PHYSICS

The Charge of the Electron

"A Classic of Science"

One of the classic researches of Dr. Robert A. Millikan, now Chairman of the Executive Council of the California Institute of Technology, was the determination of the charge on the electron, an achievement which was recognized by the Nobel prize award to him in 1923. As retiring president of the American Association for the Advancement of Science next week in Cleveland, Dr. Millikan will explain phases of his continued probing into the constitution of matter. For several years he has studied the powerful cosmic radiation which he first measured. The cover of this week's SCIENCE NEWS LETTER shows Dr. Millikan holding the latest type of cosmic ray electroscope which measures the intensity of the radiation.

A NEW MODIFICATION OF THE CLOUD METHOD OF DETERMINING THE ELEMENTARY ELECTRICAL CHARGE AND THE MOST PROBABLE VALUE OF THAT CHARGE. By Prof. R. A. Millikan. In the London, Edinburgh and Dublin Philosophical Magazine and Journal of Science. Vol. XIX, February, 1910.

AMONG all physical constants there are two which will be universally admitted to be of predominant importance; the one is the velocity of light, which now appears in many of the fundamental equations of theoretical physics, and the other is the ultimate, or elementary, electrical charge, a knowledge of which makes possible a determination of the absolute values of all atomic and molecular weights, the absolute number of molecules in a given weight of any substance, the kinetic energy of agitation of any molecule at a given temperature, and a considerable number of other important physical quantities.

While the velocity of light is now known with a precision of one part in twenty thousand, the value of the elementary electrical charge has until very recently been exceedingly uncertain. The results herewith presented seem to show that the method here used for its determination—a modification of the Thompson-Wilson cloud method—furnishes the value of e with a directness, certainty, and precision, easily comparable with that obtained by any of the methods which have thus far been used, the error in the final mean value being not more than 2 per cent. Furthermore, with the use of a chronograph in place of a stop watch for taking time intervals, the method is perhaps capable of a slightly greater accuracy than has yet been given to it.

As is well-known, H. A. Wilson's modification of Thomson's cloud method of determining e consists in observing first, the rate of fall under gravity of a cloud produced in an ionized fog-chamber by a sudden expansion, and second, the rate of fall of a like cloud when a vertical electrical field is superposed upon gravity. . .

The outstanding causes of uncertainty in Wilson's method, as used by ourselves, were as follows:

1. There is an experimental difficulty involved in obtaining clouds which fall without any distortion of the upper surface because of air currents.

2. The upper surface of a cloud falling in an electrical field is exceedingly difficult to follow on account of the scattering of the cloud which is usually produced by throwing on the field.

3. The method necessitates the assumption that it is possible to obtain in successive expansions exactly identical drops, so that r_2 and v_1 can be used as though they applied to the same drop.

4. The assumption is made that the cloud falls uniformly, and that there is no appreciable evaporation during the time of observation.

5. The assumption is made that the temperature of the air through which the cloud falls is the equilibrium temperature after condensation—a quantity obtained from theoretical considerations relating to the adiabatic expansion of saturated vapours and the experimental curve expressing the relation between the temperature and density of a saturated vapour.

The results obtained by the method herewith presented are freed from all of these sources of uncertainty. . .

Balancing Individual Charged Drops By An Electrostatic Field

My original plan for eliminating the evaporation error was to obtain, if possible, an electric field strong enough to exactly balance the force of gravity upon the cloud and by means of a sliding contact to vary the strength of this field so as to hold the cloud balanced throughout its entire life. In this way it was thought that the whole evaporation-history of the cloud might be recorded, and suitable allowances then made in the observations on the rate of fall to eliminate entirely the error due to evaporation. It was not found possible to balance the cloud as had been originally planned, but it was found possible to do something very much better; namely, to hold individual charged drops suspended by the field for periods varying from 30 to 60 seconds. I have never actually timed drops which lasted more than 45 seconds, although I have several times observed drops which in my judgment lasted considerably longer than this. The drops which it was found possible to balance by an electrical field always carried multiple charges, and the difficulty experienced in balancing such drops was less than had been anticipated.

The procedure is simply to form a cloud and throw on the field immediately thereafter. The drops which have charges of the same sign as that of the upper plate or too weak charges of the opposite sign, rapidly fall, while those which are charged with too many multiples of sign opposite to that of the upper plate are jerked up against gravity to this plate. The result is that after a lapse of 7 or 8 seconds the field of view has become quite clear save for a relatively small number of drops which have just the right ratio of charge to mass to be held suspended by the electric field. These appear as perfectly distinct bright points. I have on several occasions obtained but one single such "star" in the whole field and held it there for nearly a minute. For the most part, however, the observations recorded below were made with a considerable number of such points in view. Thin, flocculent clouds, the production of which seemed to be facilitated by keeping the water-jackets J_1 and J_2 a degree or two above the temperature of the

room, were found to be particularly favorable to observations of this kind.

Furthermore, it was found possible to so vary the mass of a drop by varying the expansion, or the charge carried by a drop by varying the ionization, that drops carrying in some cases two, in some three, in some four, in some five, and in some six, multiples could be held suspended by nearly the same field. The means of gradually varying the field which had been planned were therefore found to be unnecessary. If a given field would not hold any drops suspended it was varied by steps of 100 or 200 volts until drops were held stationary, or nearly stationary. When the P.D. was thrown off it was often possible to see different drops move down under gravity with greatly different speeds, thus showing that these drops had different masses and correspondingly different charges.

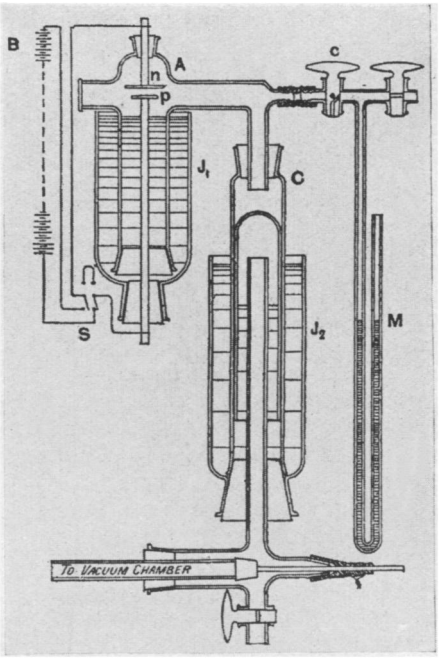
The life history of these drops is as follows. If they are a little too heavy to be held quite stationary by the field they begin to move slowly down under gravity. Since, however, they slowly evaporate, their downward motion presently ceases, and they become stationary for a considerable period of time; then the field gets the better of gravity and they move slowly upward. Toward the end of their life in the space between the plates, this upward motion becomes quite rapidly accelerated and they are drawn with considerable speed to the upper plate. This, taken in connection with the fact that their whole life between plates only 4 or 5 mm. apart is from 35 to 60 seconds, will make it obvious that during a very considerable fraction of this time their motion must be exceedingly slow. I have often held drops through a period of from 10 to 15 seconds, during which it was impossible to see that they were moving at all. Shortly after an expansion I have seen drops which at first seemed stationary, but which then began tc move slowly down in the direction of gravity, then became stationary again, then finally began to move slowly up. This is probably due to the fact that large multiply-charged drops are not in equilibrium with smaller singly-charged drops near them, and hence, instead of evaporating, actually grow for a time at the expense of their small neighbors. Be this as it may, however, it is by utilizing the experimental fact that there is a considerable period during which the drops are essentially stationary that it becomes possible to make measurements upon the rate of fall in which the error due to evaporation is wholly negligible in comparison with the other errors of the experiment. Furthermore, in making measurements of this kind the observer is just as likely to time a drop which has not quite reached its stationary point as one which has just passed through that point, so that the mean of a considerable number of observations would, even from a theoretical standpoint, be quite free from an error due to evaporation.

The observations on the rate of fall were made with a short-focus telescope T placed about two feet away from the plates. In the eyepiece of this telescope were placed three equally spaced cross-hairs, the distance between the extreme ones corresponding to about one-third of the distance between the plates. A small section of the space between the plates was illuminated by a very narrow beam from an arc-light, the heat of the arc being absorbed by three water cells in series. The air between the plates was ionized by 200 mg. of radium, of activity 20,000, placed from 3 to 10 centimetres away from the plates. A second or so after expansion the radium was removed, or screened off with a lead screen, and the field thrown on by hand by means of a double-throw switch. If drops were not found to be held suspended by the field the P. D. was changed or the expansion varied until they were so held. The cross-hairs were set near the lower plates, and as soon as a stationary drop was found somewhere above the upper cross-hair, it was watched for a few seconds to make sure that it was not moving, and then the field was thrown off and the plates short-circuited by means of the double-throw switch, so as to make sure that they retained no charge. The drop was then timed by means of an accurate stop-watch as it passed across the three cross-hairs, one of the two hands of the watch being stopped at the instant of passage across the middle cross-hair, the other at the instant of passage across the lower one. It will be seen that this method of observation furnishes a double check upon evaporation; for if the drop is stationary at first, it is not evaporating sufficiently to influence the reading of the rate of fall, and if it begins to evaporate appreciably before the reading is completed, the time required to pass through the second space should be greater than that required to pass through the first space. It will be seen from the observations which follow that this was not, in general, the case.

It is an exceedingly interesting and instructive experiment to watch one of these drops start, and stop, or even reverse its direction of motion, as the field is thrown off and on. I have often caught a drop which was just too light to remain stationary and moved it back and forth in this way four or five times between the same two cross-hairs, watching it first fall under gravity when the field was thrown off, and then rise against gravity when the field was thrown on. The accuracy and certainty with which the instants of passage of the drops across the cross-hairs can be determined is precisely the same as that obtainable in timing the passage of a star across the cross-hairs of a transit instrument. . . .

Conclusion:

1. The temperature of the fog chamber a very few seconds after expansion



ELECTRONS ISOLATED HERE

Between the plates of this apparatus, Dr. Millikan saw the minute clouds formed in ionized gas, disperse into star-like points of light which he proved to be drops carrying from two to six electrons.

in the form of apparatus shown in the figure is essentially the temperature of the room.

2. The balanced drop method herewith presented for the determination of e involves an experimental error of not more than 2 per cent., and is entirely free from all theoretical uncertainties except such as are incident to the application of Stokes' law to liquid spheres of diameters varying from 30 to 50 times the mean free path of air molecules.

3. The results obtained by this method taken in connection with Rutherford's experiments seem to constitute experimental verification of Stokes' law for these drops.

4. Positively charged drops of water and alcohol are found by direct measurement to carry charges which are multiples of 4.65×10^{-10}, and all of the multiples from 2 to 6 inclusive have been obtained.

5. The mean of the five most reliable determinations of e is 4.69×10^{-10}. The corresponding value of n (the number of molecules in 1 cubic cm. of gas at 0° C., 76 cm. pressure) is 2.76×10^{19}: that of N (the number of molecules in a gram-molecule) is 6.18×10^{23}; that of *eta* ($= 3/2 \frac{RT}{N}$, the kinetic energy of agitation in ergs of a molecule at 0° C., 76 cm. pressure) is 2.01×10^{-16}; that of m (the mass in grams of an atom of hydrogen) is 1.62×10^{-24}.

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EXPLORATION

Shippe-Johnson Expedition To Explore Peru By Air

THE Shippe-Johnson expedition to explore Peru by air is now on its way to that country. The party of young adventurers and scientists will be gone four or five months during which time they hope to rediscover from the air Peru's arid coastal plain, the heights of the Andes, and jungles at the headwaters of the Amazon.

The members of the expedition, which is financed by private capital and is endorsed by the American Geographical and Harvard Geological Societies, are George R. Johnson, 30, former New York newspaperman, once chief photographer of the Peruvian Naval Air Service, leader; Robert Shippe, 20, co-leader, second pilot, geologist and historian; Irving G. Hay, 24, erstwhile tugboat captain of New York, chief pilot; Valentine Van Keuren, 30, civil engineer, and Max Distel, 24, mechanic.

The party plans to visit all points of geologic, archaeologic and geographic interest from Lake Titicaca, 11,500 feet up among the Andean peaks at the Bolivian border, to the sparsely settled gold country of the Maranon river watershed 1,100 miles to the north. Ruins of huge Inca edifices in southern Peru, notably near Hauraz and Cuzco, and Chan-chan, crumbled capital of the Grand Chimu, near Trujillo, will be pictured from above.

El Misti, the 20,000-foot world-famous quiescent volcano, is to be aerially mapped, as well as more than two score agricultural communities of the Colca valley, long isolated in the Andes and practically unknown even to Peruvians. Pictures of bird colonies on the guano islands along the Peruvian coast and of impenetrable jungles at the source of the Amazon, will also be taken.

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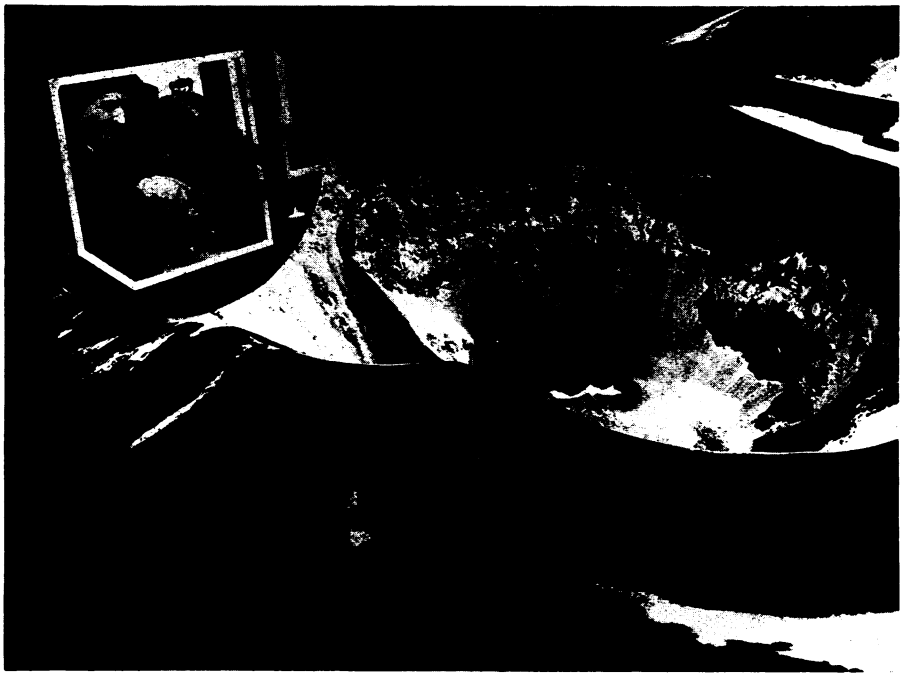

ONE GOAL OF THE AIR EXPEDITION

El Misti, 20,000-foot volcano in Peru to be mapped from air by five young explorers. Insert, George R. Johnson, 30, leader, once chief photographer for the Peruvian Naval Air Service.

CHILD CARE

Don't Let Junior Chew Paint From Toys

THE chewing of paint from toys, cribs, and woodwork constitutes a real danger to children, facts gathered by a life insurance company of New York indicate.

Chronic lead poisoning occurs much more frequently among infants and young children than has been generally supposed, the report declares, and it would be more prominent in sickness statistics but for the fact that it is often unrecognized by physicians.

The poisoning usually comes from the sucking or chewing of paint containing lead, although sometimes lead ointments on the breasts of nursing mothers are at fault.

Health officials agree that parents should recognize the danger from this source, and should prevent the paint-eating habit in infants or else select furniture and toys free of the poisonous lead.

Many of the new lacquers and enamels put on with the spray process avoid the use of lead bases, and one of the well known makers of children's toys advertises that their paints are absolutely harmless.

Perhaps the greatest danger lies in the home use of cheap paints containing a large proportion of lead.

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