Philosophical Magazine Series 5

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/tphm16>

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Published online: 08 May 2009.

To cite this article: William Ramsay F.R.S. (1894) XXII. The passage of hydrogen through a palladium septum, and the pressure which it produces , Philosophical Magazine Series 5, 38:231, 206-218, DOI: [10.1080/14786449408620622](https://doi.org/10.1080/14786449408620622)

To link to this article: <http://dx.doi.org/10.1080/14786449408620622>

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and the components of the force on the pole itself at any time t are found by multiplying these expressions by the strength of the pole, *i. e.* by $f(t)$, and putting $x=\xi(t)$, $y=\eta(t)$, $z=\zeta(t)$ after the differentiations have been performed.

In particular, if the pole moves along a straight line perpendicular to the plate, and we take this line as axis of z , the force on the moving pole itself

$$=f(t) \times \left\{ \frac{f(t)}{\{2\zeta(t)\}^2} - 2R \int_{-\infty}^t \frac{f(\tau) d\tau}{\{\zeta(t) + \zeta(\tau) + R(t-\tau)\}^3} \right\}. \quad (23)$$

The well-known case in which a pole is suddenly generated at the time $t=0$, and its strength remains constant and equal to m after that time, is deduced by making

$$f(t)=0 \quad \text{from } t=-\infty \text{ to } t=0,$$

$$f(t)=m \quad \text{from } t=0 \text{ to } t=+\infty.$$

We therefore have to write m for $f(t)$ in the above expressions and to reduce the inferior limit of integration with respect to τ from $-\infty$ to 0 .

The advantage of starting with a fixed instead of a moving pole is more evident in the case of a cylindrical or spherical sheet, especially in the latter, since we are thus enabled to use zonal spherical harmonics only and the analysis is consequently much simplified.

XXII. *The Passage of Hydrogen through a Palladium Septum, and the Pressure which it produces.* By WILLIAM RAMSAY, F.R.S.*

IT has been frequently cited as an argument in favour of attributing the osmotic pressure exercised by a substance in dilute solution on the walls of a vessel permeable to the solvent but not to the dissolved substance, that if a vessel were constructed of palladium, which, as Graham's researches showed, is permeable to hydrogen, but not to many other gases, such a vessel would be subjected on its interior walls to a high pressure if it were filled with an indifferent gas and exposed on its exterior to an atmosphere of hydrogen. The gas confined in the vessel, not being able to escape, would exert the pressure at which it was allowed to enter; while

* Communicated by the Physical Society: read May 25, 1894.

the interior of the vessel would be a vacuum to hydrogen ; and as its walls are permeable to hydrogen, pressure should rise by passage of hydrogen into the interior, until the pressure of the hydrogen on the interior walls became equal to that on the exterior walls. The effect of this would be to superadd the pressure of the hydrogen to that of the gas originally contained in the vessel ; and if it be supposed that the vessel was originally filled at atmospheric pressure, the entry of hydrogen should increase that pressure by another atmosphere, providing the hydrogen surrounding the exterior walls of the vessel be at atmospheric pressure.

It has been suggested that when pressure is raised by the passage of water into the interior of a cell with semipermeable walls containing a solution, the rise of pressure is due, not to the pressure exercised by the molecules of the dissolved substance, but to that produced by the entering water. Gases present us with an exact analogy. It is idle to inquire what causes the rise of pressure in the interior of such a palladium "cell." The total pressure is due to the hydrogen and to the gas with which the cell was originally filled ; the original pressure has undoubtedly been increased by the entry of hydrogen. But a portion of the pressure—and the effective portion, from the point of view of osmotic pressure—is due to the original gas, whether nitrogen, carbon dioxide, or any gas whatever to which the cell-walls are impervious, and which is not chemically attacked by hydrogen. It is therefore quite correct to ascribe osmotic pressure to the dissolved substance, although it is apparently produced by entry of solvent.

The experiments to be described were made with the object of submitting this entry of hydrogen through the walls of a palladium cell to quantitative study. After considerable progress had been made, a paper by A. Biltz (*Zeitschr. f. phys. Chem.* ix. p. 152) was published, describing lecture-experiments devised to show the ordinary diffusion of gases without a septum, diffusion with a leaky septum of porous earthenware, and also diffusion with a semipermeable septum, permitting the passage of hydrogen, but hindering the passage of other gases. Biltz employed for the last-mentioned purpose an iron tube, and made a few rough quantitative measurements ; but he does not appear to have continued any experiment long enough to obtain a maximum pressure, nor was his apparatus designed with the object of quantitative measurement, but only for the purpose of class demon-

Description of Apparatus.

The apparatus which was employed is represented in the accompanying woodcut.

AB is a tube of platinum, the top portion of which, at A, is of palladium and closed at its upper end. At B the platinum tube is sealed or cemented on to a glass tube C, with a lateral branch, represented in the figure as drawn off and closed. Somewhat lower down, the tube is sealed to a capillary D, on which graduations are etched. The tube then widens to a bulb, and is finally connected by thick flexible tubing to a reservoir of mercury E.

The palladium tube is surrounded by a glass tube F, also provided with a lateral exit at G, and fitting tightly into a jacket H, which may be heated by boiling the liquid in the bulb I. A gas, passed in at F, would thus surround the palladium tube and escape at G; or if heavier than air, if introduced at G it would escape at F. The palladium cell could be heated to any desired temperature by choosing an appropriate jacketing vapour. The whole apparatus stood in front of a glass mirror-scale, on which the level of the mercury at D and E could be read off. It was possible to read to one tenth of a millimetre, but such accuracy of reading was generally unnecessary.

Description of an Experiment.

A clip was placed on the india-rubber tube joining D and E, and the side-tube C, which at this time was open, was connected with a reservoir of some gas, *e. g.* of nitrogen, by means of a three-way tap. The palladium tube was pumped empty, and then filled with dry nitrogen; the operation was repeated ten times, so as to ensure absence of air. The nitrogen was finally allowed to enter the apparatus under slight pressure, and the side-tube C was sealed. The liquid in I was then boiled so as to jacket the tubes F and A, and

the clip on the india-rubber tube was opened. When the temperature had become constant, the reservoir of mercury E was brought approximately to a level with a mark on the capillary tube D, and the capillary tube at C was broken. Gas then escaped through C until the pressure in the tube A became equal to that of the atmosphere. The capillary point was again sealed. An accurate reading was then taken, the mercury reservoir being placed so that an exact volume of gas was contained in the palladium cell under a known pressure.

Hydrogen carefully purified by washing with potassium permanganate, silver nitrate, and caustic potash, and dried by passage through sulphuric acid and over phosphorus pent-oxide, was then passed in through the tube F, escaping at G. Pressure rapidly rose in the interior of the apparatus, and was measured by raising the mercury reservoir. When it had attained its maximum a reading was taken, the position of the mercury in the capillary stem being so adjusted that the capacity of the cell was accurately the same as at the commencement of the experiments. The difference between the initial and final pressure is due to entry of hydrogen.

The success of such experiments depends on the condition of the palladium. After having been used once or twice the interior of the palladium tube became coated with mercury, even although the level of mercury (which was cold) lay far below the palladium top. It appears that palladium absorbs mercury-vapour with avidity, thus rendering the palladium cell a partial vacuum to mercury-vapour. Vapour rises from the cold mercury to restore pressure, and is again absorbed. It was therefore necessary to heat the palladium tube after each experiment in order to expel mercury. This had the effect of oxidizing the palladium and of covering it with a brownish-black film. To remove the oxide, the tube was made the negative pole of a battery, and dilute sulphuric acid was electrolysed, both on the inside and outside of the palladium tube. It was then dried at a low temperature; the external surface was polished with a little dry emery; the tube was cemented into its place, and was ready for a fresh experiment. Without such precautions the passage of hydrogen is very slow and incomplete. It should be mentioned that before commencing an experiment it was necessary to jacket the palladium tube at 220° and to pass a current of air over it for some time. In this way the combined hydrogen was removed; hydrogen escaped from the exterior of the tube and was replaced by air or some other gas in the interior.

Phil. Mag. S. 5. Vol. 38. No. 231. Aug. 1894. P

Account of Experiments.

The experiments admit of classification under five heads:—

1. Experiments with the tube filled with air.
2. Experiments with the tube filled with nitrogen.
3. Experiments in which the hydrogen passed over the exterior of the tube was diluted with nitrogen or other gases, when it exercised only a partial pressure on the exterior walls of the tube.
4. Experiments in which the palladium tube was filled with other gases.
5. Experiments with a nickel tube and carbon monoxide.

Experiment 1.—The tube was filled with air and jacketed with bromonaphthalene, boiling at about 280° . The barometric pressure during the experiment was constant at 743.1 millim. On passing hydrogen for three hours the pressure in the palladium cell had become constant; the rise of pressure was 573 millim.

Water appeared on the surface of the mercury in the capillary tube, showing that the hydrogen had combined with the oxygen of the air. The rise of pressure measured should therefore have been that of the nitrogen remaining in the cell, viz. 585 millim.

It may be concluded, then, that hydrogen combines with oxygen in presence of palladium at 280° , and that the residual nitrogen exerts nearly its partial pressure; or, as will be afterwards shown to be a more correct statement, the nitrogen exerts its full partial pressure, and the hydrogen in the interior exerts a large fraction of the pressure of the external hydrogen.

Experiment 2.—The tube was filled with pure dry nitrogen, and exposed to hydrogen, as before, at the same temperature. The pressure, after it had become fairly steady, was 703.2 millim. in excess of that of the atmosphere (748.1 millim.). The hydrogen was next removed by passing a current of air over the exterior of the tube, and the pressure was again raised by a current of hydrogen. After about three-quarters of an hour the pressure was 699.8 millim. in excess of that of the atmosphere, a quarter of an hour later it was 721.1 millim., and in another quarter of an hour it had risen to 733.0 millim. It appeared then to be stationary. The barometric pressure was still 748.1 millim.; it therefore appears that the pressures of the hydrogen on the exterior and interior of the palladium tube were nearly equal.

It was noticed during these experiments that when the gas was changed the pressure invariably fell a little on admitting hydrogen and rose a little on admitting oxygen; the direction

of the pressure then changed, and the usual rise with hydrogen and fall with air occurred. I think that this is to be attributed to the fact that the palladium vessel increases its capacity suddenly on exposure to hydrogen, and decreases it on exposure to air after having been exposed to hydrogen. But the total change of volume is a very minute one; it is noticeable only by the rise or fall of the mercury in the capillary tube to the amount of one or two millimetres; and the total change of volume is certainly less than 0.1 per cent. of the capacity of the vessel.

Experiments 3, 4, and 5.—The next three experiments gave readings much lower than those previously obtained. The barometric reading was 748.6 millim. The rise in experiment 3 was 650.3 millim.; in experiment 4, 654.2 millim.; and in experiment 5, 657.8 millim.

This led me to suspect that the palladium tube had undergone alteration. It was therefore disconnected and cleaned as before described. It was finally filled with nitrogen.

Experiments 6, 7, 8, 9, and 10.—The barometric pressure was 770.2 millim. The final pressure in experiment 6 was 698.5; in 7, 692.1; in 8, the barometric pressure being 768.8 millim., the final pressure was 686.4 millim. In experiment 9, with a barometer-reading of 762.2 millim., the reading was 692.4 millim.; and in 10, the barometer-reading being 759.2, the pressure was 688.4 millim.

To summarize these results it is necessary to compare the pressure of the internal hydrogen with that of the external hydrogen. The following table gives their ratios:—

Experiment.	(1)	(2)	(3)	(4)	(5)
Ratio	0.9400	0.9798	0.8687	0.8739	0.8780
Experiment.	(6)	(7)	(8)	(9)	(10)
Ratio	0.9069	0.8986	0.8928	0.9084	0.9067

These results do not exhibit any great degree of constancy, but I am sure that their difference depends largely, if not wholly, on the state of the surface of the palladium. The mean result is 0.9053, a number closely approximating to the last five determinations. This would lead to the conclusion that the pressure of the internal hydrogen rises to rather more than $\frac{9}{10}$ of the pressure of the external hydrogen at 280°.

Experiment 11.—The temperature was now kept at the boiling-point of quinoline (about 237°). The passage of hydrogen through palladium is so slow at this temperature that

patience failed me to make more than one determination. It was begun on May 4th. On May 10th pressure was still rising, but very slowly. On May 11th it had reached 501·7 millim.; on the 13th it was 525·2 millim., and on the 14th 531·2 millim. Taking the figure actually read, the fractional pressure (barometer = 766·3 millim.) was 0·6932. Judging from this experiment, the pressure would appear to depend on the temperature of the palladium and of the hydrogen. Still, it is possible that had the experiment been carried on sufficiently far, the pressure might have risen much higher.

Experiment 12.—The next set of experiments was made at a higher temperature—that of the boiling-point of dibenzylketone (335°). The pressure registered at a barometric height of 758·7 millim. was 681·6 millim. The ratio is 0·8984, practically identical with that obtained at the boiling-point of bromonaphthalene.

Experiments 13, 14, and 15.—The hydrogen in these experiments was mixed with 50 per cent. of nitrogen, so that the exterior of the palladium tube was exposed to a partial pressure of hydrogen. The first of this set gave a pressure of hydrogen of 367·9 millim., the barometer standing at 770·9 millim.; the second, 352·9 millim., barometer at 771·8 millim.; and the third 362·7 millim. at the same pressure.

Experiment 16 was made with a mixture of one volume of hydrogen to three of nitrogen; the read pressure was 176·7 millim., the barometric height being 756·5 millim.

The ratios are:—

Experiment.	13	14	15	
Ratio	0·4771	0·4573	0·4700.	Mean 0·4681.

Experiment 16 : Ratio 0·2336.

Multiplying the first mean ratio by 2, and the second by 4, the products are comparable with that from pure hydrogen. The figures are:—

Pure hydrogen	0·9053
Hydrogen + 50 p. c. nitrogen . . .	0·9362
Hydrogen + 75 p. c. nitrogen . . .	0·9344

The pressure, as might have been anticipated, is proportional to the partial pressure of the external hydrogen.

It is obviously possible to test the percentage of hydrogen in coal-gas by this means, provided the other constituents of coal-gas are unable to pass through palladium. An experiment with marsh-gas showed that it is not capable of permeating palladium; and the vapour of ether is also unable to pass.

Experiments 17 and 18.—At 280° the pressures with a sample of London coal-gas were 364.4 millim., at a barometric pressure of 760.4 millim.; and 361.8 millim. at a barometric pressure of 761.5 millim. The ratios are 0.4792 and 0.4751 respectively. Supposing the highest attainable ratio to be 0.9053, as deduced from the ten experiments with pure hydrogen, the percentage of hydrogen is easily found by the ratios $(0.4792 \times 100)/0.9053$, and $(0.4751 \times 100)/0.9053$. The numbers are 52.94 and 52.49 per cent. respectively. It would be possible thus to have a continuous register of the percentage amount of hydrogen in coal-gas, provided the palladium did not alter its state. As it is, I am afraid that the apparatus will not retain its activity for a sufficiently long time. It should also be remarked that it is necessary to wash the coal-gas with a solution of potassium permanganate, in order to free it from sulphur compounds. If this precaution is not taken, the palladium becomes coated with a layer of sulphide, and it ceases to be permeable to hydrogen.

Experiments were next made in which the palladium tube contained various gases.

Experiment 19.—The tube contained carbon dioxide. On exposing it to hydrogen at 280° the pressure rose with great rapidity—much more rapidly than had previously been observed. The rise ceased at 735 millim., the barometric pressure being 764.0. The quotient is 0.9621, a higher number than any yet obtained.

Experiment 20.—Carbon monoxide was in the interior; the pressure rose rapidly on admission of hydrogen to 734.5 millim., the barometer reading 769.5. The quotient is 0.9545, also a very high number. In both of these experiments the fall on passing air over the exterior of the tube was much slower than the rise with hydrogen. The end point was difficult to note, for the last change of pressure was very slow. It may be that the exterior surface of the palladium being exposed to hydrogen alone, little difficulty was experienced in molecules entering; but that on reversing the action, the contact of hydrogen with the interior walls was interfered with by the indifferent gas present. The same phenomenon had previously been noticed, but in a minor degree. It is noteworthy that no trace of water was formed in either case. Hydrogenized palladium is without action on carbon monoxide or dioxide at 280° .

Experiment 21.—The tube was filled with cyanogen. The total pressure was 741 millim., the barometer standing at 764.5 millim. The quotient is 0.9693, a very high number. On substituting air, the cyanogen exerted finally a pressure of

740 millim. This would appear to indicate that palladium is quite impermeable to cyanogen, and is not attacked by it at 280°.

Experiment 22.—Nitric oxide was introduced into the tube, at a barometric pressure (corrected) of 765 millim. On passing hydrogen the pressure rose 368 millim.; the total pressure of the gases in the tube was $368 + 763 = 1131$ millim., the barometric height being 763 millim. The increase of pressure was therefore $1131 - 765 = 366$ millim. Supposing that the nitric oxide had reacted with the hydrogen, forming nitrogen and water, thus :—

the pressure of the nitric oxide would have been halved, and would have amounted to $765/2 = 382.5$ millim. But it is to be supposed that the resulting water would have exerted its usual vapour-pressure; and as its temperature was 22°, the pressure of the water-vapour would be 18.5 millim.

We have thus :—

				millim.
Pressure of $\text{H}_2 + \text{N}_2 + \text{H}_2\text{O}$ vapour .	368	+	763	= 1131
Pressure of $\text{N}_2 + \text{H}_2\text{O}$ vapour . .	382.5	+	18.5	= 401

Hence pressure of hydrogen alone = 730

and the quotient $730/765 = 0.9543$, a number almost identical with those previously obtained.

Experiment 23.—A similar experiment was made with nitrous oxide. Here, too, reduction occurs at 280°; but the volume of the residual nitrogen is equal to that of the nitrous oxide.

The initial pressure of the nitrous oxide was 772 millim. After passing hydrogen, the total pressure was 1489.5 millim. The difference, 717.5 millim., is to be ascribed to hydrogen and water-vapour. The barometer stood at 761 millim. Deducting 18.5 millim., the pressure of water-vapour at 22°, the pressure of the hydrogen alone is 699 millim. And the quotient $699.0/761 = 0.9186$.

The hydrogen was then removed by a current of air on the external surface of the palladium. The pressure of the nitrogen was then 780.5 millim. Again restoring hydrogen on the exterior, the pressure rose to 727.5 millim., the barometric pressure being 761 millim. The pressure ascribable to hydrogen and water-vapour is thus 708 millim.; subtracting the pressure of water-vapour, 22.5 millim., the remainder, 685.5 millim., is due to hydrogen. The quotient is 0.9008. Here again a reasonable correspondence is found.

It is evident that in all cases the pressure of the hydrogen in the interior of the palladium tube is lower than the barometric pressure, *i. e.* lower than the pressure of the hydrogen on the exterior. It will be convenient here to tabulate the ratios found :—

<i>a.</i> Mean ratio from hydrogen and nitrogen at 280° .	0.9053
<i>b.</i> Ratio at 335°	0.8984
<i>c.</i> Ratio with 50 per cent. of hydrogen at 335° . .	0.9362
<i>d.</i> Ratio with 25 per cent. of hydrogen at 335° . .	0.9344
<i>e.</i> Ratio from hydrogen and carbon dioxide at 280° .	0.9621
<i>f.</i> Ratio from hydrogen and carbon monoxide at 280° .	0.9545
<i>g.</i> Ratio from hydrogen and cyanogen at 280° . .	0.9693

I omit the two last determinations, as uncertainty was introduced owing to the presence of water-vapour.

On reviewing these results, it would appear that the ratio is not altered by rise of temperature above 280°. The same number was obtained at 280° and at 335°. But at a lower temperature the ratio is much smaller, if, indeed, the end-point was really reached. Dilution of the hydrogen appears to raise the ratio; and the presence of carbon dioxide, carbon monoxide, or cyanogen in the interior of the palladium tube appears to be favourable to the passage of hydrogen.

To what are these results to be ascribed?

Troost and Hautefeuille have determined the pressures of dissociation of the definite hydride of palladium, Pd_2H (*Compt. rend.* lxxviii. p. 686). At 130° the pressure is nearly equal to that of the atmosphere, it is 624 millim.; while at 140° the pressure is 812 millim. It rises rapidly with temperature, and at the highest temperature given, 170°, it amounts to the large number 1840 millim. It is impossible to believe, then, that any hydride of palladium should exist even at the lowest of the temperatures employed, 223°. Yet palladium becomes quickly permeable to hydrogen only at a higher temperature.

Two questions require answer :—(1) Why is palladium permeable to hydrogen? and (2) Why is the pressure of the internal hydrogen always less than that of the external hydrogen?

(1) It is hardly probable that the palladium acts simply as a filter, allowing small molecules of hydrogen to pass while blocking the passage of larger molecules of other gases. Graham, however, appears to regard this as in some measure the cause of the passage. His words are :—“ Such phenomena of gaseous penetration appear to suggest a progression in the degree of porosity. There appear to be (1) pores through which gases pass under pressure or by capillary transpiration, as in

dry wood and many minerals ; (2) pores through which gases do not pass under pressure, but pass by their proper molecular movement of diffusion as in artificial graphite ; and (3) pores through which gases pass neither by capillary transpiration nor by their proper diffusive movement, but only after liquefaction, such as the pores of wrought metals and the finest pores of graphite."

It is noteworthy that Graham considers that gases are liquefied in the pores of metals. But in the experiments here described this can hardly be the case. For at 270° and at higher temperatures hydrides of palladium do not exist, as is conclusively shown by Troost and Hautefeuille ; just as water does not exist in superheated steam. And yet it is at these temperatures that palladium is permeable to hydrogen, and not at temperatures at which hydride of palladium is stable.

There are several facts which must be borne in mind in seeking for an interpretation for the phenomenon of the passage of hydrogen through palladium.

First. The hydrogen in the act of passing is a reducing agent, as shown by its behaviour towards the oxides of nitrogen. At such temperatures as were here employed, hydrogen is without action on the lower oxides of nitrogen.

Second. Bellati and Lussano have shown (*Atti R. Ist. Ven.* i. series vii. p. 1173) that hydrogen "diffuses" through an iron plate which is used as a negative electrode on electrolysing dilute sulphuric acid. Their observation has been confirmed and amplified by Shields (*Chem. News*, lxxv. p. 195). Shields has shown that neither lead nor platinum nor palladium allow hydrogen to pass under similar circumstances, and experiments made by myself show that nickel does not allow carbon monoxide to pass at temperatures at which that compound is stable.

Third. Iron and platinum, as shown by Deville and Debray (*Compt. rend.* lvii. p. 965), are permeable at a red heat to hydrogen.

I think these considerations prove that it is necessary to add a fourth class to the three classes suggested by Graham. Graham's first class involves actual holes, that is, passages large in comparison with the molecular diameter ; his second implies pores small compared with molecular diameter, but still greatly exceeding that diameter ; his third class would be termed "solid solution" in the present state of our knowledge, *i. e.* when coal-gas passes through india-rubber, the latter dissolves the gas on the side exposed to it, while the gas evaporates from the other side, so as to render the pressure of the dissolved gas equal on both sides of the membrane.

The case is precisely analogous to the passage of water through a semi-permeable diaphragm. But, in order that hydrogen may pass through iron, it must be in the state in which it is liberated by an electric current, or it must be hot. That hydrogen will not pass through palladium at the ordinary temperature appears to show that the compound of palladium and hydrogen has practically no dissociation pressure at ordinary temperature; otherwise the hydrogen would pass by solution, in the same manner as coal-gas passes through india-rubber, or water through a semi-permeable diaphragm. That it will not pass, even when liberated by an electric current on one side of the palladium membrane, shows that it at once enters into combination with the palladium, and is no longer *in statu nascendi*, to use a generally understood expression which is independent of theory. But that it passes through hot palladium appears to show that it is then in a state analogous to that of electrically liberated hydrogen.

It is known that electrified bodies are discharged if a flame burns in their vicinity. This may be attributed to the liberation of atomic oxygen in a kind of Grotthus chain. For it may be imagined that when a molecule of oxygen encounters the oxidizable matter of a flame, it is dissociated: while one atom serves to oxidize the carbon, the other exchanges with a neighbouring molecule, and a succession of exchanges occur till the atomic oxygen near the electrified body receives or communicates a charge, and restores the potential of the charged body to that of surrounding objects.

To ascertain whether a flame of oxygen burning in hydrogen would similarly cause the hydrogen to assume the atomic state, a piece of apparatus was contrived in which such a flame burned in close proximity to a very thin iron plate, on the other side of which a Torricellian vacuum was maintained. No hydrogen passed through the plate: hence either the hydrogen was not atomically transferred, as oxygen is supposed to be under similar circumstances, or such atoms were unable to pass through the plate as they would have done if liberated electrically. It must be noticed, however, that it is conceivable that the double atom of hydrogen which we term a molecule may have united directly with the oxygen, without separating into its two components. The result of this experiment is therefore inconclusive.

It appears to me necessary to suppose that at a temperature far above that at which hydride of palladium is capable of existence, the palladium has still the power of so attracting the hydrogen that the molecule is split. This necessarily implies a gain of energy, so far as the splitting of the

hydrogen molecule is concerned, for any energy lost by the temporary and transient union of hydrogen and palladium is at once gained during its escape on the other side of the partition. But the hydrogen in expanding, which it does on passing through the partition, loses energy, and hence, on the whole, energy will probably be lost during the process. It is to such theories, I think, that we must look to explain the passage of hydrogen through a palladium diaphragm.

(2) In answering the question why the pressure raised by the entering hydrogen is never equal to that of the atmosphere, I think it must be admitted that the gas contained in the palladium vessel is not without influence on the passage of the hydrogen. A diminution of the pressure of the external hydrogen by the addition of nitrogen considerably increases the partial pressure of the internal hydrogen. Here the action of external nitrogen apparently neutralizes partially the effect of the internal nitrogen, and more hydrogen penetrates the metallic diaphragm. With gases other than nitrogen in the interior, the pressure of the hydrogen becomes more nearly equal to that on the exterior. The constancy of the results, however, proves that the deficiency is not due to experimental error.

This whole subject is full of difficulty. Experiments are in progress on the absorption of gases by platinum, and on the passage of gases through other metallic diaphragms, which may ultimately render an explanation possible. But I have thought it desirable to place these experiments on record, incomplete as they are, rather than wait for a complete solution to the problem.

I cannot conclude without acknowledging the able manner in which my late assistant, Mr. Percy Williams, has aided me in carrying out these experiments.

XXIII. *Note on the Rigidity of the Earth.*

By M. P. RUDSKI, Odessa.*

PROF. NEWCOMB † has estimated the Rigidity of the Earth from the observed 427 days' ‡ period of the Variations of Latitude, and found it to be somewhat greater than that of steel. His estimation being a rough one, I have undertaken a more precise calculation with the help of the formulas of Thomson and Tait.

* Communicated by the Author.

† Monthly Notices Astron. Soc. 1892, pp. 336-341.

‡ The recent investigations of the astronomers of Poulkova confirm also this period.