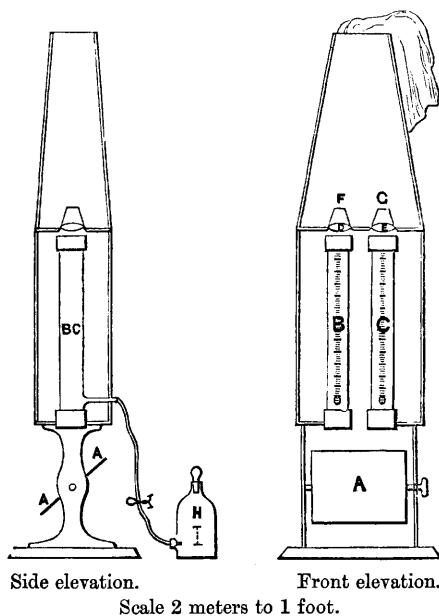


XXVI.—*On the Reflection from Copper and on the Colorimetric Estimation of Copper by means of the Reflection Cuprimer.*

By THOMAS BAYLEY.

THE author has shown (*Phil. Mag.*, March, 1878) that a remarkable relation exists between the light reflected from metallic copper and that transmitted by solutions of its salts. The light reflected from the surface of the metal contains all the elements of white light, but the region of the spectrum to the red side of the D line is more intense than in the spectrum of the reflection from a white surface of equal illumination, and lengthened out for a short distance beyond the point where the visibility of the ordinary spectrum ceases. The light transmitted by dilute solutions of cupric salts is deficient in those rays which the spectrum of reflection has in excess, and the space below the sodium line is dark. It follows then that if we look at a copper surface through a sufficient thickness of cupric sulphate solution, the metal appears silver-white, for the solution absorbs the excessive rays which make the copper red. Upon these facts the construction of the reflection cuprimer is based. The instrument (as made by Messrs. Jackson, 65, Barbican) is shown in the accompanying figure: it is a mirror of copper supported upon a horizontal axis, and capable of rotation. The direct light from the sky is reflected from this surface vertically upwards through two tubes B and C, closed at the bottom by plates of glass, and protected from extraneous light by a wooden case. The sheaves of light passing up the tubes are concentrated by the convex lenses D and E upon the semi-transparent discs F and G, composed of two or three layers of white tissue paper moistened with glycerin. Surmounting the case containing the lenses and tubes is a

conical box blackened inside, which screens the discs and the eye of the operator from foreign light. The glass tubes are fitted at their lower extremities with side tubes which communicate by caoutchouc piping with the aspirators H and I. The right-hand tube contains a



standard solution of copper; in the other is placed the solution under examination, and the level of the liquid in either tube can be regulated by means of the aspirator. The standard solution is made by dissolving 1 gram of pure copper in nitric acid, adding a slight excess of sulphurous acid, and diluting to a liter at 15° C. The depth of this solution required to produce a white disc was determined in the following manner:—The surface of half the mirror was replaced by silver, so that the silver reflection passed through one tube and the copper reflection through the other. The former tube contained distilled water, the standard-copper-solution was placed in the latter, and its depth adjusted until both discs were equally white. In operating for this purpose, it is best to make four determinations, starting with the column alternately too long and too short; the errors then have a tendency to be alternately positive and negative, and the mean of the series is very near to the true result. Whatever the tint of the disc over the varying column, the eye invests the white disc with the complementary colour, but when the blue liquid exactly neutralises the

reflection from the copper both discs are white. In these preliminary experiments the tubes were graduated in centimeters, and the means of three series of experiments of six each were 8·00, 8·01, and 8·03; we may therefore take the length of the column of standard solution required to balance the reflection from the plate as 8·01 cm. The density of a solution of copper containing 1 gram per liter, after correcting for the acid, is not far from that of distilled water, so that the liquid contains approximately ·1 per cent. of the metal. Optically such a liquid may be considered as copper diluted and freed from the conditions which fetter it in the state of solidity. Solid copper is coloured because it decomposes part of the incident white light, reflecting the red rays and suppressing the remainder; but that this remainder penetrates a minute distance into the metal we know from the experiments of Faraday, who showed that thin films transmit bluish light. In the dilute solution the molecules are emancipated from the conditions which produce opacity. Since the length of the column required to produce white light is inversely as the quantity of copper present, and since a solution of copper containing ·1 per cent. required a length of 8·01 cm., a solution of copper containing 100 per cent. of metal, that is to say pure copper, would require a thickness of ·0801 mm., supposing its molecular condition to remain unaltered. We thus arrive at an abstract conception of copper derived from the ordinary conditions of solidity, existing as a transparent substance transmitting blue light.

The length ·0801 mm., which we may call a "cuper," is conveniently used as the basis of the graduation of the cuprimer. The standard solution requires a thickness of 1,000 cupers to produce a white disc, and represents copper 1,000 times diluted. A solution containing half this quantity of copper requires a thickness of 2,000 cupers and represents copper 2,000 times diluted. In general if c equals the number of cupers expressing the thickness of the solution when the disc is white,

c = vol. of liquid (in cubic centimeters) which contains 1 gram of copper,

and $\frac{1,000}{c}$ = amount of copper in grams contained in one liter of solution.

The following, which are the results of an actual series of observations, indicate the degree of accuracy possible with the instrument. The solution contained ·801 gram of copper per liter.

True reading.	Observed readings.	Corresponding to copper per liter.
1248	1240	0·806 gram
	1230	0·813 „
	1250	0·800 „
	1260	0·793 „
	1260	0·793 „
	1230	0·813 „
	<hr/>	<hr/>
Mean	1245	Mean.. 0·803 „

Iron in considerable quantity is not injurious, if it is reduced to the ferrous condition. A solution containing 1 gram of iron and ·5 gram of copper per liter gave the following readings :—

1980
1970
2000
2000
2010
2020

In estimating the copper in an ore, or in brass, such a quantity as is supposed to contain about 1 gram of copper is dissolved in nitric acid, treated with excess of sulphurous acid, boiled, cooled, and made up to a liter. The solution is then observed in the instrument. The plate must be uniformly polished, and quite free from tarnish. It might, of course, be possible to dispense with the standard solution and balance the unknown solution against a plate of silver; but although under these circumstances the two discs are white, they are not equally illuminated, as it would seem, for the following reasons:—A silver plate reflects a certain quantity of white light; an equally polished copper plate reflects the same amount of light, minus that abstracted from the portion corresponding with the red residuum. This residuum being absorbed by the solution, it follows that the reflection from the copper is less intense than the silver reflection by the amount of light thus disposed of by transmission and absorption.

The frosted surface of copper produced by electrodeposition has conditions of reflection differing widely from that of polished surfaces. Such a surface reflects a larger quantity of red light, and requires a much greater thickness of copper solution to neutralise it. It is possible, however, that the white light reflected is greater in equal proportion, for the surface thus neutralised has the brilliant appearance of pure white paper. I hope to return to this subject in a future communication. It is worthy of remark in passing that the same relation seems to exist between the hydrated oxides of copper as between the metal and

its solutions. The hydrated suboxide (Cu_2O) seen through a strong solution of copper has a dead black appearance. Its reflection consists principally of red rays, and it therefore appears black when these are absorbed. The hydrated oxide (CuO) has more or less the colour of cupric solutions. It may be observed that the same relations exist between certain salts of nickel and cobalt, which, when mixed together, yield a colourless grey powder or a colourless solution.
