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A Physical Theory of Electrification

BY

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WITH TWO PLATES AND ELEVEN TEXT FIGURES

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INTRODUCTION.

The following attempt at a mechanical explanation of some of the simpler phenomena of electrification is due to the opinion that the Faraday-Maxwell theory, based, as it is, upon the assumption of two electricities capable of neutralizing each other's properties, and of attraction as the fundamental phenomenon—making repulsion a special case of attraction—has proved inadequate to explain many of the well known phenomena of static electricity, and has broken down completely in attempting to explain current electricity.

I have tried elsewhere* to show that the physical lines or tubes of force which are an essential part of this theory are incompetent to explain the phenomena for which they were invented, and are inconsistent with our experimental knowledge of facts. It is the purpose of this paper to attempt to show that the mechanical theory of electrification may be greatly simplified by starting with Franklin's theory of a single electricity** and by regarding repulsion, rather than attraction, as the fundamental phenomenon.

Since it is the purpose of this paper to present a physical, rather than a mathematical, theory of electricity, no attempt has been made to state the subject in a mathematical form. The quantitative relations of the electric field have been very satisfactorily expressed both in terms of action at a distance and in terms of lines or tubes of force. It is believed that the equations based upon the notion of lines of force will apply equally well to this presentation of the subject by merely changing the necessary plus and minus signs.

The Electrical Substance.

We have at the present time very definite experimental knowledge of a single electrical substance, divisible into very small particles which are usually associated with other small material particles to make up the ordinary chemical atoms and molecules, but which may exist in bodies in excess of the number actually combined with material particles. I

*Sanford, Phys. Rev. xxvi, 306, Apr. 1908.

**See note on The Electrical Theory of Benjamin Franklin at the end of this paper.

have ventured to call the sub-atoms with which electrons are combined the material part of the atom, as distinguished from the electrical part, because the atomic mass seems to be chiefly associated with this part, and mass is regarded as the material constant of nature.

Electrification.

Electrification was assumed by Franklin to consist of an excess or a deficiency of the electrical fluid (which he sometimes called the "electrical fire") which was assumed to exist as a common stock in the earth and all bodies connected with it. A body was positively electrified when it contained an excess, and a body was negatively electrified when it contained a deficiency of this electrical fire. Applying this definition to our present state of knowledge, we may say that a body is resinously or negatively electrified (using negatively as meaning resinously, and not as indicating a deficiency of the electrical fluid) when if put in electrical contact with the earth or with the inside of a hollow conductor on the earth it will lose electrons, and it is vitreously electrified when if placed under similar conditions it will gain electrons.

In this sense, non-electrification is a relative condition. A body may be non-electrified on the earth, when if moved to another planet it might be electrified.

Since this definition is, in a way, a departure from general usage, it may be well to give it further consideration. On the assumption of two electrical fluids it was supposed that these fluids existed in exactly equal quantities in the earth and in bodies on its surface, and that they were capable when combined of so neutralizing all each other's properties that the existence of either or both could not be detected by any known means. This notion of neutralization has been carried over into the single fluid theory, only here the atoms are regarded as essentially electropositive, just as electrons are essentially electronegative, and it has been assumed that there is just a sufficient number of electrons in the world to neutralize, that is, to render non-attractive and non-repulsive, the atoms of bodies.

This assumption seems to be based wholly on the supposed electrical neutrality of the earth as a whole. If it be possible to show that there is no necessity in electrical theory for such a neutral condition, the argument for equivalent numbers of electrons and atoms falls.

Electrification of the Earth.

If we consider the experimental arguments for or against the equivalent number of electrons and positive atoms, they seem to be universally against such assumption. Even if there were equivalent numbers of the two kinds of charged particles to begin with, there seem to be many reasons why this equivalence could not be maintained.

For example, radioactive changes are taking place on the earth, and apparently in the atmosphere. There are indications that these changes have been more important in the past than they are at the present time. In some of these changes the negative electrons are sent off at very high speeds, and it seems probable that some of them have escaped from the earth.

On the other hand, it seems probable that the earth is receiving electrons from the sun. There are evidences of extensive radioactivity, or at least of extensive dissociation of atoms, on the sun, and there are reasons for thinking that streams of electrons are being discharged from the sun to the earth. The Aurora is generally attributed to a discharge of electrons taking place toward the earth through the very highly rarefied upper atmosphere. No corresponding discharge in the opposite direction is known.

In this connection Sir Oliver Lodge* says: "The earth is in fact a target exposed to cathode rays, or rather to electrons emitted by a hot body, viz., the sun." Again: "The gradual accumulation of negative electricity by the earth is a natural consequence of this electric bombardment extending to greater distances across space, where no residual matter exists; and the fact that the torrent of particles constitutes an electric current of fair strength, gives an easy explanation of one class of magnetic storms; these storms having long been known, by the method of concomitant variations, to be connected with sun spots and aurorae."

The phenomenon of radioactivity, itself, seems to indicate that the electrical conditions on the earth have changed since the present unstable atoms were originally formed. If the atoms consist of electropositive parts combined with electrons, the characters of the groups which constitute the atoms were determined in the beginning by the relative numbers of electrons and positive sub-atoms. If this relation should change with time, certain of the original combinations would become unstable. In fact, the changes which are supposed to occur in the successive disin-

*Lodge, Electrons, p. 168.

tegration of radium, indicate that there are more alpha particles than electrons set free, even though two electrons are required to neutralize the charge of one alpha particle. Thus, in the complete disintegration series of uranium as given by Soddy,* there are seven alpha particles to four electrons set free. In several changes, only alpha particles are given off. If the atom was neutral before the alpha particle escaped it must have been negatively charged afterward, yet no less than four successive changes of this kind are shown, beginning with the parent of radium and ending with Ra-A.

Aside from the above argument, we have strong experimental proof that the earth is an electrically charged planet. It is well known that the electrical potential rises rapidly with distance above the earth. Within the range of most observations this change is very irregular, though usually in the same direction. This irregularity has been attributed to the irregular distribution of charges on clouds in the earth's atmosphere, which, in order to account for the observed rise of potential must usually be positively electrified. Observations made in the highest balloon ascensions, which are certainly above most of the positively charged clouds, still show a rise of potential which seems to tend toward a constant value. From the sixteen recorded observations on the rise of potential at heights between two and three miles which I have been able to find, the average rise is 10.7 volts per meter. The nine recorded observations above three miles give an average rise of 7.1 volts per meter. Two of these were at heights of approximately four miles, and were respectively 8.4 and 7.9 volts per meter.

These numbers are undoubtedly too small, since in none of the recorded ascensions has there been suitable provision for discharging the balloon. In ascensions to heights of four miles the total rise of potential has been approximately 200,000 volts. If the balloons have retained the electrical charge which they had on leaving the earth, they were about 200,000 volts electronegative to the surrounding air when these highest measurements were made. Since the measurements have regularly been made at a distance of only a few meters below the balloon, the error due to the charge of the balloon has evidently been considerable.

The total change of potential for a height of one mile near the surface, assuming the earth to be an electrified sphere, should be about 1/2000 of the potential of the earth. Assuming the change to be at the rate which has been observed at a height of four miles, the negative potential of the earth would be about 25,600,000 volts. This estimate

*Soddy, The Interpretation of Radium, p. 205.