For moderate ranges *of* temperature the binomial formula of Μ. P. Avenarius is generally sufficient, and has been employed by many observers. It is figured by Avenarius *(Fogg. Ann., 119,* p. 406) as a semi-circle, but it is really a parabola with its axis parallel to the axis of £, and its vertex at the point *t≈-b∣2c,* which gives the neutral temperature. We have also the relations *dE∣dl≈b+2cl* and *diE∣dP-2c.* The first relation gives the thermoelectric power *p* at any temperature, and is probably the most convenient method of stating results in all cases in which this formula is applicable. A discussion of some of the exponential formulae is given by S. W. Holman *{Phil. Mag.,* 41, p. 465, June 1896).

7. *Experimental Results.—*In the following comparative table of the results of different observers the values are referred to lead. Before the time of Tait’s researches such data were of little interest or value, on account of insufficient care in securing the purity of the materials tested; but increased facilities in this respect, com­bined with great improvements in electrical measurements, have put the question on a different footing. The comparison of inde­pendent results shows in many cases a remarkable concordance, and the data are becoming of great value for the testing of various theories of the relations between heat and electricity.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table I.—Thermoelectric power, *ρ=dE∣dt,* in microvolts at 50’ C. of pure metals with respect to lead. (The mean change, *2c = <PE∣dP,* of the thermoelectric pow’er per degree C. over the range covered by the experiments, is added in each case.) | | | | | | | | |
| Metal. | Tail (00 | to 300e). | Steele (oβ to ιooβ). | | Noll (o, | **to ÎOO\*).** | Dewar and Fleming ( 4- ι∞, to — 2OO\*). | |
| Aluminium | A  -O∙56 | 2C.  + ∙∞39 | *P-* -0-42 | *2C.*  + ∙OO2I | *P∙* -0-41 | *2C,*  + ∙OOI74 | A  -o∙394 | 2C.  + ∙∞398 |
| Antimony |  |  | +42-83 | +∙145o\* |  |  | +3∙210 | + •02817 |
| Bismuth .... |  |  |  |  |  |  | -76-870 | — ∙08480 |
| Cadmium . | +4∙75 | +∙0429 | +4∙79 | +•0389 | +4∙71 | +∙0339 | +4∙792 | +•02365 |
| Carbon . . . . |  |  |  |  |  |  | +12∙795 | +•03251 |
| Copper | + ι∙8ι\* | +∙0095 | +3∙37 | + ∙0I22 | +3∙22 | +∙0080 | +3∙,56 | +•00683 |
| Cobalt |  |  |  |  | -19∙252 | -∙0734 |  |
| Gold . | +3∙3O | + ∙0I02 | +3· 19 | + ∙Oi3i | +3∙I0 | +•0063 | + 1∙161 | +•00315 |
| Iron . | ÷I4∙74 | -∙O487 |  |  | +n∙835 | -•0306 | + 14∙522 | —OI33θ |
| Steel (piano) | +9∙75 | -∙O328 |  |  |  |  | +9∙600 | — •01092 |
| Steel (Mn 12%) |  |  |  |  |  |  | -5∙73 | --00445 |
| Magnesium | + ι∙75\* | -∙OO95 |  |  | -o∙113 | + ∙0019 | -0-126 | +∙00353 |
| Mercury ... |  |  |  |  | -4∙03 | — •0086 |  |
| Nickel .... | -24-23\* | -∙05i2 |  |  | -20∙58 | — ∙0302 | -18∙87 | -•05639 |
| Palladium | -8-04 | -•0359 |  |  |  |  | —9∙IOO | -∙04714 |
| Platinum ... | -1-15\* | — ∙OIIO |  |  | -4∙09 | — ∙O2I1 | -4∙347 | — •03708 |
| Silver | +2-86 | +•0150 | +3∙07 | + ∙0II5 | +2∙68 | +•0076 | +3∙317 | +∙00714 |
| Thallium .... |  | . . | +l∙76 | -∙OO77 |  |  |
| Tin | -o∙ι6 | +∙∞55 | —o∙o91 | + ∙OOO4 | -0-067 | +•0019 | +0∙057 | +∙00021 |
| Zinc ... | +3∙5i | +∙0240 | + ι∙77\* | + ∙OI95 | +3∙318 | +•0172 | +3∙233 | + ■01040 |

*Explanation of Table.—*The figures marked with an asterisk (\*) represent discrepancies which are probably caused by impurities in the specimens. At the time of Tait’s work in 1873 it was difficult, if not impossible, in many cases to secure pure materials. The work of the other three observers dates from 1894-95. The value of the thermoelectric power *dE!dt* at 50o C. is taken as the mean value between o’ and 100° C., over which range it can be most accurately determined. The values of *d-E∣dfi* agree as well as can be expected, considering the difference of the ranges of temperature and the great variety in the methods of observation adopted; they are calculated assuming the parabolic formula, which is certainly in many cases inadequate. Noll's values apply to the temperature of -∣-ιoo0 C., Dewar and Fleming’s to that of —ιooc C., approxi­mately.

In using the above table to find the value of £ or *dF.∣dt* at any temperature or between any limits, denoting by *p* the value of *dEjdt* at 500 C., and by *2c* the constant value of the second coeffi­cient, we have the following equations :—

*dE∣'dt = p+2c(t-ζo'),* at any temperature *t,* Cent. . . (3)

E(1√) = (Z-Z')(Z>+c(l-H,-ιoo)) (4)

for the E.M.F. between any temperature Z and *t'.*

8. *Methods of Observation.—*In Tait's observations the E.M.F. was measured by the deflection of a mirror galvanometer, and the temperature by means of a mercury thermometer or an auxiliary thermocouple. He states that the deviations from the formula were " quite within the limits of error introduced by the altera­tion of the resistance of the circuit with rise of temperature, the deviations of the mercury thermometers from the absolute scale, and the non-correction of the indications of the thermometer for the long column of mercury' not immersed in the hot oil round the junctions.” The latter correction may amount to about ιo° C. at 350o. Later observers have generally employed a balance method (some modification of the potentiometer or Poggendorf balance) lor measuring the E.M.F. The range of Steele's observations was too small to. show any certain deviation from the formula, but he notes capricious changes attributed to change of condition of the

wires. Noll employed mercury’ thermometers, but as he worked over a small range with vapour baths, it is probable that he did not experience any trouble from immersion corrections. He docs not record any systematic deviations from the formula. Dewar and Fleming, working at very low temperatures, were compelled to use the platinum thermometer, and expressed their results in terms of the platinum scale. Their observations were probably free from immersion errors, but'they record some deviations from the formula which they consider to be beyond the possible limits of error of their work. The writer has reduced their results to the scale of the gas thermometer, assuming the boiling-point of oxygen to lie -182∙5° C.

9. *Peltier Effect.—*The discovery by *J. C.* A. Peltier (1834) that heat is absorbed at the junction of two metals by passing a current through it in the same direction as the current produced by heating it, was recognized by Joule as affording a clue to the source of the energy of the current by the application of the principles of thermodynamics. Unlike the frictional generation of heat due to the resistance of the conductor, which Joule (1841)

proved to be proportional to the square of the current, the Peltier effect is reversible with the current, and being directly' propor­tional to the first power of the current, changes sign when the current is reversed. The effect is most easily shown by con­necting a voltaic cell to a thermopile for a short interval, then quickly (by means of a suitable key, such as a Pohl commutator with the cross connectors removed) disconnecting the pile from the cell and connecting it to a galvanometer, which will indicate a current in the reverse direction through the pile, and approxi­mately proportional to the original current in intensity, provided that the other conditions of the experiment are constant. It was by an experiment of this kind that Quintus Icilius (1853) verified the proportionality of the heat absorbed or generated to the first power of the current. It had been observed by Peltier and A. E. Becquerel that the intensity of the effect depended on the thermoelectric power of the junction and was independent of its form or dimensions. The order of the metals in respect of the Peltier effect was found to be the same as the thermoelectric scries. But on account of the difficulty of the measurements involved, the verification of the accurate relation between the Peltier effect and thermoelectric power was left to more recent times. If *C* is the intensity of the current through a simple thermocouple, the junctions of which are at tempera­tures *t* and *t',* a quantity of heat, *PXC,* is absorbed by the passage of the current per second at the hot junction, *t,* and a quantity, *P'* X *C,* is evolved at the cold junction, ∕'. The co­efficients, *P* and *P',* are called coefficients of the Peltier effect, and may be stated in calorics or joules per ampere-second. The Peltier coefficient may also be expressed in volts or micro­volts, and may be regarded as the measure of an E.M.I'. located