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VI. *Note on the Examination of certain Alloys by the Aid of the Induction-balance.* By W. CHANDLER ROBERTS, F.R.S., *Chemist of the Mint**.

[Plate VI.]

SOME weeks since, Prof. Hughes showed me that equal volumes of various metals give widely different indications with the induction-balance. It appeared probable that a careful examination of a definite series of alloys would prove to be of interest; and as Prof. Hughes at once gave me the most generous assistance, teaching me the manipulation and controlling the results, I am able to submit the following observations to the Society.

The relative values of different metals as indicated by the induction-balance were given by Prof. Hughes in a paper read before the Royal Society on the 15th of May last. They do not accord with the values usually accepted as representing the relative conductivity of the respective metals; and this being the case, it became important to ascertain what relation the indications given by alloys, when under the influence of the induced current, bear to their electric conductivities, which afforded Matthiessen a basis for dividing them into groups†.

A series typical of each group was therefore taken; the constituent metals were melted together in the requisite proportions; and the thoroughly mixed alloys were carefully rolled to a uniform thickness, usually 1·3 millim. Disks 24 millims. in diameter were then cut with the same punch; and these disks were placed in succession on one side of the balance, so that their bases lay exactly on a line midway between the primary and secondary coils, this having been found to be the plane of maximum force. The respective values of the alloys were ascertained either by introducing the sonometer into circuit, or by superposing a graduated wedge-shaped scale of zinc over the opposing coil of the balance, as has already been explained by Prof. Hughes.

The alloys of Lead and Tin were selected as an example of Matthiessen's first group. The results are recorded in the following Table, and are graphically indicated in the curve No. 1, Plate VI. The readings are those of the zinc scale‡.

The Gold-Silver alloys, representing the second group, presented no difficulty of manipulation; and the observations were made on disks 1·3 millim. thick and 24 millims. in dia-

* Communicated by the Physical Society.

† British-Association Report, 1863, p. 37.

‡ The use of a scale of greater accuracy than the one employed may slightly alter some of the figures, but it can hardly change the general nature of the curves.

meter. The results are given in the Table and in curve No. II.

The alloys of Tin and Copper, taken as representative of the third group, are peculiar. Their tints and fractures are widely different; and the series is interesting as having various industrial applications. As many of them are too brittle to roll, a block of each alloy 18 millims. square by 7 millims. thick was formed with the file. The results are given in the Table and on the curve No. III.

No.	Percentage composition.	Approximate formula.	Readings on Induction-balance.
TIN-LEAD.	1. 100 (pure tin).		67.5
	2. 77.37	$\text{Sn}_6 \text{Pb}$	62.0
	3. 69.60	$\text{Sn}_4 \text{Pb}$	59.0
	4. 53.20	$\text{Sn}_2 \text{Pb}$	52.5
	5. 36.30	Sn Pb	51.0
	6. 22.30	Sn Pb_2	47.0
	7. 12.50	Sn Pb_4	45.0
	8. 8.60	Sn Pb_6	46.0
	9. 0 (pure lead).		43.0
SILVER-GOLD.	1. 100 (pure silver).		225
	2. 99.97		209
	3. 99.90		205
	4. 99.50		192
	5. 99.10		170
	6. 98.02		148
	7. 94.93		115
	8. 90.00		84
	9. 81.40	$\text{Ag}_3 \text{Au}$	60
	10. 68.70	$\text{Ag}_4 \text{Au}$	48
	11. 52.30	$\text{Ag}_2 \text{Au}$	44.5
	12. 35.50	Ag Au	42.8
	13. 21.50	Ag Au_2	44
	14. 12.00	Ag Au_4	49
	15. 8.30	Ag Au_6	60
	16. 4.1		90
	17. 0 (pure gold).		150
COPPER-TIN.	1. 100 (pure copper).		167
	2. 89.00	Sn Cu_{15}	65
	3. 84.33	Sn Cu_{10}	51
	4. 79.02	Sn Cu_7	45
	5. 72.91	Sn Cu_5	40
	6. 68.28	Sn Cu_4	37
	7. 65.00		49
	8. 61.79	Sn Cu_3	83
	9. 51.84	Sn Cu_2	73
	10. 34.99	Sn Cu	73
	11. 9.73	$\text{Sn}_5 \text{Cu}$	82
	12. 0 (pure tin).		85

Note.—The Alloys were not annealed; and the temperature was about 15° C.

If the curves for Lead-Tin and Gold-Silver are compared with those given by Matthiessen* for the same alloys, their similarity will at once be evident. On the other hand, the induction-balance curve of the Tin-Copper series, while bearing some general resemblance to Matthiessen's curve of conductivity, differs essentially from it in certain parts. Matthiessen's curve falls rapidly from 93 (the conductivity of pure copper) to 9 (that of the alloy containing 85 volumes per cent. of copper). It then passes horizontally in a line which is approximately straight to 13, the conductivity of Tin.

Some light would appear to be thrown on the difference between the two curves by the work of M. Alfred Rich† on the density of alloys of copper and tin. He showed that copper and tin contract in alloying, the contraction being regular from pure tin up to the alloy containing 38 per cent. of tin, the density of which is higher than that of pure copper. M. Rich's experiments were conducted on alloys both in the form of powder and ingots; the latter have alone been given in the curve marked with his name on the Plate; and the relation between the two curves, especially at the points a , a' , b , b' , is too evident to need comment.

It may ultimately prove that if the alloys were rolled or compressed the curve would be modified; and, on the other hand, further experiments on the conductivity of the alloys may reveal points of identity between the conductivity and induction-balance curves; the part where the former from being vertical becomes horizontal would be especially worth examination. It may be well to point out that the alloys SnCu_3 and SnCu_4 , which occupy critical positions on the induction curve, have been shown by M. Rich to be singularly free from the disturbing influence of liquation.

The work would appear to be interesting as showing that the induction-balance may afford a simple means for detecting variations in the molecular structure of alloys and for indicating allotropy in metals with greater accuracy than has hitherto been possible.

Practical application.—The possibility of ascertaining the standard fineness of alloys by the aid of electricity long ago occupied the attention of physicists. In 1823 M. Becquerel‡ suggested that trustworthy indications might be afforded by the electromotive force developed when the alloy is placed in an exciting fluid, together with an alloy of known composition.

* *Op. cit.* p. 46, and Watts's Dictionary of Chemistry, vol. iii. p. 943.

† *Ann. de Chimie et de Phys.* tome xxx. 1873.

‡ *Ibid.* t. xxiv. p. 343 (1823).

The subject was partially investigated by Ørsted in 1828*; and as its practical importance was further indicated by Gay-Lussac in 1830†, I made a series of experiments in order to ascertain how far the more delicate appliances in use at the present day could be made available. The results, however, were not entirely satisfactory.

Prof. Hughes's Induction-balance rendered it possible to resume the research on a new basis. It is only necessary to glance at such a curve as that of the Gold-Silver series No. II. to be satisfied of the probability that certain parts of it, at least, would indicate minute differences of standard. I would therefore direct special attention to the series of alloys which lie between pure silver and silver alloyed with 5 per cent. of gold. These are shown in a separate curve, where the scale of percentages is more extended. Such alloys as Nos. 2 to 6 are known to refiners as doré; and No. 2 contains less than 2 grains of gold to the pound troy, a quantity which could not be extracted with profit by the ordinary operation of "parting." Small as the amount of precious metal is, its presence is clearly indicated on the induction curve, as are also the larger amounts of gold contained in Nos. 3-5.

Experiments are in progress on other series which promise to afford trustworthy indications; but of course the establishment of a method of verifying the composition of alloys of the precious metals must in part depend on the degree to which the presence of traces of foreign metals influence the accuracy of the results.

My object in these notes is not to insist on any particular application, but to bear testimony from a metallurgical point of view to the delicacy and simplicity of the instrument which Prof. Hughes has placed at our disposal; and I would offer him my sincere thanks for the liberal aid he has so readily given me.

VII. *On the Theory of Faults in Cables.*

By OLIVER HEAVISIDE.

1. **T**HE only kind of fault to be here considered is either a local defect in the insulation, or an artificial connexion between the conductor of a cable and the earth. When a fault occurs in a submarine cable, its most manifest effect on the working is to increase the strength of current leaving the sending end, because the resistance is reduced; while at the same time the strength of current arriving at the distant

* *Ann. de Chimie et de Phys.* t. xxxix. 1828, p. 274.

† *Instruction sur l'Essai des Matières d'Argent par la Voie Humide.* Paris, 1830.

