II. "Colour Photometry. Part III." By Captain W. de W. Abney, C.B., R.E., D.C.L., F.R.S., and Major-General Festing, R.E., F.R.S. Received December 14, 1891.

(Abstract.)

The authors refer to their paper on Colour-Photometry (Bakerian Lecture, 1886), in which a method was given of forming a curve of luminosity of the spectrum, the source of light being the crater of the positive pole of an electric arc lamp.

They point out that in making the observations for forming this curve no attention was paid to the part of the retina of the eye which was used, and which embraced the "yellow spot" and some of the surrounding portion.

In their further researches this point came to be of importance, and they describe how, by modifications of the apparatus and of the methods of observing, they were able to use either the yellow spot or portions outside it, and they give the results of the observations, showing how the curves become modified in each case.

The absorption by the yellow spot takes place in all rays more refrangible than E; but to the less refrangible rays the outer part of the retina is less sensitive than the central part.

The Limit of Colour Vision.—It is well known that when light of any colour becomes enfeebled to a certain degree, the eye fails to see colour, though it may still recognise the existence of light. Observations were made to determine the point at which, for each part of the spectrum, the sensation of colour is lost. The same apparatus as before was used for forming the spectrum and the "reference" beam of white light, and a supplementary apparatus was devised for reducing the beam of light and for measuring the amount of reduction. Each coloured beam was reduced until, in comparison with a feeble white beam, it appeared colourless. The amount of reduction in each case being measured, a curve was plotted showing the proportional reduction in part of the spectrum. The absolute intensity of the beam from D having been measured by comparison with an amyl acetate lamp, that of each other part of the spectrum was calculated by aid of the luminosity curve above referred to. It then became possible to plot a curve which shows the intensity of the original source at which, in each part of the spectrum, colour first becomes visible.

The portion of the spectrum in which colour is visible from the feeblest source is between about λ 500 and λ 615. This accounts for the fact that in a feeble light, such as that of the moon, objects appear to be of a greenish hue, and also that moonlight passing through coloured windows does not give a coloured image in most cases.

Extinction of the Light of different Parts of the Spectrum.—A full description is given of the apparatus used and of the method of observation for determining how much the light of each part of the spectrum must be reduced in order that it may be extinguished. Observations were made (1) with the central part of the eye only and (2) with the whole eye.

From these observations curves were plotted, showing the proportion of the beam from each part of the spectrum which was just not visible. These are called extinction curves. They differ only in that part of the spectrum where the yellow spot absorption takes place. The minimum ordinate is at about λ 5300, and represents $65/10^7$, that being the proportion to which the beam had been reduced at extinction, the intensity of the unreduced beam from D in the same spectrum being that of an amyl acetate lamp at 6 feet. The intensity of other beams of the spectrum was calculated from this by the aid of the luminosity curve as before. A curve was then derived from each of the extinction curves by taking as ordinates the product of such ordinate of an extinction curve and the luminosity of the corresponding beam; these derived curves then represent (on the supposition that all the beams were originally of the same luminosity as D), the proportion, and therefore the absolute intensity, of any beam which would be just not visible. These two curves differ slightly at the part affected by the yellow spot, but that for the whole eye is horizontal from the extreme violet end to about λ 4800; it then rises rapidly to λ 6840, and again becomes horizontal. This seems to confirm the view that a single sensation only is excited by each of the ends of the spectrum.

The reciprocals of the ordinates of either of the first two extinction curves being taken, what is called a "persistency" curve is formed. The curve for the whole eye and that for the central portion are given. It is reasonable to expect that the "persistency" curve should have relation to some colour sensation of the eye, which may perhaps be looked upon as the dominant sensation, as it is excited by the smallest quantities of light.

An examination with the results of observations made by colour-blind people is then entered on.

A gentleman, M., made a series of observations. He has two colour sensations only, which he calls "red" and "black." Yellow he describes as "white," green as "bright black," blue as "darker black." His luminosity curve has been plotted on such a scale that the red portion corresponds with that of the normal curve. The rest, however, falls below this, and it leaves off a little beyond F. The curve formed by the differences of his and the normal ordinates may be considered to be M.'s deficiency curve.

Two brothers, P. and Q., were also examined. They have the same

vision, which is monochromatic. Their luminosity curve, M.'s deficiency curve, and the normal persistency curve correspond very nearly except in the part affected by the yellow spot. It therefore appears as if P. and Q. had only the sensation which is looked upon as the dominant sensation in the normal eye, and of which M.'s eye is devoid, and that P.'s and M.'s eyes together would make up a normal eye.

The results are also given of the examination of the vision of a red-blind (H. R.) and of a green-blind person (V. H.). Their "persistency" curves, as well as that of P., nearly correspond generally with each other and with that of normal vision. The "absolute intensity" extinction curves of H. R. and V. H. also do not differ notably from the normal; but in P.'s case the ordinates are larger, from which it may be inferred that his sense of vision is less acute.

Assuming blue, green, and red to be the three primary sensations, P.'s and Q.'s luminosity curve or M.'s deficiency curve would represent the first, and V. H.'s deficiency curve the second, but H. R.'s deficiency curve would not quite represent the third, as he is not entirely devoid of appreciation of red.

Luminosity Curve of Spectrum of Low Intensity.—The normal persistency curve being apparently the same as the luminosity curve of persons with but one colour sensation, experiments were made to determine what would be the luminosity to the normal eye of the different parts of a spectrum of a very low intensity. A spectrum was formed of which the beam from D was equal in intensity to 1/132·5 of an amyl acetate lamp at 1 foot. The luminosity curve of this was found to correspond very nearly to that of P., and to the normal persistency curve. By reducing the light in less degrees, luminosity curves were produced corresponding to those of persons more or less red-blind.

Experiments were then made to ascertain whether this change in the relative luminosities of the different rays would continue to vary with constantly increasing intensity of the light, or whether a point would be reached after which the curve, when it had the same maximum ordinate, would be constant.

A beam being taken from one point in the spectrum, it was compared with the reference (white) beam. Rotating sectors were placed in both beams, and equality of luminosity thereby produced. The aperture of one set of sectors being varied, the alteration of the other which was necessary to re-establish the equality of illumination in each case was noted. Curves were then plotted for several rays, of which the ordinates represent the apertures in the coloured beams and the abscissæ those in the white beam when the illumination is equal. Clearly, if these curves ever became straight lines for all parts of the spectrum, the luminosity curve would become constant.

This was found to be the case. The curve of the beam from scale No. 46·3 of the spectrum (about λ 5613) was found to be straight from the origin. Those of beams of greater refrangibility were at first concave to the axis of abscissæ, those of less refrangibility convex; but all had become straight before an intensity of 1/60 of an amyl acetate lamp at 1 foot had been reached.

III. "On certain Ternary Alloys. Part V. Determination of various Critical Curves, and their Tie-lines and Limiting Points." By C. R. Alder Wright, D.Sc., F.R.S., Lecturer on Chemistry and Physics in St. Mary's Hospital Medical School. Received November 19, 1891.

The triangular method of graphical representation suggested by Sir G. G. Stokes, and described in Part IV ('Roy. Soc. Proc.,' vol. 49, p. 174), substantially amounts to the tracing out of a curve ("critical curve") which shall express the saturation of the solvent C with a mixture in given variable proportions of the other two constituents, A, B; the variation being such that any given point on the curve is related to some other point ("conjugate point") in a way given by the consideration that all mixtures of the three constituents, A, B, C, represented by points lying on the line ("tie-line") joining these two conjugate points ("ideal" alloys, or mixtures), will separate into two different ternary mixtures corresponding with the two points respectively; whereas any mixture of the same constituents, represented by a point lying *outside* the critical curve, will form a "real" alloy, or mixture, not separating spontaneously into two different fluids but existing as a stable homogeneous whole.

The experiments described in Part IV unmistakably point to the conclusion that *whenever sufficiently intimate and prolonged intermixture of the three constituents can be effected, there is no variation whatever* in the position of the point experimentally determined as conjugate to some other given point on the curve, no matter what may be the proportions subsisting between the three constituents employed; but that when metals are used, the practical difficulty in effecting thorough intermixture by stirring when molten is occasionally so great as to lead to slight, but sensible, differences in the composition of the ternary alloys formed simultaneously with some one given alloy approximately conjugate thereto, in different cases where the relative proportions of the constituents are materially different.

A large number of additional experiments on this point have been made, the general result of which is completely to corroborate and