



## XV. Cathode disintegration in the discharge through gases at low pressures

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To cite this article: L. Holborn & L.W. Austin (1904) XV. Cathode disintegration in the discharge through gases at low pressures , Philosophical Magazine Series 6, 8:44, 145-157, DOI: [10.1080/14786440409463183](https://doi.org/10.1080/14786440409463183)

To link to this article: <http://dx.doi.org/10.1080/14786440409463183>



Published online: 08 Jun 2010.



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were magnetized first, so far as is known, some fifty years ago, and are not known to have been remagnetized since.

The magnets 140, 138, and 60 vary in age from five to twenty years. They too are supposed never to have been remagnetized. It would seem worth inquiry whether mere age, as apart from change of strength, may not tend to increase the pole-distance.

Experiments with a set of collimator magnets, following the same lines as those with the six mirror magnets, would have been of fully greater interest; and the combination of the results obtained for the collimator magnets alone, and for the mirror magnets alone, with results obtained by employing the collimators to deflect the mirror magnets, would have formed a promising though laborious line of research. Ordinary magnetometers, however,—except those by Messrs. Cooke of the India Office pattern—do not possess a deflexion-chamber sufficiently long to take a collimator magnet; and no opportunity of carrying out deflexion experiments on collimators has presented itself.

XV. *Cathode Disintegration in the Discharge through Gases at Low Pressures.* By L. HOLBORN and L. W. AUSTIN \*.

THE use of the disintegration of the cathode in the vacuum discharge for the production of thin metal films was first proposed by Plücker †. This proposal was later carried out by Wright ‡ and Kundt §. The first quantitative observations were made by Crookes ||, who compared the disintegration of a large number of metals by means of a rotating switch which connected alternately four cathodes in the same exhausted tube with an induction-coil. In each of the experiments, which lasted several hours, one of the cathodes was gold, which was chosen as the standard with which the disintegration of the other metals was compared. Metals with a high melting-point were used in the form of wire. The more easily melted metals, such as tin, cadmium, and lead, were in the form of thick rods surrounded by porcelain cups. In the latter cases the gold was in similar form.

\* Communicated by the Authors. See *Wiss. Abh. d. P. T. Reichsanstalt*, Band iv. Heft 1, p. 101 (1903).

† J. Plücker, *Pogg. Ann.* cv. p. 68 (1858).

‡ A. W. Wright, *Amer. Journ. of Sc. & Arts*, (3) xiii. p. 49, and xiv. p. 169 (1877).

§ A. Kundt, *Wied. Ann.* xxvii. p. 59 (1886).

|| W. Crookes, *Proc. Roy. Soc.* i. p. 88 (1891).

Crookes's results are given in the following table, the disintegration of gold being represented arbitrarily by 100.

Palladium....	108	Brass.....	52	Iridium.....	10.5
Gold.....	100	Platinum....	44	Iron.....	5.5
Silver.....	83	Copper.....	40	Aluminium..	0
Lead.....	75	Cadmium....	32	Magnesium..	0
Tin.....	57	Nickel.....	11		

Recently Granquist\* has investigated the disintegration of gold, platinum, silver, and copper. The metals were used in the form of foil in a tube 20 cm. long and 3.5 cm. in diameter, in which five cathodes could be inserted by means of ground-glass connexions. The current from a battery of small storage-cells was sent for a given length of time, one hour or less, through one cathode at a time, the potential as well as the gas-pressure being kept as constant as possible during the time of the experiment.

From these experiments Granquist drew the following conclusions:—That the loss in weight increases rapidly with decreasing pressure; below 0.6 mm. pressure gold appears to disintegrate more rapidly than the other metals, then follows platinum, and finally copper and silver. The last two metals, at any rate within the range of pressure investigated with the copper cathode, disintegrate in about the same degree. At pressures above 0.6 mm. platinum shows the greatest disintegration. If the pressure of the gas be kept constant so that the difference of potential increases with increasing current, the disintegration is nearly proportional to the square of the current strength. Platinum cathodes heated to a red heat show the same disintegration as at ordinary temperatures.

With the idea that the investigation of the disintegration of the cathode is of great importance for an understanding of the passage of electricity through gases, we have again taken up the investigation of the subject.

### 1. Arrangement of Apparatus.

The cathodes consisted of circular disks of metal, 1 cm. in diameter, hung on wires of the same metal †, and were introduced by means of ground-glass connexions into the side tubes of the 4.5 cm. wide glass tube A (fig. 1). In order to make the connexions air-tight, mercury was at first used, but was soon abandoned and pump-grease was substituted, since it was difficult to prevent small drops of mercury entering the tube in the frequent opening of it; and it was soon found that if the

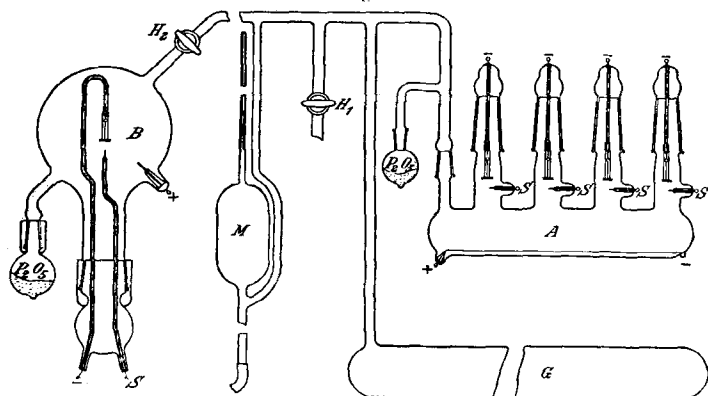
\* G. Granquist, *Öfvers. af K. Vetenskaps-Ak. Förhandl.* p. 709 (1898).

† Iron wire was used to suspend the cathodes of Sb, Bi, Zn, Sn, and Pb.

discharge struck even the smallest particle of mercury the cathodes became amalgamated\*, a phenomenon which was most marked in the case of gold.

In order to confine the disintegration to the front of the cathode, the back was covered by a disk of mica and the supporting wire was surrounded by a narrow glass tube.

Fig. 1.



A few millimetres below the cathode a platinum wire S was sealed into the tube, and the difference of potential between this and the cathode was measured with Braun electrometers, one reading to 1500 V. and the other to 10,000 V. During each series of observations, the difference of potential was kept as constant as possible by regulating the gas-pressure. As this was found to be a rather difficult matter, a glass tube G of 1 litre capacity was connected with the apparatus in order to diminish the lowering of the gas-pressure, and the accompanying increase of potential-difference which took place when the current flowed. Notwithstanding this, it was frequently necessary to admit air from the Kahlbaum pump through the cock  $H_1$  into the apparatus. With a little practice it became possible, by turning the cock more or less rapidly, to introduce the desired quantities of gas, if the pressure in the pump was kept a little higher than in the discharge apparatus. The pressure was measured in the ordinary way, by means of a MacLeod manometer M.

A 30-plate Toeppler machine furnished the current, which in most of the experiments was kept constant at  $0.6 \times 10^{-3}$  amp. It was found possible to prevent the current from varying

\* The amalgamation of Al cathodes was observed by E. Warburg (Wied. *Ann.* xxxi. p. 577, 1887).

more than 1 per cent. for hours at a time by regulating the electric motor, which was driven by the current from a storage-battery. The cathodes were connected to earth through a very sensitive milliamperemeter.

In the course of the investigation, a second spherical tube B, 12 cm. in diameter, was connected to the first. A cathode and its attendant exploring wire were placed approximately in the centre of the tube. As this tube was also frequently used for regulating the gas-pressure, it was separated from the rest of the apparatus by a cock  $H_2$ .

## 2. Observations in Tube A.

Four cathodes were situated in tube A, and the discharge was sent through one of them at a time for from 15 to 30 minutes. Before using, the cathodes were left over-night *in vacuo*. The weighings before and after the passage of the current gave the loss of weight with a certainty of 0.01 mg. In the tables the losses in weight are calculated for a uniform time of 30 minutes on the assumption that the loss is proportional to the time of passage of the current.

The cathode-fall was varied from its normal value (about 350 V.) where the negative discharge begins to cover the whole cathode, to about 2500 V. Experiments in which the potential was higher were inclined to give contradictory results, probably on account of irregularities in the discharge. These irregularities appeared to begin as soon as the negative column began to contract so that it ceased to cover the whole of the surface of the cathode. If the potential was forced still higher, so that green phosphorescence appeared on the glass, the loss of weight of the cathode decreased in a marked degree, whereas before it had steadily increased with increasing potential-difference. The metal deposits on the walls of the tubes were not removed between the series of observations. The mica disks on the backs of the cathodes, on which a deposit was also formed, were removed after each experiment.

Table I. contains the observations on different metals. Under the cathode-fall  $V$  are given the means of the readings taken every five minutes during the course of the discharge. The loss of weight  $y$  (for a time of discharge of 30 minutes and a current-strength of  $0.6 \times 10^{-3}$  amp.) are given in  $\text{mg.} \times 10^{-2}$ , the gas-pressure  $p$  in mm. Hg.

For all the metals, with the exception of gold, the loss of weight  $y$  from a certain point on increases directly as the cathode-fall  $V$  (fig. 2, p. 150). All these curves prolonged backwards cut the axis of abscissas at the point  $V=495$ . It is to be observed that the disintegration does not disappear at this point, but appears to decrease asymptotically as  $V$  approaches the normal value.

TABLE I.—Disintegration in Tube A.

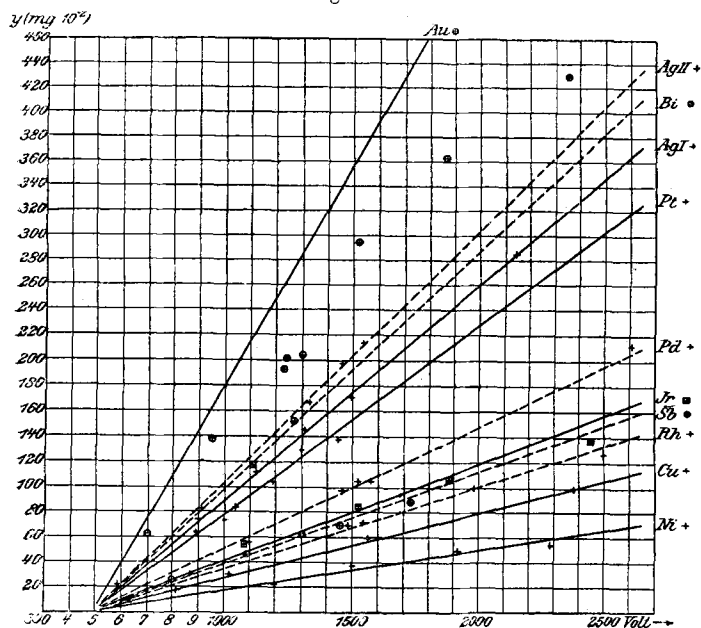
Cathode.	$p$ (mm. Hg)	$V$ (Volts)	$y$ (mg $\times 10^{-2}$ ).		$p$ (mm. Hg)	$V$ (Volts)	$y$ (mg. $\times 10^{-2}$ ).	
			Obs.	Obs. - Cal.			Obs.	Obs. - Cal.
Silver $a$ .					Bismuth.			
B 3	0.38	900	73	+2	0.27	1110	117	-2
A 1	0.28	1120	109	0	0.22	1270	152	+2
B 1	0.27	1310	145	+2	Palladium.			
B 2	0.25	1490	172	-3	0.45	870	29	-8
A 2	0.20	2140	288	0	0.39	1100	55	-4
Silver $b$ .					0.28	1460	97	+2
A 4	0.6	590	21	+2	0.27	1520	104	+2
A 7	0.40	910	82	-2	0.27	1570	104	-1
A 12	0.24	1330	167	-3	0.17	2610	214	+7
A 6	0.23	1460	198	+1	Antimony.			
A 5	0.24	1540	215	+2	0.31	800	25	+2
Platinum.					0.26	1090	46	+2
A	0.34	890	63	+3	0.22	1450	69	-2
B	0.28	1040	83	0	0.21	1730	88	-4
A	0.28	1190	104	-2	Rhodium.			
B	0.25	1300	129	+6	0.58	590	7	+1
A	0.25	1440	138	-6	0.40	1020	29	-5
Iridium.					0.28	1480	69	+5
	0.52	640	10	-1	0.27	1540	71	+3
	0.31	1080	53	+7	0.22	1980	99	+3
	0.29	1300	62	1	0.19	2500	127	-3
	0.26	1520	84	+3	Gold.			
	0.21	1880	106	-3	1.25	360	8	...
	0.18	2450	138	-16	0.48	700	62	-4
Copper.					...	950	138	-9
	...	450	2	...	0.25	1230	193	-45
	0.45	810	15	-1	0.26	1240	202	-40
	0.33	1010	27	0	0.26	1300	205	-57
	0.25	1560	58	+2	0.23	1520	296	-37
	0.19	2380	99	0	0.18	1860	365	-78
Nickel.					0.15	2350	433	-169
	0.33	1200	22	-1				
	0.26	1500	36	+3				
	0.25	1920	48	+1				
	0.23	2290	53	-6				

The values of  $y$  are calculated from the equations:—

$$\begin{aligned}
 \text{Silver } a, \quad y &= 0.175(V-495) = 0.00162A(V-495); \\
 \text{Silver } b, \quad y &= 0.204(V-495) = 0.00189A(V-495); \\
 \text{Platinum, } y &= 0.153(V-495) = \frac{1}{3}A \times 0.00157(V-495); \\
 \text{Iridium, } y &= 0.0786(V-495) = \frac{1}{4}A \times 0.00163(V-495); \\
 \text{Copper, } y &= 0.0525(V-495) = \frac{1}{3}A \times 0.00165(V-495); \\
 \text{Nickel, } y &= 0.0328(V-495) = \frac{1}{4}A \times 0.00168(V-495); \\
 \text{Bismuth, } y &= 0.193(V-495) = \frac{1}{3}A \times 0.00185(V-495); \\
 \text{Palladium, } y &= 0.0982(V-495) = \frac{1}{3}A \times 0.00184(V-495); \\
 \text{Antimony, } y &= 0.0745(V-495) = \frac{1}{4}A \times 0.00186(V-495); \\
 \text{Rhodium, } y &= 0.0646(V-495) = \frac{1}{4}A \times 0.00188(V-495); \\
 \text{Gold, } y &= 0.325(V-495) = 0.00165A(V-495).
 \end{aligned}$$

If we now determine the inclination of the different curves, the equations for which are written after the tables, it is seen that the ratios of the trigonometric tangents of the angles stand in simple relations to the ratios of the atomic weights  $A$ . It is necessary, indeed, to distinguish two groups of the metals, to the first of which belong silver, platinum, iridium, copper, and nickel; to the second, silver, bismuth, palladium, antimony, and rhodium. The members of each group disintegrate in equivalent proportions at the same potential, when for the individual metals valencies are assumed which are recognized in chemistry.

Fig. 2.



The disintegration of silver, which belongs to both groups, follows two different curves, whose ordinates stand in the ratio  $189 : 162.5 = 1.16$ . The cause of this difference has not been made clear. It can only be said that the silver cathode A (Table I.) gave first the values given under silver  $a$ , and represented by the curve Ag I, and after being in use for some time suddenly began giving the values given under silver  $b$ , and shown in curve Ag II. A fresh silver cathode B, put in the same place in the tube, gave values for  $y$  corresponding to the lower curve. The order in which the observations

were taken is indicated by the numbers in the first column in the two tables. A difference in gas-pressure for the same cathode-fall could not be discovered in the two cases.

In the two groups of metals, the loss of weight  $y$  of the cathode, due to the passage of a current of  $0.6 \times 10^{-3}$  amp. for half an hour is represented very closely by the equations

$$y = 0.00163 \frac{A}{n}(V - 495), \text{ or}$$

$$y = 0.00186 \frac{A}{n}(V - 495) \text{ mg.} \times 10^{-2}.$$

In a voltameter during the same time, the same current would deposit  $0.0112 \frac{A}{n}$  mg. according to the Faraday law, where  $\frac{A}{n}$  denotes the chemical equivalent. This quantity is disintegrated in the discharge at low pressures (tube A) at a cathode-fall of 1180 V. or 1090 V. respectively. A second effect must be assumed in addition to the Faraday law to explain the change of disintegration with the change of potential.

A similar curve has been calculated for gold as a univalent metal. The calculated values are all larger than the observed, and the difference increases with increasing cathode-fall.

Several easily oxidized metals of low melting-point were also observed. At low potentials, zinc gave fairly good results, on the assumption that it is a di-valent metal. We do not lay great stress on this, however, as the cathode was strongly oxidized as soon as the cathode-fall was increased above 1600 volts. After this experiment, the loss of weight was found to be abnormally large, and the cathode and walls of the tube were entirely covered with white oxide. The surface also showed a crystalline structure which denoted a high temperature. Cadmium, lead, and tin were also tried, but as they are still more easily oxidized the results are not taken into consideration, as we desired to investigate the disintegration under conditions as far as possible free from sublimation and ordinary oxidation. Many of the metals given in the tables were coloured on account of slight oxidation, especially after the discharge at low potentials. Even platinum showed the Priestley rings at the point opposite the exploring wire. Sometimes however, this point remained unchanged, and the rim of the cathode showed the coloured rings.

We must also mention the experiments with aluminium, iron, and steel, all of which show very little disintegration. In the case of steel we examined both a hard and a soft specimen, to see whether the hardness of the material was a cause of difference. The loss of weight in both cases was so small, however, that the difference fell within the limits of



the observation errors. The loss of weight of the aluminium cathode was only 0.01 to 0.02 mg. ( $V=800$  to  $1800$ ), while iron and steel at  $1000$  V. did not seem to disintegrate at all, and at  $2000$  V. lost 0.15 mg.

In the above-mentioned observations on gold, it appears that the amount of the disintegration is too small in comparison with the chemical equivalent, considering gold as a uni-valent metal. As gold in some other cases, as we shall see later, behaves regularly, we can suppose that possibly the irregularities are caused by the method of observation\*, or we may suppose that a portion of the atoms under certain conditions assume a larger valency.

Observations on platinum and bismuth make the last assumption probable, since a few cases occurred in which both metals, which we have assumed to be di-valent, must be treated as tri-valent if we are to make the formula agree with the observed values. For example, for  $V=800$  and  $900$ , bismuth gave the disintegration  $y=44$  and  $51$  (the tri-valent metal would give  $39$  and  $52$  as the calculated values). In the case of platinum, for  $V=1900$  the value  $y=140$  was once found (the tri-valent metal would indicate  $143$ ). If it is possible for atoms to be thrown off having different valencies, the curves calculated for the smaller valencies can only be considered an upper limit for the possible loss in weight of the cathodes.

### 3. Observations of Granquist.

We will now undertake to determine how far our hypothesis can be applied to the observations made by Granquist. These were made with comparatively strong currents; the losses of weight, however, are given only to tenths of milligrams. The difference of potential between the cathode and the tube-wall was not often more than  $1000$  V. Several observations were made at very low potential, which on account of the above mentioned grounds we do not consider. With these exceptions, we make use of practically all of his observations, and, indeed, not only those from his Tables IV. to VI. where the current was constant, but also the values in Tables I. to III. and in Table VII. where it was varied. The cathodes were in most cases thin metal sheets,  $12$  mm. long and  $4.8$  mm. broad, which hung parallel to the axis of the tube, so that both sides were subject to disintegration. It was

\* A recent observation indicates that gold which has stood under vacuum for a long time in connexion with a mercury-pump becomes amalgamated.

only in the case of platinum that cathodes of larger and smaller dimensions were used\*.

We have calculated from Granquist's values the disintegration for a time of discharge of 30 minutes and a current-strength of 20 scale-divisions =  $2.49 \times 10^{-3}$  amp., on the assumption that the disintegration was proportional to the current-strength, which assumption seems to be at least approximately true according to our own observations. We leave out of account the difference in current-density, as Granquist's Table I. shows that with increasing current-density the disintegration and potential increase in the same ratio.

TABLE II.—Observations of Granquist.

i.	$p$ (mm. Hg.)	$V$ (Volts)	$y_1(\text{mg.} \times 10^{-1}).$		i.	$p$ (mm. Hg.)	$V$ (Volts)	$y_1(\text{mg.} \times 10^{-1}).$	
			Obs.	Obs. — Cal.				Obs.	Obs. — Cal.
Gold.					Platinum.				
20	0.23	1050	80	— 3	* 20	0.38	1300	55	0
19	0.20	950	74	+ 3	* 20	0.38	1075	43	+1
20	0.27	865	48.5	—12	20	0.38	825	30	+2
30	0.39	825	51	— 5	* 20	0.38	600	15	0
30	0.39	725	45	+ 1					
20	0.39	625	34	+ 1	30	0.54	945	37	+2
20	0.39	625	32.5	0	25	0.54	920	32	—1
20	0.39	620	32.5	0	20	0.54	835	20	—8
20	0.55	605	19.5	—10	15	0.54	645	17	0
Silver.					35	0.95	630	20	+4
20	0.13	1050	44	—1	35	0.95	625	18.5	+2
20	0.21	755	20.5	—5	25	0.95	580	13	0
20	0.23	700	19	—4	23	0.95	515	12	+2
20.5	0.31	625	14	—4					
Copper.					20.5	0.17	1330	63	+6
15	0.20	1410	19	—1	19	0.20	1265	48	—5
28	0.31	1130	16	+1	21	0.23	985	46	+9
28	0.47	1150	3	—2	21	0.38	835	30	+2
10	0.47	590	7	+2	20	0.54	835	20	—8
28	1.01	525		0	23	0.95	580	13	0
					23	0.95	515	12	+2

The values of  $y_1$  are calculated from the equations:—

Gold,  $y_1 = 0.118(V - 350) = 0.00060A(V - 350)$ ;  
Silver,  $y_1 = 0.0648(V - 350) = 0.00060A(V - 350)$ ;  
Copper,  $y_1 = 0.0191(V - 350) = \frac{1}{2}A \times 0.00060(V - 350)$ ;  
Platinum,  $y_1 = 0.0584(V - 350) = \frac{1}{2}A \times 0.00060(V - 350)$ .

\* The observations when the cathodes had other dimensions are marked with an asterisk.

In this way we obtain Table II., in which  $i$  represents the current-strength in scale-divisions,  $V$  the difference of potential between the cathode and the neighbouring tube-wall, and  $y$  the loss in weight of the cathode for a current of 20 scale-divisions  $2.46 \times 10^{-3}$  amp. flowing for 30 minutes. The observed values of  $y$  are compared with values calculated on the assumption that the loss of weight of different metals is proportional to their chemical equivalents. With the exception of a few large deviations where the observed values are too small, the differences (observed—calculated) fall within the limits of the errors of observation.

The values for  $y$  lie in a straight line which cuts the axis of abscissas at the point  $V=350$ . The value 0.00060, which when multiplied by the chemical equivalent gives the trigonometric tangent of the angle between the axis of abscissas and the given line, would correspond to 0.00146 for a current-strength of  $0.6 \times 10^{-3}$  amp. and 0.01 mg. as the unit of weight. From these observations it is impossible to discover any direct influence of gas-pressure on the disintegration.

#### 4. Observations in Tube B.

The fall of potential at the cathode depends not only on the gas-pressure and the current-density, but also on the situation of the cathode. A cathode surrounded by a narrow tube shows in general a higher cathode-fall for the same pressure and current-density than one in a wider tube. We have attempted to discover how these conditions affect the disintegration by observations on platinum, gold, and silver in tube B (fig. 1).

Table III. contains the results for platinum, silver, and gold. In the case of platinum the cathodes B and C were of the form already described, while D was of similar form but of twice the diameter. This difference in size made no appreciable difference in the disintegration. As in the former experiments, the current-strength was  $0.6 \times 10^{-3}$  amp., with the exception of the two cases marked with an asterisk, where the observed loss of weight was doubled since the current-strength was only  $0.3 \times 10^{-3}$  amp. The table shows that for platinum the loss of weight is the same as in tube A.

Gold and silver behave differently. The loss of weight, indeed, would be represented graphically by straight lines, which when extrapolated cut the axis of abscissas at the point  $V=610$  and rise much more steeply than in the former cases. For the same potential, the equivalent losses of weight stand in the relation  $300:267=1.12$ , which is the same ratio as exists between the two groups of silver observations.

As the tables show, the silver cathode had already begun to give the higher values in tube A before it was used in tube B.

TABLE III.—Disintegration in Tube B.

Cathode.	$p$ (mm. Hg)	V (Volts)	$y(\text{mg.} \times 10^{-2}).$		Cathode.	$p$ (mm. Hg)	V (Volts)	$y(\text{mg.} \times 10^{-2}).$	
			Obs.	Obs. - Cal.				Obs.	Obs. - Cal.
Platinum.					Silver.				
B	1.25	360	1		A 11	0.25	970	115	-2
B	1.10	400	3		A 10	0.23	1120	168	+3
B	0.48	600	31		A 8	0.15	1390	255	+2
B	0.29	960	70	- 1	A 9	0.14	1530	296	-2
D	...	1200	104	- 4					
C	...	1200	122	+14					
B	0.11	1540	156	- 4					
D	0.05	1850	211	+ 4					
C	...	2210	252*	-10					
D	0.03	2220	267	+ 3	...	0.20	1000	210	+4
C	...	2360	280*	- 5	...	0.19	1040	223	-3
					...	0.12	1270	345	-3
					Gold.				

The values of  $y$  are calculated from the equations:—

$$\begin{aligned} \text{Platinum, } y &= 0.153(V - 495) = \frac{1}{2}A \times 0.00157(V - 495); \\ \text{Silver, } y &= 0.324(V - 610) = 0.00300A(V - 610); \\ \text{Gold, } y &= 0.527(V - 610) = 0.00267A(V - 610). \end{aligned}$$

### 5. Disintegration in Hydrogen.

Observations were also made in hydrogen. Two cathodes of each metal were used, one which had been before used in air and one fresh one. No difference in the behaviour of the two was observed. In order to be able to disintegrate more cathodes at one filling of the apparatus with hydrogen, a second tube of the form A was added. The hydrogen was produced electrolytically and freed from oxygen by passing it through an alkaline pyrogallol solution.

Before each series of observations the whole apparatus was several times pumped out and partially filled with hydrogen. Notwithstanding this, it is hardly to be assumed that the tube contained only pure hydrogen, especially as it was not possible to heat the apparatus during the pumping. Small quantities of oxygen undoubtedly adhered to the walls and to the cathodes, and were set free when the discharge passed. At high potentials, when the cathode becomes heated, oxygen must be certainly given off, especially in the cases of the more easily oxidized metals. Nevertheless, the deposits of

TABLE IV.—Disintegration in Hydrogen.

$P$ (mg. Hg).	V (Volts).	$y$ (mg. $\times 10^{-2}$ ).	$P$ (mm. Hg).	V (Volts).	$y$ (mg. $\times 10^{-2}$ ).
Gold.			Copper.		
0.55	1020	112	0.55	1250	31
0.53	1060	144	0.54	1420	57
0.41	1330	126	0.39	1790	52
0.44	1520	142	0.41	2070	68
...	1780	178			
0.36	1800	191			
Silver.			Nickel.		
0.56	1130	121	0.57	1220	20
0.53	1300	119	0.44	1670	23
0.50	1410	95	0.45	1810	22
0.42	1470	124	0.40	1930	8
0.44	1660	143			
0.42	1680	142			
Platinum.			Iridium.		
0.53	1280	54	0.53	1100	18
0.45	1430	82	0.39	1660	19
0.39	1890	83	0.36	1700	15
0.37	1930	92	0.36	2000	18
...	2090	74			
Palladium.			Rhodium.		
0.52	1110	38	0.46	1140	16
0.46	1350	48	0.39	1590	19
0.39	1720	51	0.36	1770	13
0.36	1840	47	0.36	1960	9
0.37	1930	86			
0.30	2200	82			

gold, silver, copper, and nickel on the tube-walls now appeared in the colours of the pure metals without oxide. In the case of the platinum metals the deposit was in part black, especially in the cases of iridium and rhodium. But it is quite possible that these metals in a finely divided condition would give this colour.

On the assumption that the disintegration in air is caused by oxidation\*, it seems quite possible to suppose that the somewhat irregular disintegration in hydrogen, which is

\* The discovery of E. Goldstein (*Ber. d. Deutsch. Chem. Ges.* xxxvi. p. 3042, 1903) that the oxygen is practically all transformed into ozone during the discharge, is of interest in this connexion.

considerably smaller than in air, is produced by the traces of oxygen remaining.

The observations in Table IV. show no regular increase of loss of weight with increasing cathode-fall. In several cases a limit seemed to be reached at a comparatively low potential, beyond which there is no increase in disintegration. The loss in weight of silver and nickel, which is approximately constant, agrees fairly with Faraday's law, while iridium and rhodium disintegrate much less.

Physikalisch-Technische Reichsanstalt,  
February 1904.

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XVI. *Conduction of Electricity through High Vacua, under the influence of Radioactive Substances.* By HON. R. J. STRUTT, *Fellow of Trinity College, Cambridge*\*.

IT is a matter of no great difficulty to detect the negative charge carried by the  $\beta$  rays of radium; but all attempts to observe directly the positive charge carried by the  $\alpha$  rays have hitherto been unsuccessful. I have recently made some experiments on the subject, which have satisfied me that even in high vacua there is a loss of electricity from a charged body, in presence of the  $\alpha$  rays, independent of traces of residual gas. This effect necessarily defeats any attempt to detect the charge of the  $\alpha$  rays.

A rod of bismuth made active by a deposit of "radio-tellurium" was used. This emitted  $\alpha$  rays only, and thus any complication due to the negative charge of the  $\beta$  rays was avoided. A further advantage was the absence of any gaseous emanation. The rod was attached to an electroscope, and the whole arrangement hung up by an insulating support, in a vessel which could be exhausted very much after the manner described in a former paper (Phil. Mag. Nov. 1903)†. By means of an iron wire, movable by an external magnet, the insulated system could be charged up when desired. The position of the leaf was read by a microscope, as usual. The apparatus was connected to a Töpler pump, a manometer, and a Röntgen focus-tube, which latter served to show when a really good vacuum had been attained.

The system was charged, and the rate of loss of the charge measured at various pressures. At pressures of from 300 mm.

\* Communicated by the Author.

† Some experimenters have experienced difficulty in projecting that apparatus on the screen owing to radiometer effects. I have not found this, using a limelight, and a thick alum cell to absorb heat.