the above mentioned electrification processes is the most effective one as compared with the well-known processes of electrification without any electric field. Charges of the opposite sign arising on particles of different sizes will form the electric field when those particles are separated in the field of gravity. The electric field will increase rather rapidly as a result of high rate of hail falling and intensive electrification. However, the electric charge dissipation increases with the increase of the electric field, first of all, because of the increase of conductivity in thunderclouds (MUCHNIK, 1960). Indeed, as has been shown by IMIANITOV (1956) and FRIER (1962), the thundercloud conductivity was rather high.

Our approximate calculation leads to a conclusion that the mechanism of electrification of hydrometeors in the electric field ensures rapid accumulation of charges in thunderclouds sufficient for the formation of lightning discharges. However, our knowledge of the structure and development of thunderstorms is insufficient to create a reliable theory of thunderstorm electricity. We are firmly convinced that the creation of a theory of thunderstorm and shower is impossible without using the mechanisms of electrification and growth hydrometeors in the electric field.

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