

THE ABSORPTION OF HYDROGEN BY METAL FILMS.

BY WALTER HEALD.

IT is known that under certain conditions a number of the metals absorb gas. Some, such as silver and gold, are capable when in a molten state of absorbing it from the air, as is the case with other liquids, this gas being given up again when the metal solidifies. Palladium absorbs very large quantities of hydrogen even when in the solid state. For instance, if a piece of palladium is used as the negative pole in the electrolysis of a dilute solution of sulphuric acid, it takes up about nine hundred times its own volume of hydrogen.

Skinner¹ has found that most of the metals give off hydrogen when used as cathode in a discharge tube, which shows that in their natural condition the metals contain a certain amount of absorbed hydrogen.

In the present investigation, while trying to determine the quantity of gas that a given amount of metal evolved when vaporized by a large electric current in an atmosphere of hydrogen, it was noticed that after the vaporization took place, the gas pressure gradually decreased. This could not be accounted for by a decrease in temperature, which could last only a short time, because the pressure continued to decrease in some cases for an hour or more. Before the electric current had passed the gas pressure was noted as constant. After it had been broken, apparently the only change that had taken place in the tube was that a metal film had been deposited on the walls of the tube. Therefore, the conclusion is drawn that the newly deposited metal gradually absorbed hydrogen from the molecular state.

In the case of its absorption by a palladium cathode during electrolysis of a dilute solution of sulphuric acid, the hydrogen is in a nascent state. Such may also be the case when it is absorbed

¹PHYS. REV., vol. 21, no. 1, July, 1905.

by hot metals, the temperature at least aiding dissociation. If, then, hydrogen, which is in the molecular state is absorbed by a cold metal film, it seems most likely that the metal in this condition dissociates the hydrogen, though possibly it has a strong affinity for and absorbs the hydrogen molecule. At any rate it is interesting to learn something concerning the absorption of hydrogen by films of different metals produced in the above manner.

The purpose of this investigation was therefore to obtain deposits of a number of different metals in a tube containing hydrogen, and to measure the amount and rate with which each absorbed the gas. The deposits were produced as indicated by vaporizing the metal in a discharge tube by means of a large electric current and allowing it to condense on the walls of the containing tube. It was hoped that the quantity of the active metal might also be determined but this proved too small to measure.

APPARATUS AND METHOD OF EXPERIMENT.

The form of discharge tube used is shown by diagram in Fig. 1.

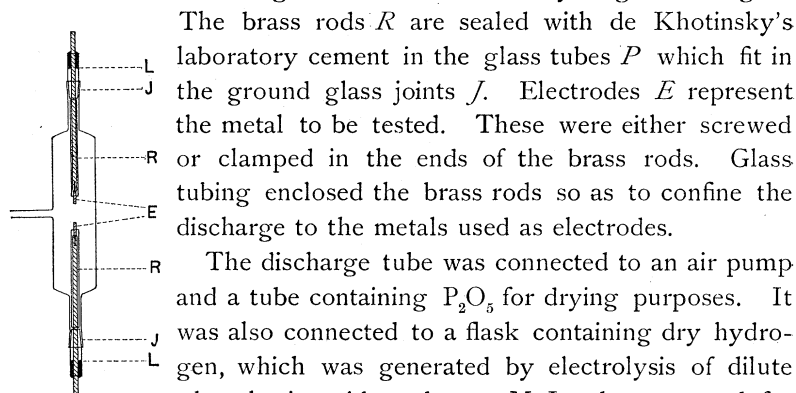


Fig. 1.

The discharge tube was connected to an air pump and a tube containing P_2O_5 for drying purposes. It was also connected to a flask containing dry hydrogen, which was generated by electrolysis of dilute phosphoric acid, and to a McLeod gage used for measuring pressure. This gage magnified the pressure one hundred times.

After exhausting the discharge tube it was allowed to stand in connection with the P_2O_5 tube several hours before admitting hydrogen.

The current used for vaporizing the metal was supplied by a battery of small accumulators. Usually a potential difference of about a thousand volts was employed, the amount of current being regu-

lated by placing a copper fuse wire in the circuit. The current passed until this melted, which took from about a half second to two or three seconds. Most of the time the fuse wire used was No. 32 *B* and *S* gage. In some cases a No. 36 wire was placed in parallel with it.

The discharge tube was filled with hydrogen to a pressure of from one to six millimeters and through this the vaporizing current was passed. The volume of the chamber occupied by the gas was about five hundred cubic centimeters.

With most of the metals there was considerable difficulty in obtaining a sufficient deposit to give appreciable results. Two methods for vaporizing the metal were tried. The first was to use two pieces as electrodes, these being placed about an inch apart. The second was to connect the two brass rods *R* with a wire of the metal to be tested; then to melt it by sending an electric current through it, so that the arc, arising when the connection was broken by fusion, vaporized part of it. The first method proving the more satisfactory was the one used most of the time. Following is given an account of metals tested and results obtained.

CADMIUM.

Cadmium was tested first because of its having a comparatively low boiling point, hence would vaporize easily. With a cadmium disk serving as cathode and a steel disk as anode, the metal film seemed to come wholly from the cathode, since the deposit formed only on the walls of the tube near the cathode. Besides, the surface of the cathode alone should erosion. The same was true with other metals. Therefore it is assumed that the deposit in all cases was of the same material as the cathode.

Three deposits of cadmium were produced each accompanied by some absorption of gas. In the case where it was heaviest the following results were obtained.

Time deposit was made 2:10 P. M.

Time, P. M.	Pressure, mm.
2-10-30	1.365
2-15-30	1.340
2-25-30	1.330

After this the pressure remained constant.

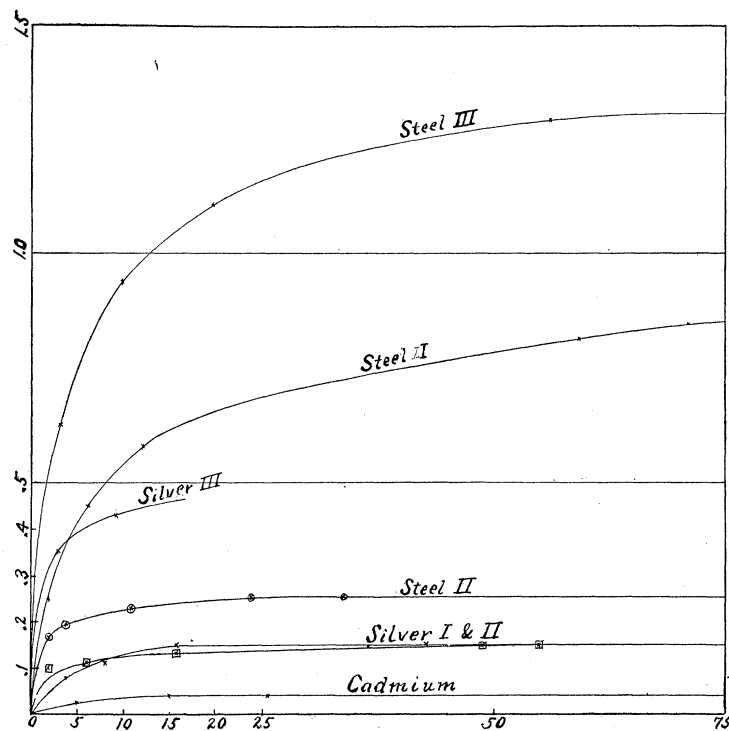


Fig. 2.

The absorption curve plotted from these results is found in Fig. 2 in which the ordinates represent the decrease in gas pressure.

STEEL.

Both methods were tried for a depositing of steel. By the first, with disk electrodes, the following results were obtained :

1. A fairly heavy deposit over a length of three or four centimeters of the tube :

Time deposit was made 10-13-30 A. M.

Time, A. M.	Pressure, mm.
10-14	4.48
10-16	4.23
10-20	4.03
10-26	3.90
11-13	3.67
11-25	3.638
11-58	3.629
P. M.	
2:30	3.628

2. Only a very light deposit :

Time of deposit 8:58 A. M.

Time, A. M.	Pressure, mm.
8-58-10	2.61
9-00	2.44
9-02	2.42
9-09	2.38
9-22	2.355
9-32	2.36

3. The deposit was heavier than either of the other two :

Time of deposit 9:35 A. M.

Time, A. M.	Pressure, mm.
9-35-10	5.626
9-38	5.0
9-45	4.687
9-55	4.515
10-37	4.336
11-37	4.285
P. M.	
1-38	4.302

The absorption curves plotted from these results are also in Fig.

2. Obviously the difference in the curves arises from the quantity of metal deposited.

Using the second method, there was only one case in which any appreciable deposit was obtained, and then not only was the steel wire vaporized but also part of the ends of the brass rods and some of the solder used to hold the clamps ; hence results are not given.

SILVER.

A silver disk was used as cathode, a steel disk as anode. Only slight deposits were obtained, except in case 3 in which it was fairly heavy. Following are the results :

1. Time of deposit 9-8 A. M.

Time, A. M.	Pressure, mm.
9-8-10	2.162
9-12	2.08
9-16	2.05
9-24	2.01
9-45	2.015
9-51	2.01

2. Time of deposit 10-35-30 A. M.

Time, A. M.	Pressure, mm.
10-35-40	2.09
10-37-30	1.987
10-41-30	1.976
10-51-30	1.954
11-24-30	1.94
11-35	1.942

3. Time of deposit 11-40 A. M.

Time, A. M.	Pressure, mm.
11-40-5	2.74
11-43	2.39
11-49	2.308

See Fig. 2 for absorption curves plotted from these results.

ZINC.

When making experiments with zinc the first method only was used with electrodes of zinc wire. The results seemed to be rather inconsistent. Part of the time there was apparently a slight increase of pressure and part of the time a slight decrease after the zinc film had been deposited. The effect, however, was in each case small enough to be accounted for by error in reading the pressure.

ALUMINIUM.

Several attempts were made to obtain deposits of aluminium, using pieces of wire for both anode and cathode. In two cases a slight one was obtained. There was very little if any decrease in pressure with time. There was, however, quite a decrease arising from the momentary current. In the first case this was .42 mm. and in the second .17 mm. It is probable therefore that all absorption took place within five seconds after the deposit was made.

PLATINUM.

Using small platinum wires as electrodes, slight deposits were obtained. As with aluminium there seemed to be no decrease in pressure after the deposition took place, but quite a large decrease during the passage of the current. In one instance this amounted to .53 mm. Since it is known that platinum absorbs large quantities of hydrogen, and very rapidly under certain conditions, it may

be that with the platinum film as with the aluminium, the gas was absorbed at such a rapid rate as to fully charge the metal before the pressure could be read.

Of the metals studied, cadmium, silver and steel gave definite results as to the rate of absorption of hydrogen by the films ; aluminium and platinum merely indicate that marked absorption occurs on depositing ; while zinc is the only metal tested which did not exhibit this quality.

I wish to express here my appreciation and thanks to Dr. Skinner for his help and inspiration to me in this work, as well as for the laboratory facilities placed at my disposal at the University of Nebraska where the work was done.

BUREAU OF STANDARDS,
WASHINGTON, D. C.