the "logarithmic rate" of change of resistance seems to be very approximately inversely as the absolute temperature. In nickel and iron, in which the law of the Thomson effect is peculiar, such a simple relation between resistance and temperature does not hold.

Electrical Properties of Hydrogenised Palladium.

By

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This note is also an abstract of a paper, read before the Royal Society of Edinburgh in July 1886, and now appearing in the Transactions. It consists of two parts, the first being a study of the electrical resistance of palladium at various stages of hydrogenisation, and the second a study of the thermoelectric properties.

It has been known for some time that the resistance of a palladium wire charged with hydrogen at ordinary atmospheric temperatures increases at a rate almost strictly proportional to the amount of charge. When fully saturated the resistance of the wire is about 1.7 times its resistance in the pure state. The interesting question as to the effect of change of temperature on the resistance of hydrogenised palladium seems, however, never to have been approached by former experimenters. If a pretty strongly charged palladium wire be taken and slowly heated, the resistance will be found to grow steadily up to a temperature of 130° C. Above this temperature a somewhat more rapid increase of resistance is generally observable until 200° C. is reached. Thereafter, in virtue of the escape of the hydrogen from the palladium, the resistance ceases to increase; and as the heating is continued past 250° C. a very rapid *diminution* of resistance sets in, until, as the temperature approaches 300° C. all the hydrogen is driven out, so that the wire becomes pure palladium and behaves accordingly.

An unexpectedly simple relation was found to hold very approximately between the temperature coefficients for different amounts of charge. The relation may be expressed in two ways, thus:—the *resistance* of a given wire in different states of charge increases by approximately the same amount for a given rise of temperature; or the *total* increase of resistance of a palladium wire when charged to a certain amount is the same at all temperatures below 150°. This requires that the temperature coefficient is smaller for the higher charges. Thus, if R_0 is the resistance of pure palladium at 0° centigrade and a the temperature coefficient so that the resistance at $t°$ is

$$R_t = R_0 (1 + a t)$$

and if r_0 be the resistance at 0° C. of the same wire with a given charge of hydrogen, then its resistance at $t°$ is

$$\begin{aligned} r_t &= r_0 + R_0 \, a t \\ &= r_0 \left(1 + \frac{R_0}{r_0} a t\right) \end{aligned}$$

Hence the temperature-coefficient for a given specimen of wire charged with hydrogen is inversely as the resistance of the wire. In the following table the first column gives the resistances of the same wire at successive saturations; the second column contains the corresponding temperature-coefficients; and the third gives the product, which in accordance with the above statement, should be the same for all.

Resistance.	Temperature-Coefficient	Product.
1	.00293	.00293
1.07	.00319	.00341
1.13	.00299	.00338
1.27	.00273	.00347
1.41	.00257	.00362
1.51	.00214	.00323
1.63	.00198	.00323

When the peculiar conditions of the experiment are borne in mind, more especially the uncertainty of the charge being uniformly distributed in the wire, it will probably be granted that the products are sufficiently alike to justify the conclusion drawn. At any rate the approximation to constancy among these products is very remarkable when taken in connection with the rapid increase of resistance due to charging as shown in the first column.

The thermoelectric current obtained with a palladium hydrogenium pair is one of surprising magnitude, being greater than for a palladium copper circuit. When the heated junction is at or near a temperature of 200° C., peculiar irregularities appear which depend upon whether the temperature is for the moment rising or falling. This no doubt is due to the hydrogen being driven out of the highly heated parts near the junction, and to its partial return from colder contiguous portions of the wire as the junction is being cooled down again. After experiencing such a high temperature, the charged wire at the junction does not, however, wholly regain its original condition—the electromotive force in the circuit for a given difference of temperature being appreciably, sometimes very markedly, smaller than at first. So long as the temperature is kept below 150° C., the charged wire is as constant in its thermoelectric properties as the pure wire. In all cases, the thermoelectric current is from the pure palladium to the charged palladium through the hot junction, is for any given pair very nearly proportional to the difference of temperature of the junctions, and is greater for the greater charge of hydrogen in the one wire. Thermoelectrically, fully saturated hydrogenium lies between iron and copper at ordinary atmospheric temperatures. On the thermoelectric diagram the hydrogenised palladiums of different charge are represented (up to a temperature of 150° C.) by a series of straight lines approximately parallel to palladium, an appreciable deviation from parallelism occurring only for the highly charged specimens. The thermoelectric powers at 0° C. expressed in C. G. S. units range roughly from -600 (pure palladium) to $+1400$ (saturated palladium), the thermoelectric power for lead being zero.* In other words, the electromotive force in a circuit of palladium and saturated hydrogenium, when the temperature of the junctions are 0° C. and 100° C., is about 20×10^4 C. G. S. units or .002 volts.

The deviation from parallelism between the lines for pure palladium and saturated hydrogenium, referred to above, is of such a nature as to produce intersection of the lines at a point corresponding to $-350°$ C. This of course is an unattainable temperature ; but the existence of such a 'neutral point' (as it were) must have some significance. The data, upon which the estimation of this point was made, are somewhat doubtful, the range of temperature employed in the experiments being limited. With the object of testing this supposed convergence of the palladium and hydrogenium lines, Messrs. Saneyoshi and Hirayama undertook a series of experiments, in which

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* Compare Everett's "Units and physical constants" page 151, where, however, the signs are reversed. It seems preferable to draw the diagram as in Tait's classical memoir or as described in Maxwell's *Elementary Treatise on Electricity* and in Tait's *Heat*. The lines which have *positive* inclination according to the usual convention are then the lines of metals, in which the Thomson Effect is *positive*. [I notice that Professor Everett has, in the 2nd edition lately published, altered the signs so as to agree with this convention.]

the hydrogenium line was traced out by its neutral points with conveniently situated imaginary lines formed by combination of iron and nickel wires with adjustable resistance in the two branches. They obtained for the point of convergence the value —260° C. The conclusion seems to be that the hydrogen line, if it could be found, would pass through this same point—*i. e.* have a neutral point with palladium at temperature of about —300° C.

The thermoelectric peculiarities of hydrogenium may be prettily shown by the following experiment. Let a palladium wire, by immersion to half its length in the electrolytic cell, be hydrogenised throughout that half length. Attach the ends of this seeming single uniform wire to the terminals of a galvanometer, and let a flame be allowed to play gently at the central point of the wire. A large current is at once obtained, which grows to a maximum, and then diminishes to zero as the temperature rises to a red heat. There is no such current during cooling. This spurious neutral point during heating is due to the hydrogen being driven out of the heated portion, partly, no doubt, into the contiguous colder portions. By following up with the flame the ever-shifting point of separation between the charged and uncharged portions, we may repeat the experiment indefinitely until the hydrogen is all driven out of the wire or until the distribution of the charge has become fairly uniform.