It is often supposed that the reality of alchemy, the transformation of the base into the noble metals, was generally accepted by orientals. But, according to Herr E. Wiedemann (*Ann. der Phys.* No. 10), some of the most noted *savants* rejected the idea. In his Prolegomenon, Ibn Khaldûn maintains that the transformation of metals is impossible, the philosopher's stone cannot exist, and the study of alchemy is ruinous. His own views, however, interest us less than his citation of Avicenna and his school as opponents of alchemy. While Abn Nasir al Farâbi, an older philosopher, held that all metals belong to the same species, and differed only in accidents, so that a transformation of these into each other was possible, Avicenna maintained that the metals differed in species, and that their specific differences, ordained by God, were therefore not alterable by chemical operations. A noted alchemist, Togair, contended, against this, that the task of alchemy was not to impart these differences to metals, but only to alter the latter so that they might be enabled to acquire them; the means to this being the elixir. A great predecessor of Avicenna, Al Kindi, also appears to have opposed alchemy.

The additions to the Zoological Society's Gardens during the past week include two Vulpine Phalangers (*Phalangista vulpina*), a Rufous Rat Kangaroo (*Hypsiprymnus rufescens*) from Australia, presented by Mr. F. J. Horniman, F.Z.S.; a Ring-necked Parrakeet (*Palæornis torquata*) from India, presented by the Countess Dowager of Lonsdale; two Long-eared Owls (*Asio otus*), British, presented by the Rev. J. A. Wix; two Grey Wagtails (*Motacilla sulphurea*), British, presented by Mr. Swaysland; a Dufresne's Amazon (*Chrysotis dufresniana*) from South-East Brazil, a Yellow-cheeked Amazon (*Chrysotis autumnalis*) from Honduras, an Orange-winged Amazon (*Chrysotis amazonica*) from South America, deposited; a Pluto Monkey (*Cercopithecus pluto*), a Sykes's Monkey (*Cercopithecus albogularis*) from West Africa, a Darwin's Rhea (*Rhea darwini*) from Patagonia, a Picazuro Pigeon (*Columba picazuro*) from South America, two Spotted Zenaida Doves (*Zenaida maculata*) from La Plata, two Dominican Gulls (*Larus dominicanus*) from Antarctic America, purchased.

EXPERIMENTS ON COLOUR[1]

In a former paper with the above title (Nature, vol. iii. p. 234) I described some combinations of absorbing media capable of transmitting the red and green, while stopping the other rays of the spectrum. In this way I obtained a *purely compound* yellow, made up of red and green, and free from homogeneous yellow light. In devising such combinations we have in the first place to seek an absorbing agent capable of removing the yellow of the spectrum, while allowing the red and green to pass. For this purpose I used an alkaline infusion of litmus, or solution of chloride of chromium, placed in a trough with parallel glass sides. In order to stop the blue rays we may avail ourselves of chromate of potassium. If a second trough be not objected to, it is best to use the bichromate, as exercising the most powerful absorption upon the upper end of the spectrum; but the bichromate cannot be mixed with litmus without destroying the desired action of the latter upon yellow. In this case we must content ourselves with the neutral chromate.

During the last year and a half I have resumed these experiments with the view, if possible, of finding solid media capable of the same effects, and so of dispensing with the somewhat troublesome troughs necessary for fluids. With this object we may employ films of gelatine or of collodion, spread upon glass and impregnated with various dyes, gelatine being chosen when the dye is soluble in water, and collodion when the dye is soluble in alcohol. Thus in the case of litmus a slightly warmed plate is coated with a hot and carefully filtered solution of gelatine, allowed to remain in a perfectly horizontal position until the gelatine is set, and then put aside to dry, by preference in a current of warm air. The films thus obtained are usually somewhat rough upon the surface, so that I have preferred to use two pieces cemented together, coated sides inwards, with Canada balsam. In conjunction with the litmus we may employ a silver-stained orange glass, and so isolate the red and green rays. For the orange glass Mr. C. Horner has substituted a film of collodion stained with aurine. Samples possibly vary; but that which I have used, though extremely opaque to the blue green rays, and therefore so far very suitable for the purpose, allows a considerable quantity of the higher blue to pass. By spreading aurine upon a pale yellow glass, I obtained a very perfect absorption of the blue-green and higher rays. Plates prepared as above described answer the purpose very well; but I have found that in some cases the litmus in contact with the balsam becomes slowly reddened, the action creeping inwards from the edge. A dye, capable of replacing litmus, and free from this defect, is "soluble aniline blue," whose absorption, as I found rather unexpectedly, begins in the yellow and orange. Bichromate of potash and aniline blue may be mixed in the same solution, and there is no difficulty in so adjusting the proportions as to secure a good compound yellow. To obtain solid films gelatine must be used, as in the case of litmus, for the dye is not soluble in collodion. With aniline there is no difficulty from the Canada balsam, and two plates cemented together answer perfectly.

For systematic observations on compound colours nothing probably can be better than Maxwell's colour box in its original form; but it seemed to me that for the examination of certain special questions a more portable arrangement would be convenient. In an instrument of this class a full degree of brightness requires that the width of the eye-slit, placed where the spectrum is formed, should not contract the aperture of the eye, *i.e.* should not be less than about one-fifth of an inch; and although the maximum of brightness is not necessary, considerations of this kind largely influence the design. If we regard the width of the eye-slit as given, a certain length of spectrum is necessary in order to attain the desired standard in respect of purity of colour; so that what we have to aim at is a sufficient linear extension of the spectrum. A suitable compromise can then be made between the claims of brightness and purity.

The necessary length of spectrum can be obtained by increasing either the angular dispersion of the prisms or the focal length of the lens by which the image is formed. If portability be no object, the latter is the preferable method, and the focal length may well be increased up to five or six feet; in this way we may obtain a field of view of given purity of colour and of maximum brightness, at the expense only of its angular extent. If, however, we desire an instrument which can be moved from one place to another without losing its adjustment, the focal length of the lenses must be kept down, and then a large prismatic dispersion is the only alternative.

Increased dispersion can of course be obtained by multiplication of prisms; but for the purpose in view, high resolving power is not wanted, and our object may be attained with a comparatively small total thickness of glass, either by the use of higher angles than usual, or by giving the light a more nearly grazing emergence. The latter was the course adopted in designing the first instrument of which I have to speak. A pair of prisms of 60°, cut from an ordinary single $1\frac{1}{4} \times 1\frac{1}{4}$-inch prism along a plane bisecting at right angles its refracting edge, were arranged in the corner of a shallow box, so as to form what Thollon calls a *couple*. Considered as a simple, rigidly connected refractor, the pair of prisms are placed so as to give minimum deviation, but the incident and emergent light makes smaller angles with the final surface, than if each prism were adjusted separately for minimum deviation. The collimating and focussing lenses are common spectacle glasses of about 8″ focus. The box is 12″ × 12″ × 3″ Light entering at a slit on one of the sides of the box would be turned by the prisms through an angle rather greater than a right angle, and throw a pure spectrum upon another side of the box. This side is cut away, and provided with movable screens of cardboard, so that any part may be open or closed as desired. When the eye is applied to the first slit, the prisms are seen uniformly illuminated with colours whose composition depends upon the situation and width of the slits between the cardboard screens through which light is allowed to enter. In this way we may obtain a uniform field of view lighted with any combination of spectral colours. My object, however, was to obtain an instrument for making comparisons between the simple and compound yellow, and for this purpose an addition was necessary. This consisted

[1] Read before Section A of the British Association, September 2, 1881, by Lord Rayleigh, F.R.S.

of a very acute-angled prism held close to the dispersing prisms in such a position that its refracting edge was horizontal, dividing the field of view into two equal parts. The action of this prism is most easily understood by again supposing the light to enter at the eye-slit. Half of the light proceeds as before, forming ultimately a pure spectrum upon the side of the box. The upper half of the beam, however, is deflected by the acute-angled prism, and the corresponding spectrum is thrown upwards, so as to lie somewhat higher upon the side of the box. This part is also cut away, and provided with movable screens. By the principle of reversibility the consequence is that an eye placed at the first slit sees *two* uniform patches of colour, the lower formed as before by light from the lower set of slits, the upper, covering the acute-angled prism, by light from the upper set of slits. These colours are in close juxtaposition, and may be compared with ease and accuracy.

The great difficulty in this class of instruments is to devise any efficient and reasonably simple method of controlling the position and widths of the slits. In the present case I contented myself with strips of blackened cardboard cemented to the side of the box with sealing-wax, or soft wax, according to the degree of permanence of adjustment aimed at. One part of the field was illuminated with homogeneous yellow (about the line D) from a single slit. The other half was lighted with a mixture of full red and full green, and the observation consisted in adjusting the widths of the slits through which the red and green were admitted, until the mixture was a match with the simple yellow.

The first trials of this instrument in the spring of last year revealed an interesting peculiarity of colour vision, quite distinct from colour blindness. The red and green mixture which to my eyes and to those of most people matches perfectly the homogeneous yellow of the line D, appeared to my three brothers-in-law hopelessly too red, "almost as red as red sealing-wax." In order to suit their eyes the proportion of red had to be greatly diminished, until to normal sight the colour was a fair green with scarcely any approach to yellow at all. So far as could be made out at the time, the three abnormal observers agreed well among themselves, a fact which subsequent measurements have confirmed. It appeared afterwards that a fourth brother was normal as well as the three sisters.

These peculiarities were quite unexpected. After the fact had been proved, I remembered a dispute some years before as to the colour of a dichromatic liquid, which appeared to me green, while one of my brothers-in-law maintained that it was red; but the observation was not followed up, as it ought to have been, each of us, I suppose, regarding the other as inaccurate. After the establishment of the difference I determined to carry out a plan, which I had tried with success some years before (October 1877), for a colour-mixing arrangement depending on double refraction, by which I hoped to obtain an easily adjustable instrument suitable for testing the vision of a number of persons.

In my original experiments I used a 60° doubly refracting prism of quartz, which threw two spectra of the linear source upon the screen containing the eye slit. These oppositely polarised spectra partially overlapped, and by suitable placing of the prism could be made to furnish red and green light to the eye. By the rotation of a small Nicol held immediately behind the eye slit, the red or green could be isolated or mixed in any desired proportion. One advantage of this arrangement is that the two component lights come from the same slit, so that we are less dependent upon the uniformity of the light behind; but it is perhaps a greater merit that the adjustment of proportions is effected by simple rotation at the eye slit, allowing the observer to try the effect of small changes with ease and rapidity.

In the new instrument, which was completed during the autumn of last year, separate prisms were used to effect the dispersion and double refraction. For the sake of compactness, a direct vision prism by Browning, containing two flints and three crowns, was chosen, in conjunction with a small achromatic double image prism. At one end of a long narrow box, 24" × 2" × 2", the light is admitted through a slit whose position and width can be adjusted by sliding its jaws along a divided scale. After travelling about $9\frac{1}{4}$" it falls upon the double image prism mounted upon a small table so as to allow of rotation, and then after two more inches upon a collimating lens, by which the two beams are rendered parallel. Next comes the dispersing prism, and then the focussing lens, throwing pure spectra upon the other end of the box, which carries the eye slit. The distance between the two lenses is $3\frac{1}{2}$", and the entire length of the box is about 24". The eye slit is a fixture, and immediately behind it is the rotating Nicol, whose position is read by a pointer on a divided circle.

The parts of the spectrum from which the component lights are taken can be chosen over a sufficient range by use of the two adjustments already mentioned. By rotation of the table on which the double image prism is mounted, the separating power is altered, and one spectrum made to slide over the other, while by moving the entrance slit the spectra are shifted together without relative displacement.

It yet remains to describe the parts by which the comparison colour is exhibited. Between the double image prism and the collimating lens a small vertical reflector is mounted on a turn-table at an angle of about 45°. Its dimensions are such that it covers the lower half of the field of view only, leaving the upper half undisturbed, and its function is to reflect light coming from a lateral slit through the dispersing prism so as to throw a third spectrum upon the eye. The lateral slit is carried in a small draw tube projecting about 2" from the side of the box, and the light proceeding from it is rendered nearly parallel before reflection by a lens of short focus. No adjustment is provided for the position or width of the lateral slit; all that is necessary in this respect being attainable by rotating the mirror and by varying the brightness of the light behind. As sources of light I have found Argand gas flames, surrounded by opal globes, to be suitable. The gas tap supplying the lateral flame is within reach of the observer, who has thus the means of adjusting the match both with respect to colour and with respect to brightness, without losing sight of the subjects of comparison. The zero of the divided circle corresponds approximately to the complete exclusion of green, but readings were always taken on both sides of it so as to make the results independent of this adjustment. The circle is divided into 100 parts, green being excluded at 0 and 50, and red at 25 and 75. Tenths of a division could be estimated pretty correctly, an accuracy of reading fully sufficient for the purpose, as the observations of even practised observers would vary two or three-tenths.

It is evident that the numbers obtained are dependent upon the quality of the light by which the principal slit is illuminated. In order to avoid errors in the comparison of different persons' vision arising from this source, it is advisable always to take simultaneous observations from some practised individual whose vision may be treated as a standard; but no evidence appeared of any variation in the quality of the gaslight. The special application of such instruments to the comparison of the qualities of various kinds of mixed light was alluded to at the end of my paper "On the Light from the Sky," &c. (*Phil. Mag.*, April, 1871).

I have obtained matches between simple and compound yellow from twenty-three male observers, principally students in the laboratory. Of these sixteen agree with myself within the limits of the errors of observation. The remaining seven include my three brothers-in-law, and two others, Mr. J. J. Thomson and Mr. Threlfall, whose vision in this respect agrees very nearly with theirs. The vision of the other two observers differs from mine in the opposite direction. In one case the difference, though apparently real, is small, but in the other (Mr. Hart), though there was some difficulty in getting a good observation, the difference is most decided. Among seven female observers whom I have tried, there is not one whose vision differs sensibly from my own.

Although the number examined is insufficient for statistical purposes, it is evident that the peculiarity is by no means rare, at least among men. As far as my experience has gone, it would seem too as if normal vision were not of the nature of an average, from which small deviations are more probable than larger ones; but this requires confirmation. In order to give a more precise idea of the amount of the difference in question, I have calculated from the laws of double refraction the relative quantities of red and green light required by Mr. F. M. Balfour and myself to match the same yellow light. If we call R and G the maximum brightnesses of the red and green light (as they would reach the eye if the Nicol were removed), and r, g the actual brightnesses (as modified by the analyser) necessary for the match, then for Mr. Balfour—

$$r/g = 1{\cdot}50\,(R/G),$$

while for myself—

$$r/g = 3{\cdot}13\,(R/G).$$

In other words, Mr. Balfour requires only half as much red as myself, in order to turn a given amount of green into yellow.

The corresponding numbers for the other four observers of this class would be substantially the same. On the other hand, Mr. Hart requires much *more* red than I do in order to convert a given green into yellow—in the ratio of about 2·6 : 1.

Except in the case of Mr. Hart, the colour vision of these observers is defective only in the sense that it differs from that of the majority. Their appreciation of small colour differences is as distinct as usual. In order to test this Mr. G. W. Balfour made a complete series of colour matches with revolving disks in the manner described by Maxwell and in my former paper. Six matches, of which only two are really independent, were observed, the consistency of the set being a measure of the accuracy of observation. The average error proved to be only double of that which I have found in my own observations, and rather less than that usually met with in the case of observers whose vision is normal.

In connection with what has been described above with respect to trichromic vision, it is interesting to notice that corresponding and perhaps larger differences are to be found in the vision of the so-called colour-blind. The double-refraction apparatus may conveniently be used in this investigation. With the pointer adjusted to 0 or 25, we have in the upper half of the field pure red or pure green respectively, and in the lower half pure yellow as usual. By suitable adjustment of the gas taps two observers of this class, Mr. T—— and Mr. B——, are able to obtain perfect matches both between red and yellow, and between green and yellow, but the proportions necessary are very different for the two observers. In Mr. T——'s red and yellow match, the red is to normal vision dazzlingly bright, and the yellow almost too dark to be recognised; while the green and yellow match, however extravagant as to hue, appears reasonable in respect of brightness. On the other hand, to Mr. B——'s eyes, the red of the spectrum does not look nearly so dark, and the equivalent red and yellow appear to the normal eye to be much more nearly upon a level. Although these great differences exist, there is no doubt that the vision of both observers is strictly dichromic, and that, apart from brightness, all the rays of the spectrum, from red to green, have the same effect upon their eyes.

If we wish to go beyond the fact that this vision is dichromic, and inquire whether the case is one of red blindness or of green blindness, we must be careful to consider whether the question itself has a definite meaning. If trichromic vision were always the same, and if a particular case of colour-blind vision differed from it merely by the absence of the red sensation, that vision would intelligibly be characterised as red-blind. There is reason to believe that such cases exist. In all probability the suppression of my own red sensation would lead me to make matches very nearly the same as Mr. T——'s; and in this sense he may fairly be called red-blind. But under the same circumstances my matches would be altogether rejected by Mr. B——; and the question may be asked, whether his case, being certainly not one of simple red-blindness, can be brought under the head of green-blindness. To this the sufficient answer is that if I became green-blind my matches would differ from those of Mr. B—— far more than if I was red-blind. The test of green-blindness would be the possibility of matches between colours which to normal eyes appear green and purple, or green and grey. Although a good deal has been said lately on this subject, I am not aware of a case in which accurate matches of this kind have been obtained from observers whose colour-vision is in other respects acute. If such cases exist, inquiry should be instituted, in order to see how far the matches would correspond to green-blindness of an otherwise normal eye.

We see, then, that there is dichromic vision which cannot accurately be described as affected with red-blindness, and still less as affected with green-blindness. The difference from normal vision, being not simply one of defect, cannot be defined by any single phrase. To obtain a complete knowledge of it quantitative observations over the whole spectrum, such as those carried out by Maxwell, are necessary. It is fortunate that these observations are easier to arrange for dichromic than for trichromic vision.

That I might be able to form an opinion upon the general acuteness of his colour vision, Mr. T—— was good enough to observe a series of five colour matches between red, white, blue, green, and yellow, one being left out each time. The results are given in the accompanying table; those marked "calculated" being a consistent set derived by elimination from the two marked A and B. The good general agreement of the two sets of numbers is a proof that within its restricted range Mr. T——'s sense of colour is acute. The first observation in which a mixture of red and white is matched by a mixture of green and blue is the most characteristic.

	Red.	White.	Blue.	Green.	Yellow.	Dec. 2, 1880.
(1)	76·2	23·8	−23·3	−76·7	0	Observed
	77·4	22·6	−21	−79	0	Calculated
(2)	56·6	43·4	−52·3	0	−47·7	Observed
	56·2	43·8	−52·5	0	−47·5	Calculated
(3)	68·2	5·5	0	−100	26·3	Observed
	69·7	6·5	0	−100	23·8	Calculated
(4)	60·3	0	8	−100	31·7	Observed
	61·2	0	7·8	−100	31	Calculated
(5)	0	32·5	−43·5	67·5	−56·5	Observed
	0	32·3	−44·1	67·7	−55·9	Calculated
A	522	424	−511	35	−470	—
B	641	405	−470	−199	−377	—

In conclusion I will describe an apparatus by which it is possible to observe these colour-matches without rotating the disks. At the time of my first experiments, about ten years since, I was struck with the advantage which might ensue if it were possible to have the mixed colours in view during the time of actual adjustment, and I thought of a plan by which this object might be attained. The idea, which I carried out soon afterwards, was to spin an *image* of the disks instead of the disks themselves. An inverting prism was mounted in a tube which could be made to rotate. The axis of rotation is adjusted so as to point accurately to the centres of the disks mounted as usual. An eye applied to the prism sees the disks undisplaced as a whole, but inverted by reflection. As the tube rotates, the image of the disks rotates also, and with double angular velocity. When the speed is sufficient, the colours lying on any circle concentric with the disks are blended exactly as if the disks themselves revolved.

This apparatus is quite successful; but its real advantages of working at a smaller velocity, and of allowing adjustment while the rotation continues, are counterbalanced in practice by the inconvenience of having to look through a tube, and the uncertainty introduced by the possible disturbance of the match due to unequal illumination of the area occupied by the disks.

MAGNETIC DISTURBANCES, AURORAS, AND EARTH CURRENTS[1]

THE object of establishing a magnetic observatory is to determine at any instant the direction and magnitude of the earth's magnetic force. The direction of the magnetic force of the earth is the direction in which a small magnetic needle would point when it is freely suspended, so as to turn about an axis passing through its centre of gravity. But it is not easy to suspend a magnetic needle so as to turn freely and yet to be sure that the axis about which it turns passes accurately through the centre of gravity of the needle, and if it does not so pass, then on suspending the needle we have not only the magnetic force but also the gravitating force of the earth acting upon it to turn it about its axis, and the position which it takes up shows us the direction of these combined forces upon the magnetic needle.

This direction depends upon the mass of the needle, for to that its weight is due; it depends upon the form of the needle and the position of its centre of gravity with regard to the axis on which it is hung; it depends also on the magnetic properties of the substance, so that it is not easy to determine even the direction of the magnetic force by a plan which theoretically is so very simple. Instead of attempting to make the required determinations by such a method it is necessary that a steadier mode of suspension should be adopted, and that may be done as soon as it is discovered in what vertical plane the force of gravity,

[1] Lecture delivered at the Royal Institution on Friday evening, June 3, 1881, by Prof. W. Grylls Adams, F.R.S.