

PROCEEDINGS  
OF THE  
AMERICAN PHYSICAL SOCIETY.THERMAL ELECTROMOTIVE FORCE AT THE JUNCTIONS OF METALS AND  
METALLIC OXIDES.<sup>1</sup>

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THIS work suggested itself when it was noticed that considerable electromotive force is generated when a cold wire is brought in contact with a similar or dissimilar hot wire. If two iron wires are fastened to the terminals of a galvanometer, one wire heated in a flame and the heated portion is touched with the cool wire, the electromotive force is many times sufficient to throw the galvanometer deflection off the scale. If two similar wires are left in the flame, the electromotive force will reduce to zero or nearly zero; and, if they are dissimilar, the electromotive force will reduce to the value that is characteristic of the two metals at the particular temperature.

These large electromotive forces were found to be due to the oxides which formed on the heated metals and experiments were planned to investigate the thermal electromotive force at a junction of the oxide and the metal. The high resistance of the metallic oxides caused some difficulties, but if the oxides are obtained by completely oxidizing no. 12 or no. 16 wires of the metals, an inch length of the oxide can be inserted in the unknown electromotive force arm of the potentiometer and still permit the electromotive force to be measured to millivolts when a reasonably sensitive galvanometer is used to detect a balance.

The following data gives the electromotive forces of the copper copper-oxide couple and the corresponding temperatures of the hot junction while the cool

Temp. of Cold Junction.	Temp. of Hot Junction.	E.M.F. in Millivolts.
20 C.	50 C.	14.7
"	139	58.8
"	270	152.
"	393	294.2
"	455	411.
"	500	491.
"	530	556.

<sup>1</sup> Abstract of a paper presented at the Atlanta meeting of the Physical Society, December 31, 1913.

junction was maintained at about 20° centigrade. Examination of the data indicates that the thermo-electric equation of such a couple would be fairly accurately expressed by the parabola,

$$E = .105t + .00175t^2$$

where  $E$  is expressed in millivolts and  $t$  is expressed in degrees centigrade.

The iron copper-oxide couple and the iron iron-oxide couple have been examined but not sufficiently accurately to determine the exact form of their electromotive force temperature curve. The electromotive forces of the iron copper-oxide couple are of about the same magnitude as those of the copper copper-oxide couple. The electromotive forces of the iron iron-oxide couple are only about half as large as those of the copper copper-oxide couple. These couples as well as couples formed with other metallic oxides are going to be investigated with the hope of soon being able to thermo-electrically classify these oxides.

The electromotive force produced when a cool wire is brought in contact with the hot wire is, therefore, explained as due to the oxide on the wire or wires. The temperature of the oxide at the point of contact with the cool wire is much lower than the temperature of the oxide at the point of contact with the hot wire and consequently a metal metal-oxide thermo-couple is formed.

These results emphasize the necessity of close contact between the metals of any thermo-couple since a very small difference between the temperatures of the wires would produce erroneous results if an oxide separated the wires. There also seems to be sufficient reason for discarding the method that is sometimes used to test thermo-couple wires for homogeneity. This method is to bring two wires in contact in a flame and by moving from point to point along one wire non-homogeneity would result in a thermo-electromotive force if the wires were of the same material or a change in the electromotive force if the wires were of different materials. A small difference between the temperatures of the wires and an oxide between them would produce electromotive forces much larger and much more variable than the electromotive force due to non-homogeneity.

An electromotive force of half a volt or more can easily be maintained between two copper rods by heating one in a flame to redness and holding the rather sharp point of another large rod in contact with the oxide on the hot rod. Since only a small surface of the cooler rod is in contact with the oxide and since the high conductivity of the copper permits the heat to be rapidly conducted away from the point, the one rod remains comparatively cool and the electromotive force is maintained.