ethyl chloride boiling at 12°, ethyl fluoride at − 32°, propyl chloride boiling at + 45°, ethyl fluoride at − 2°.

Similar observations have been previously made by Paterno and Oliveri, and by Vallach and Heusler. These facts can also be connected with the experiments of Gladstone on atomic refraction. Finally, although clearly a member of the chlorine group, fluorine in some of its properties also presents some analogies to oxygen. The whole of these observations appear to clearly establish that fluorine would only with difficulty be reduced to a liquid, and it has already been shown by one of us that at − 95°, under ordinary pressure, it does not change its state.

In the new experiments that we now publish, the fluorine was prepared by the electrolysis of potassium fluoride in solution in anhydrous hydrofluoric acid. The fluorine gas was freed from the vapours of hydrofluoric acid by passing it through a small platinum spiral cooled by a mixture of solid carbon dioxide and alcohol. Two platinum tubes filled with well-dried sodium fluoride completed this purification. The liquefaction apparatus consisted of a small cylinder of thin glass, to the upper part of which was joined a platinum tube. The latter contained another small tube of the same metal. The gas to be liquefied arrived by the annular space, passed into the glass bulb, and passed out again by the inside tube. This apparatus was united to the tube which led in the fluorine.

In these experiments we have used liquid oxygen as the refrigerating substance. This oxygen was prepared by the methods described by one of us, and these researches have necessitated the employment of several litres of this liquid. The apparatus being cooled to the temperature of quietly-boiling oxygen (− 183°), the current of fluorine gas passed into the glass bulb without liquefying; but at this low temperature the fluorine had lost its chemical activity, and no longer attacked glass.

If now the pressure on the boiling oxygen be reduced, it is seen, as soon as rapid ebullition is produced, that a liquid trickles down the walls of the glass bulb, whilst no gas issues from the apparatus. At this moment, the exit tube is closed with the finger to prevent the entrance of any air. Before long the glass bulb becomes filled with clear yellow liquid possessing great mobility. The colour of this liquid recalls the tint of fluorine seen through a layer a metre thick. According to this experiment, fluorine becomes a liquid at about − 185°. As soon as the little condensation apparatus is removed from the liquid oxygen, the temperature rises and the yellow liquid begins to boil, furnishing an abundant evolution of a gas which presents all the energetic reactions of fluorine.

We have taken advantage of these experiments to study some of the reactions of fluorine upon bodies maintained at very low temperatures. Silicon, boron, carbon, sulphur, phosphorus, and reduced iron, cooled in liquid oxygen, and then projected into an atmosphere of fluorine, do not become incandescent. At this low temperature, fluorine does not displace iodine from iodides. Its chemical energy, however, is still sufficiently great to decompose turpentine or benzene with production of flame even at − 180°. It would seem that the powerful affinity of the fluorine for hydrogen is the last to disappear.

Finally, there is one other experiment that we ought to mention. When a current of fluorine gas is passed into liquid oxygen, there is rapidly produced a white flocculent deposit, which soon settles at the bottom of the vessel. If the mixture is shaken and poured on a filter, this precipitate is separated. It possesses the curious property of deflagrating violently as soon as the temperature rises. We are pursuing the study of this compound, as well as that of the liquefaction and solidification of fluorine, in which further experiments are required.

A NEW DETERMINATION OF THE GRAVITATION CONSTANT AND THE MEAN DENSITY OF THE EARTH.

An account of a new determination of these quantities, carried out in a very careful manner by Dr. C. Braun, S.J., at Mariaschein in Bohemia, has just been published in the *Memoirs* of the Vienna Academy (Bd. lxiv., Math. Nat. Classe).

Dr. Braun has been engaged on the work since 1887. He used the torsion-rod method, and though his apparatus was considerably larger than that of Prof. Boys, it was still much smaller than the older apparatus of Cavendish, Reich, or Baily. The rod was about 24 cm. long, and was suspended from a tripod by a brass torsion wire, nearly 1 metre long and 0·055 mm. in diameter. The whole torsion arrangement was under a glass receiver, about a metre high and 30 cm. in diameter, resting on a flat glass plate. The receiver could be exhausted, and in the later experiments the pressure was about 4 mm. of mercury, and the disturbances due to air currents were very greatly reduced. The attracted masses at the end of the rod were gilded brass spheres, each weighing about 54 grammes. Round the upper part of the receiver, and outside it, was a graduated metal ring, which could be revolved about the axis of the torsion wire, and from this were suspended, about 42 cm. apart, the two attracting masses. Two pairs were used: one a pair of brass spheres about 5 kgms. each, the other, a pair of hollow iron spheres, filled with mercury, and weighing about 9 kgms. each.

To determine the position of the torsion-rod, a mirror was fixed on the centre of the rod, and immediately in front of it was a mirror at 45° to the horizontal, throwing the reflexion down through the base plate on to the horizontal objective of the observing telescope; another mirror, immediately under the lens, was inclined at 45°, and sent the beam horizontally on to a graduated glass scale in the focal plane of the eyepiece. The object of which the image was viewed was an index mark on a plate placed horizontally just below the scale, and the light from it was made to traverse the axis of the telescope outwards by reflexion at a parallel plate of glass at 45° to the horizontal. As the index mark was nearly at the same distance from the objective as the scale, the rays fell nearly parallel on to the torsion-rod mirror, and the angular value of the scale divisions was determined from their length and the distance of the scale from the objective. It was also determined by a theodolite, viewing the scale through the object-glass, and found to be about 3½ min.

The instrument was fixed on a stone slab, in the corner of a room with very solid walls, and protected from temperature variations and electrical effects by a casing of cloth and tinplate.

As there was a continuous creep of the torsion-rod in one direction, amounting in the course of years to several lengths of the scale, it was necessary to have some method of moving the torsion-head. This was effected from outside the receiver in a very ingenious manner. A plate was fixed on a part of the torsion-head which did not revolve, and to this was attached a clock from which the escapement was removed, and on the axis of the escapement-wheel was fixed a small magnet. On the axis, where the driving spring had been, a pinion was fixed, gearing with a large wheel attached to the torsion-head. The magnet could be turned round by moving a magnet outside the receiver, and so the torsion-head could be slowly revolved. The gearing-down was such that, if the minute finger of the clock moved one minute, the image of the index in the telescope moved one scale division.

Vibrations of the torsion-rod were started by a light magnetised fork, which could be made to softly touch the rod on either side by the motion of a magnet outside the receiver.

The moment of inertia of the rod was determined, both by calculation and experiment, with very satisfactory agreement, and all the linear measurements of the apparatus, and of the distances, were made very carefully by horizontal and vertical cathetometers. Ingenious reflexion devices were used for measurements, which were made through the walls of the receiver.

Dr. Braun used both the deflexion method of Cavendish, and the oscillation method first used by Reich, to whom it was suggested by Forbes. In the deflexion method the attracting masses are placed outside the case, in such positions that their pulls on the attracted masses twist the rod round. The deflexion is observed, and the value of the corresponding torsion couple is determined by the time of vibration of the system. When the rod is deflected it does not, of course, take up its new position in a "dead beat" manner, but oscillates about it. The usual method of determining the centre of swing has been to observe successive elongations or turning-points, and by combining these in threes to eliminate the effect of decrement, and so to deduce the centre. But Dr. Braun found the centre more accurately by observing the times of transit of several scale divisions near the centre, in both directions. By interpolation he could determine the point about which the time of oscillation in either direction was the same, and this was taken as the centre of swing. The deflexion observed was about 13 divisions of the scale. The times of transit were registered on a chronograph.

The wire showed a certain amount of elastic after-action, and by subsidiary experiments on a similar wire this was as far as possible allowed for.

In the oscillation method the attracting masses are placed in a line with the torsion-rod, one at each end. Their attractions then act, not to deflect the rod, but to increase the restoring force, and so to lessen the time of vibration. The attraction is determined by comparing the times of vibration when the masses are in position, and when they are removed, or when they are placed so that the line joining their centres is at right angles to the rod.

The time of vibration observed by Dr. Braun was about 1275 seconds, and when the masses were put in position this was altered by about 46 seconds.

The results obtained in the years 1892 and 1894 were finally used, and these gave for the mean density of the earth—

	1892	1894
Deflexion method	5·529 ...	5·526
Oscillation ,, ...	5·520 ...	5·531

Giving due weight to the various observations, the final result is practically identical with that of Prof. Boys', viz.:

$$\text{Mean density} = 5{\cdot}52725 \pm {\cdot}0012$$
$$\text{Gravitation constant } G = 665{\cdot}786 \times 10^{-10}$$

J. H. P.

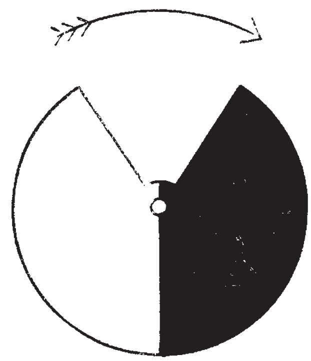
SUBJECTIVE TRANSFORMATIONS OF COLOUR.

IN a communication to the Royal Society on May 13, I described some curious experiments, showing how coloured objects might apparently be made to assume tints which were complementary to their actual hues—red, for example, appearing as green or greenish-blue, and green as pale red.

The phenomenon depends upon the rapid generation of negative after-images of the kind demonstrated by the familiar experiment with the red "wafer." If a red wafer lying upon a sheet of white paper is looked at steadily for about half a minute, and the gaze is then suddenly transferred to some other part of the paper, a greenish-blue ghost of the wafer will be seen. The portion of the retina upon which the red image at first falls becomes fatigued and partially insensible to red light; it is therefore unable to appreciate the red component of the white light afterwards reflected to it, and the sensation of the complementary colour consequently predominates.

The new experiments indicate that the preliminary stare may, under certain conditions, be an exceedingly brief one. In a paper published three years ago (*Proc. Roy. Soc.*, vol. lvi. p. 132) I called attention to an observation indicating that a short period of darkness imparts to the retinal nerves a degree of sensitiveness, which is far above the normal average in the light, and which quickly passes away again under the influence of illumination. This peculiar sensitiveness is in fact both acquired and lost in a small fraction of a second, and is therefore very favourable for the rapid production of negative after-images.

Let two small screens—one black and the other white—be held together in one hand, and arranged so that there may be a triangular gap between them. Let the black screen first cover the paper upon which the wafer is lying; this will darken a portion of the retina, and render it sensitive. Then let the screens be quickly moved sideways, so that the wafer may for a moment be exposed to view through the gap, the movement being stopped as soon as the paper is covered by the white screen. A bright but evanescent greenish-blue ghost will succeed the red impression. But the curious thing is that if the illumination is strong, and the screens are moved at the proper speed, no trace of red will be seen at all; it will appear exactly as if the actual colour of the wafer were greenish-blue. The action of light after a short period of darkness seems to have the power of appreciably diminishing the sensibility of the retinal nerve-fibres in a space of time so short, that if the light be coloured its colour is not consciously perceived. I am informed that analogous phenomena have been observed in other branches of physiology; a well-defined reaction sometimes occurs when no direct evidence can be detected of the existence of the excitation to which the reaction must have been due.



By the use of a rotating disc having a black and white[1] surface and an open sector, as in the annexed figure, the effect can be shown continuously. The disc is made to turn some six or eight times in a second, while its front surface is strongly illuminated either by bright diffused daylight or by a powerful lamp. An incandescent lamp of 32 candle-power at a distance of six inches gives excellent results; it should be placed opposite the disc, and should be provided with a small tin reflector to protect the eyes from the glare. A red card placed behind the disc is made to appear green, a green card pink, and a blue one yellow, while a black patch painted upon a white ground appears whiter than the ground itself. At the conversazione of the Royal Society on May 19, I exhibited some designs which had been prepared for the purpose of demonstrating the phenomenon in a striking manner. Among them was a picture of a lady with indigo-blue hair, an emerald-green face, and a scarlet gown, who was represented as admiring a violet sunflower with purple leaves. Seen through the disc the lady's tresses appeared flaxen, her complexion a delicate pink, and her dress a light peacock-blue, while the petals of the sunflower became yellow and its leaves green. Other designs showed equally remarkable transformations of colour.

SHELFORD BIDWELL.

[1] A pale brownish-grey tint is better than pure white.