XLII. *A Determination of the Charge on the Ions produced in Air by Röntgen Rays.* *By* HAROLD A. WILSON, *Fellow of Trinity College, Cambridge*[*].

THE experiments described in this paper were undertaken with the object of making a fresh determination of the charge on one ion. This charge will throughout this paper be denoted by e.

Prof. Townsend (Phil. Mag. Feb. 1898), in a paper on the "Electrical Properties of Newly Prepared Gases," has described a determination of the average charge on the droplets composing the cloud formed when newly prepared oxygen is bubbled through water. This charge was found to be about 3×10^{-10} electrostatic units of electricity. There are some reasons for supposing that each droplet contains one ion, and consequently Townsend's result may be regarded as a determination of the charge on one ion. The result which I have obtained is in very good agreement with his.

Prof. J. J. Thomson (Phil. Mag. Dec. 1898 and 1899) has given two estimates of e, the first depending on a determination of the average charge on the droplets of a cloud formed by condensation of water-vapour on the ions produced in air by Röntgen rays, and the second on a similar determination for the ions given off by a zinc plate under the action of ultra-violet light. The mean result of the first research was $e = 6{\cdot}5 \times 10^{-10}$ and of the second $e = 6{\cdot}8 \times 10^{-10}$[†].

Since from the value of e the number of molecules in a cubic centimetre of a gas can be immediately deduced, and also since the absolute value of e is of considerable interest in itself, a fresh determination by a different method appeared to be worth making.

The method I have used depends, like Prof. Thomson's, on the fact discovered by C. T. R. Wilson[‡], that the ions produced in air by Röntgen rays act as nuclei for the cloudy condensation of water-vapour when supersaturation exceeding a definite amount is produced by a sudden expansion.

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[*] Communicated by Prof. J. J. Thomson.

[†] Since this paper was written Prof. Thomson has informed me that he has lately made a fresh determination of e by his original method, but with an improved apparatus, and he has very kindly consented to my mentioning the result he has obtained, here. It is $e = 3{\cdot}8 \times 10^{-10}$, and so agrees very well with the mean result of my experiments, viz. $3{\cdot}1 \times 10^{-10}$. It appears that in his earlier experiments the cloud was formed mainly on the negative ions and not on both positive and negative ions as was supposed at the time, consequently the result obtained was nearly twice too big.

[‡] Phil. Trans. A. 1897, p. 265, and A. 1899, p. 403.

The droplets of the cloud produced presumably each contain one or more ions. Let a droplet containing one ion, and consequently having a charge e, have a mass m which can be determined by observing its rate of fall (v_1 say) in air. If now a vertical electrostatic field of strength X is applied to this droplet, there will be a vertical force on the droplet equal to $\mathrm{X}e$ due to the field, so that the total force on the droplet will be $\mathrm{X}e+mg$, where g is the acceleration due to gravity, and reckoning $\mathrm{X}e$ positive when it is in the same direction as the weight mg. Now the rate of steady motion of a sphere in a viscous fluid is proportional to the force acting on it, so that the rate of fall of the droplet will be altered by the electric field. Let it be now v_2. Then we have

$$\frac{mg}{mg+\mathrm{X}e}=\frac{v_1}{v_2}.$$

The relation between m and v_1 is given by the equation

$$m=3{\cdot}1\times10^{-9}\times v_1^{\frac{3}{2}}\,*$$

so that

$$e=3{\cdot}1\times10^{-9}\,\frac{g}{\mathrm{X}}\,(v_2-v_1)v_1^{\frac{1}{2}}.$$

Thus if X is known measurements of v_1 and v_2 are sufficient to determine e absolutely. This is the method which I have employed.

It was found that, using strong Röntgen rays, some of the droplets in the cloud had bigger charges than others. In fact there sometimes appeared to be several sets of droplets having charges nearly in the ratios 1 : 2 : 3. It appeared, therefore, that some of the droplets contained one ion, some two ions, and so on. This agrees with Prof. Thomson's observation that when the strength of the Röntgen rays was increased beyond a certain amount, the number of droplets in his clouds did not increase proportionally to the number of ions present at the moment of expansion. Prof. Thomson therefore used weak rays so that in his experiments each droplet probably only contained one ion, which is a necessary condition for the success of the method he employed.

The principal advantages of my method are that it is not necessary to estimate either the number of drops in the cloud, or the number of ions present at the moment of its formation, or to make the assumption that each droplet contains only one ion. Both these estimations involve assumptions which in practice can only be approximately true, and there is

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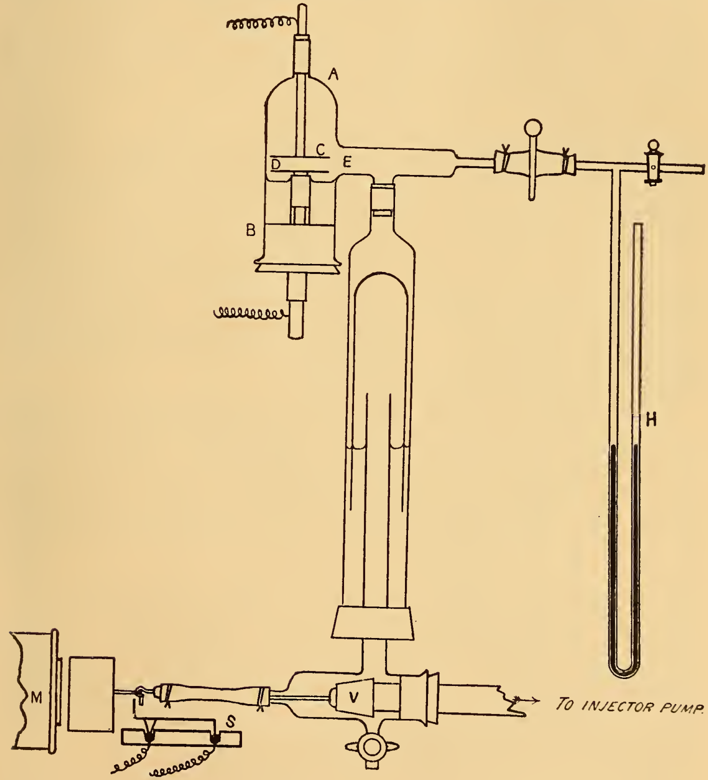
* J. J. Thomson, Phil. Mag. Dec. 1899, p. 561.

always a danger that some of the drops in the cloud contain more than one ion.

The apparatus used is shown in the accompanying diagram. It consisted of a glass tube AB about 4 cms. in diameter and 10 cms. long. Its lower end was closed by an india-rubber stopper and its upper end joined on to a short length of narrow tubing. Two circular brass disks, C and D, each 3·5 cms. in diameter, were supported one above the other in this tube as shown; the cloud on which the observations were made was formed between them, and they could be maintained at any required difference of potential up to 2000 volts by means of a battery of small secondary cells. A glass tube E was sealed on to the side of AB and served to connect the space between the disks with an apparatus for producing a sudden expansion of any desired amount. A small mercury manometer (H) was used to measure the expansion.



The expansion apparatus used was kindly lent to me by Mr. C. T. R. Wilson, and it was similar to those he has described in the papers referred to above. The apparatus was arranged so that the valve V, the opening of which produces the sudden expansion, could be pulled back suddenly by means of an electromagnet (M). This enabled the valve to be pulled away every time in exactly the same way.

The space in the tube AB below the disks was filled with water so that the air between the disks was thoroughly saturated with moisture. This air was rendered "dust free" in the usual way, by repeated expansions with intervals in between to allow the clouds formed to settle. The apparatus was then ready for a measurement of e.

A Röntgen-ray bulb was worked near AB, so that the rays passed between the disks. Then the battery circuit through the magnet was closed and a sudden expansion so produced. A cloud was thus formed between the disks, and the time which its upper surface took in falling from the upper disk to the lower disk was measured. This gave v_1 the rate of fall without an electric field. The experiment was then repeated, but immediately after the expansion the disks were connected to the battery, and so v_2, the rate of fall in an electric field, was obtained.

It was found that if the rays were kept on all the time during an experiment, then very large values for the charge on each droplet were obtained. A field of a few hundred volts per centimetre was then sufficient to cause many of the droplets to rise instead of falling. It soon became clear that the fresh ions formed after the expansion attached themselves to the droplets, so that the longer the rays were kept on after the expansion the bigger the charge on the droplets became. A switch S was therefore put in the primary circuit of the induction-coil used to excite the Röntgen bulb and arranged so that the armature of the magnet turned the switch, broke the circuit, and so stopped the rays a small fraction of a second before the expansion was produced.

The disks C and D were also connected to a commutator which first connected them together, and then on being turned connected them to the large battery used to charge them up.

A narrow beam of light was passed between the disks C and D to illuminate the cloud and enable its upper surface to be observed. The falling of the cloud was watched through a small hole on a level with the disks, and about twenty centimetres away from them in a direction nearly perpendicular to the beam of light. A second screen was put up close to the apparatus having a vertical slit in it through which only the central portion of the illuminated part of the cloud could be seen. This slit and the beam of light were each about half a centimetre wide, so that the portion of the cloud which was observed was that occupying a vertical prism half a centimetre square at the axis of the tube AB between the disks.

The disks were never more than one centimetre apart, and consequently very little circulation of the air could take place between them. When a cloud is formed by expansion in a large vessel, the walls of the vessel heat up the air near them which produces a circulation of the air upwards near the walls and downwards in the middle. If this sort of thing happened in these experiments, v_1 and v_2 would both be obtained too high ; but it was found that when the disks were not more than a centimetre apart the circulation which occurred near the glass walls of the tube did not extend to the centre, and the surface of the cloud between the disks remained plane as the cloud fell.

The disks were always connected together until the expansion had taken place, when, if it was desired to determine v_2, they were immediately connected to the battery by turning the commutator lever. If they were connected to the battery before the expansion took place no cloud was obtained because the field removed the ions as fast as they were formed.

In making a measurement of e the time of fall from the upper disk to the lower one was measured with a stop-watch, alternately with and without the electric field. v_1 and v_2 were then calculated from the mean results for the times of fall.

C. T. R. Wilson (Phil. Trans. A, 1899, p. 440) found that with an expansion of nearly 15 cms. of mercury only the negative ions acted as nuclei, but with greater expansions condensation occurred on both positive and negative ions. These results were easily verified with my apparatus. With an expansion of 15 cms. charging the upper disk negatively caused the whole cloud to fall more quickly than it fell when the disks were uncharged, while charging the upper disk positively reduced the rate of fall of the cloud. It was clear, therefore, that the droplets were negatively charged.

Also with considerably larger expansions than 15 cms. some of the droplets fell more slowly and some more quickly when the disks were charged than when they were not charged, showing that both positively and negatively charged droplets were present. However, there always seemed to be more negatively charged droplets present than positively charged ones, and unless the expansion used was nearly enough to produce a fog even in the absence of any ions, the positively charged droplets were not very easy to observe. There seemed, in fact, to be a large excess of negative ions present between the disks and not equal numbers of positive and negative ions. The explanation of this is, no doubt, to be found in the secondary radiation emitted by brass under the action of Röntgen rays. This secondary radiation has been proved to consist of negatively charged corpuscles, so that an excess of negative ions in the air near the disks might have been expected. The excess would, however, not have been expected to be as great as appeared to be the case. It is perhaps possible that when both positive and negative ions are present together, condensation takes place mainly on the negative ions, although when either kind are present alone, there is very little difference between the supersaturations required to produce condensation on the positive or negative ions.

An expansion of from 16 to 17 cms. of mercury was always used in the experiments described below, and all the results are for the charge on the negative ions.

All the droplets did not always fall at the same rate when the electric field was applied. This appeared to be nearly always the case, but was especially so when strong rays were used. There appeared to be several sets of droplets, each set falling all at the same rate. The rate of fall of the most numerous set indicated that the droplets in it had the smallest charges. The observations given below refer to this set only, the other sets will be considered later.

Since the cloud begins to evaporate soon after it is formed, it is very important to get the measurement of its rate of fall over as quickly as possible. I therefore generally only allowed it to fall about half a centimetre, and applied the electric field in the direction which increased the rate of fall. Another reason why a very small distance between the disks had to be used, was that the available P.D. was only 2000 volts, so that unless the disks were near together, the electric field between them was not strong enough to appreciably alter their rate of fall. For these various reasons nearly all the observations were made with the disks as near together as possible, because it was clear that reliable results could not otherwise be obtained. For the same reason the maximum P.D. available was used in nearly every case. It would of course have been more satisfactory if observations could have been made with a greater variety of distances between the plates, and through a larger range of P.D., but to accomplish this with the battery available was not possible.

The following table contains the results of a set of observations:—

Distance between the disks $d=0{\cdot}45$ cm.
Potential-difference used 1800 volts.

Time of Fall without P.D. $X=0$. secs.	Ditto with P.D. $X=13{\cdot}3$ E.S. units. secs.
(1) 23·6	(2) 17·8
(3) 23·3	(4) 16·9
(5) 23·9	(6) 17·0
(7) 23·8	(8) 17·2
Mean...23·65	Mean...17·22

The numbers in brackets refer to the order in which the observations were made. The above results give

$$v_1=\frac{0{\cdot}45}{23{\cdot}65}=0{\cdot}0190\,\frac{\text{cm.}}{\text{sec.}}$$

$$v_2=\frac{0{\cdot}45}{17{\cdot}22}=0{\cdot}0262\,\frac{\text{cm.}}{\text{sec.}}$$

Consequently, since

$$e=3{\cdot}1\times10^{-9}\,\frac{g}{X}\,(v_2-v_1)\,v_1^{\frac{1}{2}},$$

we have

$$e=\frac{3{\cdot}1\times10^{-9}\times981\times0{\cdot}0072\times(0{\cdot}019)^{\frac{1}{2}}}{13{\cdot}3}$$

$$=2{\cdot}3\times10^{-10}\text{ E.S. units.}$$

Also

$$m=3{\cdot}1\times10^{-9}\times v_1^{\frac{3}{2}}=8{\cdot}1\times10^{-12}\text{ gram.}$$

The method of experimenting can be varied by measuring the velocity of fall first with the field in one direction and then with the field in the opposite direction. If v_2 and v_3 are the velocities, then

$$\frac{mg+Xe}{mg-Xe}=\frac{v_2}{v_3},$$

taking v_2 to be the velocity when Xe acts in the downward direction. The mean of v_2 and v_3 gives the velocity when $X=0$.

In an experiment made in this way the following numbers were obtained:—

Distance between the disks 1·0 cm.
P.D. = 2000 volts.

Time of Fall.

	X = +6·7.		X = −6·7.
	secs.		secs.
(1)	18·4	(2)	21·6
(3)	25·7	(4)	27·1
(5)	19·4	(6)	22·4
(7)	24·2	(8)	27·8
(9)	27·0	(10)	32·6
Mean...	22·94	Mean...	26·3

These numbers give

$$v_2 = 0{\cdot}0436 \frac{\text{cm.}}{\text{sec.}}$$

$$v_3 = 0{\cdot}0380 \frac{\text{cm.}}{\text{sec.}}$$

Also

$$e = \frac{3{\cdot}1 \times 10^{-9}}{2^{\frac{3}{2}}} \frac{g}{X} (v_2 - v_3)\ (v_2 + v_3)^{\frac{1}{2}},$$

so that

$$e = 2{\cdot}6 \times 10^{-10} \text{ E.S. units.}$$

and

$$m = 3{\cdot}1 \times 10^{-9} \times \left(\frac{v_2 + v_3}{2}\right)^{\frac{3}{2}} = 2{\cdot}5 \times 10^{-11} \text{ gram.}$$

As already mentioned the cloud soon begins to evaporate after it is formed, so it is important to get the measurement of its rate of fall over as quickly as possible. It was, therefore, found most satisfactory to use the rates of fall with X = 0 and with X positive, making the rate of fall greater than when X = 0.

In making a series of measurements an observation with X positive was always made as quickly as possible after one with X = 0, in order that the strength of the rays and other conditions should be as nearly as possible the same in both cases. Although the individual observations in a series, say with X = 0, often vary a good deal, yet there is usually a corresponding variation in the observations with X positive, so that the value of *e* obtained from the mean results for the series is not necessarily affected by any error due to these variations.

The following tables contain all the other results obtained except a few done at an early stage, before the apparatus had been got to work satisfactorily, none of which are included.

$d = 0{\cdot}50$ cm.
P.D. = 2000 volts.

t_1. (X=0.) secs.	t_2. (X=+13·3.) secs.
12·2	9·6
11·1	9·3
11·4	9·3
12·0	9·2
10·6	9·6
Mean 11·4	Mean 9·4

$v_1 = 0{\cdot}0439 \quad v_2 = 0{\cdot}0530$
$m = 2{\cdot}86 \times 10^{-11}$
$e = 4{\cdot}37 \times 10^{-10}$.

$d = 0{\cdot}50$ cm.
P.D. = 2000 volts.

t_1. (X=0.) secs.	t_2. (X=+13·3.) secs.
18·3	10·8
20·3	15·6
18·2	17·6
18·0	13·8
18·4	15·4
Mean 18·64	Mean 14·64

$v_1 = 0{\cdot}0268 \quad v_2 = 0{\cdot}0341$
$m = 1{\cdot}36 \times 10^{-11}$
$e = 2{\cdot}73 \times 10^{-10}$

$d = 0{\cdot}5$ cm.
P.D. = 2000 volts.

t_1. (X=0.) secs.	t_2. (X=+13·3.) secs.
14·9	13·2
15·0	11·4
14·9	12·2
14·0	10·7
Mean 14·7	Mean 11·87

$v_1 = 0{\cdot}034 \quad v_2 = 0{\cdot}042$
$m = 1{\cdot}95 \times 10^{-11}$
$e = 3{\cdot}4 \times 10^{-10}$.

$d = 0{\cdot}55$ cm.
P.D. = 2000 volts.

t_1. (X=0.) secs.	t_2. (X=+12·1.) secs.
15·6	13·0
17·2	12·8
16·0	12·4
17·0	13·8
17·4	14·1
18·4	15·0
17·2	14·1
16·0	12·8
16·9	13·1
16·7	12·6
Mean 16·84	Mean 13·37

$v_1 = 0{\cdot}0327 \quad v_2 = 0{\cdot}0411$
$m = 1{\cdot}83 \times 10^{-11}$
$e = 3{\cdot}81 \times 10^{-10}$.

$d=0{\cdot}4$ cm.
P.D. = 2000 volts.

t_1. (X=0.) secs.	t_2. (X=+16·7.) secs.
21·5	10·1
21·9	13·0
20·9	12·0
21·0	12·0
19·4	12·0
21·6	11·6
Mean 21·05	Mean 11·80

$v_1=0{\cdot}0190$ $v_2=0{\cdot}0340$
$m=8{\cdot}1\times10^{-12}$
$e=3{\cdot}8\times10^{-10}$.

$d=0{\cdot}4$ cm.
P.D. = 2000 volts.

t_1. (X=0.) secs.	t_2. (X=+16·7.) secs.
20·0	12·0
20·4	12·0
Mean 20·2	Mean 12·0

$v_1=0{\cdot}0198$ $v_2=0{\cdot}0334$
$m=8{\cdot}64\times10^{-12}$
$e=3{\cdot}5\times10^{-10}$.

$d=0{\cdot}40$ cm.
P.D. = 2000 volts.

t_1. (X=0.) secs.	t_2. (X=+16·7.) secs.
21·0	12·4
20·4	13·2
20·6	13·0
Mean 20·7	Mean 12·9

$v_1=0{\cdot}0193$ $v_2=0{\cdot}0310$
$m=8{\cdot}3\times10^{-12}$
$e=3{\cdot}0\times10^{-10}$.

$d=+0{\cdot}40$ cm.
P.D. = +1500 volts.

t . (X=0.) secs.	t_2. (X=+12·5.) secs.
33·6	20·0
33·0	20·0
30·5	20·0
31·6	20·4
29·4	19·6
Mean 31·6	Mean 20·0

$v_1=0{\cdot}0126$ $v_2=0{\cdot}0200$
$m=4{\cdot}4\times10^{-12}$
$e=2{\cdot}04\times10^{-10}$.

$d=0{\cdot}44$ cm. P.D. = 2000 volts.

t_1. (X=0.) secs.	t_2. (X=+15·2.) secs.
21·8	15·4
22·6	18·2
23·4	16·7
23·6	17·2
	17·6
	16·4
	14·6
	14·4
	14·9
Mean...22·85	Mean...16·10

$v_1=0{\cdot}0193$ $v_2=0{\cdot}0272$ $m=8{\cdot}3\times10^{-12}$ $e=2{\cdot}3\times10^{-10}$.

The following table contains a summary of the above results:—

d.	X.	v_1.	v_2.	*m.*	*e.*
0·45	13·3	$1{\cdot}9\times10^{-2}$	$2{\cdot}62\times10^{-2}$	$8{\cdot}1\times10^{-12}$	$2{\cdot}3\times10^{-10}$
1·00	±6·7	……	4·36 ,,	25 ,,	2·6 ,,
0·50	13·3	4·39 ,,	5·3 ,,	28·6 ,,	4·4 ,,
0·50	13·3	2·68 ,,	3·41 ,,	13·6 ,,	2·7 ,,
0·50	13·3	3·4 ,,	4·2 ,,	19·5 ,,	3·4 ,,
0·55	12·1	3·27 ,,	4·11 ,,	18·3 ,,	3·8 ,,
0·40	16·7	1·9 ,,	3·4 ,,	8·1 ,,	3·8 ,,
0·40	16·7	1·93 ,,	3·1 ,,	8·3 ,,	3·0 ,,
0·40	16·7	1·98 ,,	3·34 ,,	8·6 ,,	3·5 ,,
0·40	12·5	1·26 ,,	2·00 ,,	4·4 ,,	2·0 ,,
0·44	15·2	1·93 ,,	2·72 ,,	8·3 ,,	2·3 ,,
				Mean ……	$3{\cdot}1+10^{-10}$

It will now be convenient to consider the less numerous sets of droplets which fell quicker than the principal set on which the above observations were made.

When no field was applied the whole cloud fell at the same rate and its upper surface was sharp. No sign of any separation into sets could be detected. When the field was applied the cloud fell quicker than before, but otherwise its appearance was at first the same. After a few seconds, however, the surface of the cloud began to separate into two; apparently some of the cloud falling quicker than the rest. The line of separation between the two sets was fairly sharp. Sometimes three such sets were observed.

The following numbers were obtained in one series of experiments with the disks 0·4 cm. apart:—

X=0.	X=+12·5. Principal set.	X=+12·5. Second set.	X=+12·5. First set.
secs.	secs.	secs.	secs.
33·6	20·0	15·4	11·0
33·0	20·0	15·0	10·6
30·5	20·0	14·0	10·0
31·6	20·4	...	10·8
29·4	...	...	10·4
Mean 31·62	Mean 20·1	Mean 14·8	Mean 10·56
$v_1=0{\cdot}0126$	$v_2=0{\cdot}020$	$v_3=0{\cdot}027$	$v_4=0{\cdot}038$

We might suppose that the subsidiary sets are produced by two droplets coalescing under the influence of the field, but it is easy to show by calculation, that a droplet with twice the mass and twice the charge of the others ought to have fallen in about 6 secs. in the above experiment. If we suppose that two droplets, one with a positive charge and the other with a negative charge, coalesced, which of course is a probable thing to happen, the resulting droplet with twice the mass and no charge ought to have fallen in 11·2 secs., which is very nearly the mean time (10·6 secs.) taken by the quickest set to fall. However, it is not easy to see how droplets coalescing could produce a set of drops having a sharp upper limit, for we should expect coalescence to occur from time to time during the existence of the cloud. The existence of a sharp upper surface to the set seems to show that all the droplets forming it were formed at the moment of the expansion.

Another possible explanation of these sets seems to be that when the cloud is formed some of the droplets contain more than one ion. If two ions were very near together during the expansion they might easily give rise to only one droplet. An objection to this view is that such a droplet ought to be larger than one containing a single ion. This objection, however, falls to the ground when the magnitude of the effect of the charge on the equilibrium size of the droplets is remembered, for it is known to be very small.

If we suppose that the droplets in the three sets are all of the same size, but have different charges, then it is easy to calculate these charges. The results of this calculation for the observations given above are

Principal set, charge per droplet		$2{\cdot}04 \times 10^{-10}$
Second set,	,,	$3{\cdot}94$,,
First set,	,,	$6{\cdot}94$,,

If, then, the principal set has one ion per droplet, the second has two, and the first about three.

It has been shown by Townsend (Phil. Trans. A. 1899, p. 129) that the charge on an ion produced in air by Röntgen rays or by other forms of radiation is equal to the charge on the hydrogen ion or atom in solutions. According to the result of the present experiments it consequently follows that the charge on one hydrogen atom is $3{\cdot}1 \times 10^{-10}$ E.S. unit or 10^{-20} of an electromagnetic unit. One E.M. unit of electricity deposits from a solution 0·01118 gram of silver in electrolysis, and consequently $\frac{0{\cdot}01118}{107{\cdot}11} = 1{\cdot}043 \times 10^{-4}$ gram of hydrogen. It follows that the mass of an atom of hydrogen is approximately $10^{-4} \times 10^{-20} = 10^{-24}$ of a gram. The mass of a molecule of hydrogen is therefore 2×10^{-24} of a gram, so that since the mass of one cubic centimetre of hydrogen at 0° C. and 760 mms. of mercury pressure is 9×10^{-5} gram, the number of molecules (N) in one cubic centimetre of hydrogen is $\frac{9\times10^{-5}}{2\times10^{-24}}$ or approximately $N=4\times10^{19}$.

The mean result of the present experiments, viz. $e=3{\cdot}1\times10^{-10}$ of an electrostatic unit, cannot be very far from the truth. I think that it may be considered established by these experiments that e lies between 2×10^{-10} and 4×10^{-10} E.S. unit.

The values of N which have been obtained from the kinetic theory of gases vary between rather wide limits. The value obtained depending usually on the radius assigned to a molecule of the gas under consideration. O. E. Meyer ('Kinetic Theory of Gases,' p. 333) gives the value $N=6{\cdot}1\times10^{19}$, which is based on the assumption that the average radius of a molecule of air is 10^{-8} cm. If $N=4\times10^{19}$ then the average radius of a molecule of air must be $1{\cdot}2\times10^{-8}$ cm.

A great many different lines of argument (see Meyer's 'Kinetic Theory of Gases') lead to values for the radius of a molecule or sphere of molecular action near to 10^{-8} cm., but the magnitude of this quantity certainly cannot be considered to be established except within limits not very near together. The agreement between the value of N obtained from the present experiments, and the values deduced from the kinetic theory of gases, may consequently be considered as good as could have been expected.

In conclusion I wish to say that my best thanks are due to Prof. J. J. Thomson for much valuable advice during the carrying out of these experiments in the Cavendish Laboratory.

XLIII. *The Radioactivity of Uranium.* *By* E. Rutherford, *M.A., D.Sc., Macdonald Professor of Physics, McGill University, and* F. Soddy, *M.A.* (*Oxon.*)*.

THE radioactivity of the element uranium has been examined in the light of the theory put forward by the the authors to explain the radioactivity of thorium. The constant radiating power of that element was shown to be caused by an equilibrium process, in which the decay of activity with time was balanced by the continuous production of fresh active matter at a constant rate. This explanation embraces equally well the radioactivity of uranium, although the changes that occur differ widely in degree and complexity from those that maintain the radioactivity of thorium.

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* Communicated by the Authors.