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Electrocapillary discharge of a liquid

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The current I flowing in the steady electrocapillary discharge of saturated aqueous and alcohol solutions of sodium chloride was found to be proportional to $e^{-\alpha/V}$, where V is the applied potential and α is a constant under fixed experimental conditions.

In recent years several studies of the preparation of thin films for nuclear spectroscopy and neutron cross-section measurements by the method of electrocapillary discharge of solutions have been reported (Carswell & Milsted 1957; Gorodinski *et al.* 1959; Lauer & Verdingh 1963; Michelson & Richardson 1963). This technique is particularly attractive because the loss of solute is small (Bertolini *et al.* 1964) and thin substrates do not become overheated. Although the disintegration of liquids in electric fields has been studied (Zeleny 1935; Schultze 1961; Carson & Hendricks 1964; Taylor 1964), the mechanism by which the disintegration occurs is still not entirely understood. This makes it difficult to define the conditions for a stable discharge.

The aim of the present work was to examine the discharge cinematographically and to attempt to elucidate the principles governing the disintegration mechanism.

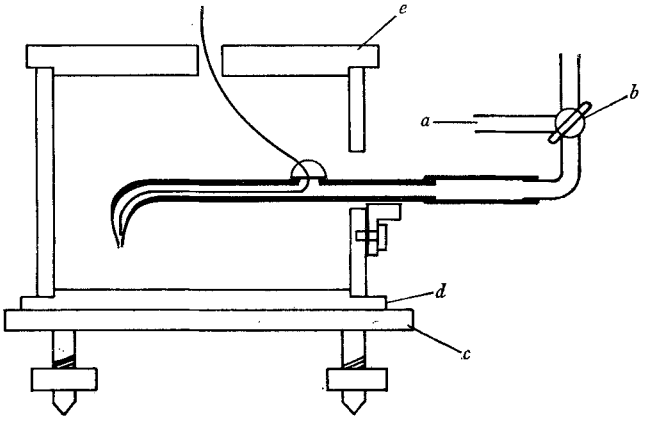

FIGURE 1. Apparatus: *a*, limb for rubber bulb; *b*, tap to pressure regulating system; *c*, base plate; *d*, metal plate holding the substrate; *e*, Perspex box.

The liquids were discharged from a pyrex tube of the form shown in figure 1. The features of discharge described by Zeleny were observed but a stable discharge could not be obtained solely through the control of the applied voltage,

and the adjustments to the hydrostatic pressure were critical. Saturated solutions of NaCl in ethyl alcohol as well as a mixture of 80 % (vol.) aqueous solutions of alcohol were used.

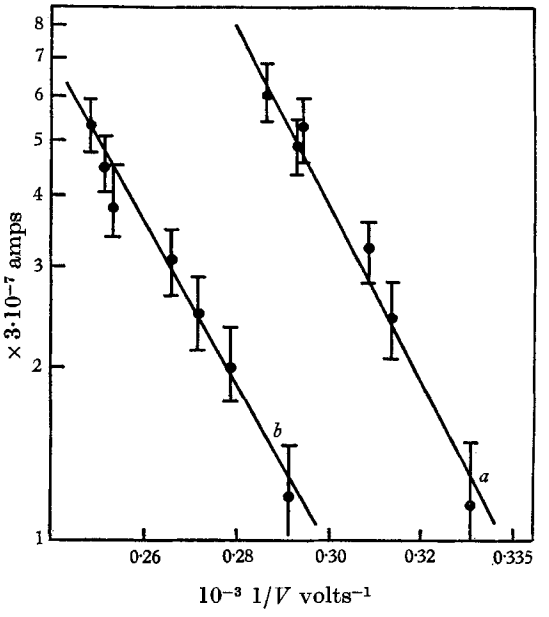

FIGURE 3. Variations of current with voltage. Curve *a*, saturated solution of NaCl in anhydrous ethyl alcohol; curve *b*, aqueous 80 % (vol.) ethyl alcohol.

Films deposited by a discharge on thin carbon backings mounted on copper grids were examined in an electron microscope and compared with films obtained by vacuum evaporation. The films deposited by the discharge consisted of uniform ($\sim$ 2000 Å diameter) randomly oriented crystals in loose contact, and the structure of the film compared favourably with that of a vacuum-evaporated layer.

From photographs, such as that shown in figure 2*b*, plate 1, of the conical drop of liquid at the tip it was possible to estimate the upper limit of the tip radius as 0·01 mm during the discharge corresponding to a field of approximately 5×10^5 V/cm. Zeleny estimated the radius of the filament from which the drops are formed as 10^{-4} cm. No spray was visible. Taylor also observed cones at the onset of the instability, but he concluded that his stability calculations could give no indications of the mechanism of the process.

The current I, voltage V relation is plotted in figure 3 and can be represented by an equation of the form

$$I = A\, e^{-\alpha/V}, \tag{1}$$

where A and α are positive constants. The similarity of this relation for the ejection of small drops to that for the emission of positive ions (Good & Müller 1956) is striking. It is interesting that the gradients of the curve do not differ very much. However, the mutual displacement of the lines shows that at the same voltage and hydrostatic pressure, the current is appreciably greater with pure alcohol than with aqueous solutions.

The form of (1) suggests a new method of approach to this problem. The significance of the parameter α can at present only be surmised.

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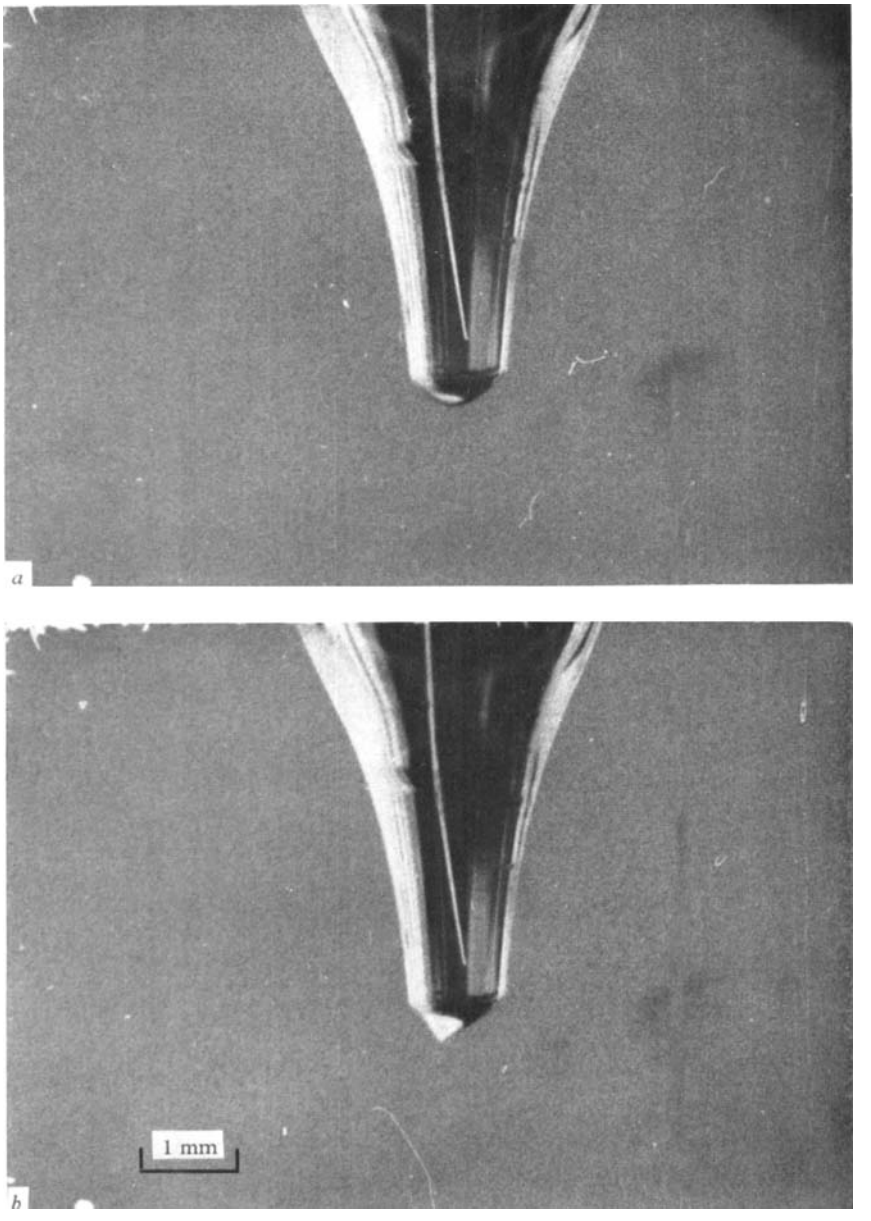

FIGURE 2. Successive frames of the tip showing the onset of the discharge. Film speed, 16 frames per second.