Habits of the Cuckoo.

ONE day last week I was in my garden—a not particularly private country one—when I heard a cuckoo close by, and, standing quite still, I saw the bird alight upon an apple tree not more than four yards from me. The bird did not appear to object to my close proximity, for it uttered its call "cuckoo" twice. Its mate then came and sat in a plum tree only five yards from me, on the opposite side of me; one of them had a caterpillar in its mouth. Then a blackbird came into another tree in a state of great excitement uttering its "pink pink," as I supposed, at the cuckoos; and the question arose in my mind, "Does the cuckoo feed its own young, and was that in the blackbird's nest?" Can any of your readers help me?

WM. H. WILSON.

Gloucester House, Sudbury, Harrow, June 19.

Economic Entomology.

CAN you tell me where I can get information as to the present condition of economic entomology in this country, more especially as to methods of research usually adopted?

Z.

MAGNETIC PERTURBATIONS OF THE SPECTRAL LINES.[1]

THE subject which we are about to consider this evening forms a connecting link between two of the most interesting branches of human knowledge—namely, that which treats of magnetism and that which treats of light. Almost as soon as the properties of magnets became known, mere curiosity alone must have prompted philosophers to ascertain if any relation existed between magnetism and "the other forces of nature," as they were generally termed. We are consequently led to expect amongst the records of early experimental investigations some accounts which treat of the action of magnetism on light.

Early Experiments.

When we seek for such accounts, however, we find that they are almost wholly absent from the literature of science, and this arises, I believe, from the great difficulty of the investigation and from the circumstance that only negative results were obtained, rather than that no such inquiry suggested itself or was undertaken. Even in quite recent times this inquiry has been prosecuted, but without success, by physicists who have published no account of their experiments. We may take it, therefore, that the inquiry is in itself an old one, although it is only now that it has been carried to a successful issue.

The earliest recorded attempt to solve this problem with which we are acquainted, is that of a celebrated British physicist whose name must for ever shed lustre on the annals of the Royal Institution—I speak of Michael Faraday. In order to understand the nature of the investigation which Faraday took in hand, and which has led up to the discourse of this evening, it is best to consider briefly some elementary facts concerning magnetism and light.

Magnetic Field of Force.

In the first place, I shall assume that we know in a general way what the peculiarities of a body are which lead us to say that it is magnetised, or a magnet. These are that, when freely suspended, it sets itself in a definite direction over the earth's surface, as illustrated by the compass needle, and that in the space around it there is "magnetic" force exerted on pieces of iron, and, in a smaller degree, on other substances. For this reason, we say that a magnet is surrounded by a magnetic field of force. The field of force is simply the space surrounding the magnet, and it extends to infinity in all directions from the magnet. Near the magnet the force is strong, and far away from it the force is almost insensible; and so we say that the field is strong at certain places near the magnet, and that it is weak at places far away from the magnet. The direction of the force at any point is the direction in which the north pole of another magnet would be urged if placed at that point, and the push which this pole experiences may be taken to represent the intensity or strength of the magnetic field at the point in question. This is represented diagrammatically by these drawings [referring to figures suspended before the audience], which show roughly the nature of the field of force surrounding an ordinary bar magnet, a horse-shoe magnet, and the much more powerful form—the electro-magnet. It will be seen that the space outside the iron is filled with a system of curved lines running from the north pole to the south pole of the iron core. Where the lines are closest together there the magnetic force is strongest, and the direction of a line at any point is the direction of the resultant magnetic force at that point—that is, the direction in which a north pole would be urged if placed at that point.

Faraday always pictured the magnetic field as filled with lines of force in this way, and the importance of the conception can scarcely be over-rated, for it leads us to view the magnetic action as being transmitted continuously through the intervention of some medium filling all space, rather than by the unintelligible process of direct action at a distance. This medium is called the ether; but as to what it is that is actually going on in the ether around a magnet, we cannot definitely say. It may be that there is a flow of ether along the lines of magnetic force, so that there is an out-flow at one end of the magnet and an in-flow at the other, or it may be that the ether is spinning round the lines of force in the magnetic field. For our present purpose, it is not a matter of very much importance what the exact condition of the ether may be in a magnetic field, for if the ether in a magnetic field is either in some peculiar condition of strain or of motion, and if light consists of an undulatory motion propagated through this same ether, then it may be naturally expected that some action should take place when light is propagated through, or radiated in, a magnetic field of force. This is what Faraday suspected, and in order that we may appreciate the problem with which he had to deal, let us place ourselves in his position and ask ourselves the question: "In what manner can we test experimentally if there is any magnetic action on light?"

Tests for Magnetic Action on Light.

In answer to this question, the first thing that occurs to us is to pass a beam of ordinary light through the magnetic field, in some chosen directions, and examine by all the means at our disposal if any action has taken place. When this is done we find that no observable effect is produced. But the scientific investigator does not rest satisfied with one negative result. He varies the conditions of the experiment, and returns to the attack with renewed vigour and hopes. In our first trial we passed a beam of light through the air-filled space around the magnet, and we may vary this experiment either by removing the air altogether, and so causing the beam to traverse a vacuum, or we may replace the air by some dense transparent substance such as glass or water. Under these new conditions, we still fail to detect any influence of the magnetic field on a beam of ordinary light. This negative result might arise from the field of force being too weak to produce an observable effect, or it might be that the effect, if any effect really does exist, may be of such a character that it is impossible to detect it with ordinary light. In common light, the vibrations take place indifferently in all directions around the ray, and follow no law or order as to their type. They

[1] Friday evening discourse delivered at the Royal Institution, May 12, by Thomas Preston, M.A., D.Sc., F.R.S.

possess no permanent relation to any direction around the ray, so that if the magnetic action should happen to be a twisting of the vibrations round the ray, it will be impossible to detect this twist in the case of ordinary light.

The Faraday Effect.

As a matter of fact it is a twist of this kind that actually happens, and this is probably what Faraday anticipated. In order to detect it, therefore, it is necessary to employ a beam of light in which the vibrations are restricted to a single plane passing through the ray. Such light is said to be plane polarised, and may be obtained by transmitting common light through a doubly refracting crystal. Faraday found that when a beam of this plane polarised light is passed through the magnetic field, in the direction of the lines of force, a distinct effect takes place, and that the effect is a twisting of the plane of polarisation of the light vibrations as they pass through the magnetic field, or, to be more precise, as the light passes through the matter occupying the field.

This is the Faraday effect. Its magnitude depends on the strength of the field, and upon the nature of the matter through which the light passes in that field. This latter is an important fact that should not be lost sight of in reasoning upon the nature of this effect. The presence of matter in the field appears to be necessary. The effect is not observed in a vacuum, but becomes greater as the field becomes filled with matter of greater density. It is therefore not a direct action of the magnetic field on the light vibrations, but rather an indirect action exerted through the intervention of the matter which occupies the magnetic field.

This action, as we have said, is a rotation of the plane of polarisation of the beam of light, and it arises from the circumstance that in passing through the magnetic field vibrations which take place from right to left do not travel forward with the same velocity as those which take place from left to right. There is no change in the periods of the vibrations, it is essentially a change of velocity of propagation that occurs. If we examine the transmitted light with a spectroscope, we find that the wave-lengths are unaltered, but that the amount of rotation of the plane of polarisation is different for waves of different lengths. The law which governs the effect is that the rotation of the plane of polarisation varies inversely as the square of the wave-length of the light employed.

Second Form of Experiment (*Faraday and Fievez*).

You will have noticed that in the foregoing experiment the source of light was placed quite outside the field of magnetic force, while the beam of light was transmitted through the field for examination. Now we might place the source of light itself in the magnetic field, and then examine if the light emitted by it is in any way affected by the magnetic force. This variation of the experiment suggests itself at once, and was indeed also tried by Faraday—in fact, it formed his last experimental research of 1862, but without success. The same experiment has been tried, no doubt, by many other physicists with the same negative result.

The first recorded success, or at least partial success, was by M. Fievez in 1885. He placed the source of light—a gas flame impregnated with sodium vapour—between the pole-pieces of a powerful electro-magnet. This being done, the light radiated by the flame was passed through the slit of a highly dispersive spectroscope and examined. What M. Fievez observed was that the bright spectral lines became broadened by the action of the magnetic field on the radiating source. His account is, perhaps, somewhat confused, owing to his imperfect apprehension of the true nature of the phenomenon which he observed, but, without doubt, he observed a true magnetic effect on the radiated light—namely, this broadening of the spectral lines—but he did not convince the scientific world that he had made any new discovery, and so the matter fell into neglect until it was revived again in 1897 by the now celebrated work of Dr. P. Zeeman.

Work of Zeeman, Lorentz, and Larmor.

The credit which attaches to Dr. Zeeman's work is that he not only, after prolonged effort, succeeded in obtaining this new magnetic effect, but he also convinced the world that the effect was a true one, arising from the action of the magnetic field on the source of light. That Dr. Zeeman was able to do this was due, perhaps, as much to the present advanced state of our theoretical knowledge of this subject as to his own skill and perseverance as an observer; and this is a striking example of the great assistance which well-founded theory affords to experimental investigation. The theory connects the facts already known in reasonable and harmonious sequence, predicts new results, and points out the channels through which they must be sought. Without such scientific theory, this general systematic advance would be impossible, and new results would be stumbled on only by accident.

To see how this applies to our case, we revert to the fact determined by Dr. Zeeman—namely, that when the source of light is placed in a strong magnetic field the spectral lines become broadened (see Fig. 1). As soon as

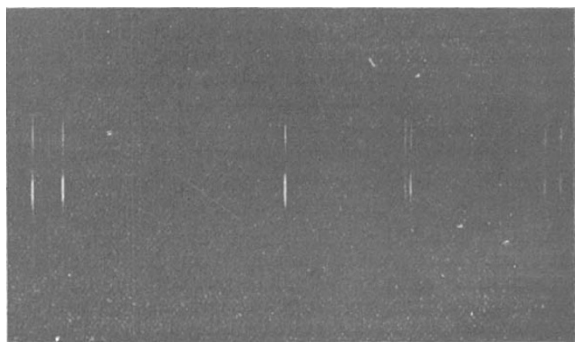

FIG. 1.—Shows the broadening of the spectral lines by the magnetic field. The upper row shows the lines when the magnet is not excited. The lower row shows the same lines when the magnet is excited. (Reproduced from a photograph, natural size.)

this was announced, Prof. Lorentz, and subsequently Dr. Larmor, examined the question from the theoretical point of view. They analysed the subject mathematically, and came to the conclusion that each spectral line should be not merely broadened, but should be actually split up into three—that is, each line should become three lines, or, as we shall say in future, a triplet. They also arrived at the further most important and interesting conclusion, viz., that the constituent lines of this triplet must be each plane polarised—the central line of the triplet being polarised in one plane, while the side lines are polarised in a perpendicular plane. In fact, the vibrations of the light forming the central line are parallel to the lines of magnetic force, while the vibrations in the side lines are perpendicular to the lines of force. This prediction of tripling and polarisation from theoretical considerations may be regarded as the key to the subsequent advance that has been made in the investigation of this region of physics. In order to understand it, let us place ourselves in Dr. Zeeman's position when he found that the spectral lines became broadened by the magnetic field, and let us be informed that this broadening is in all probability a tripling of the lines accompanied by plane polarisation. The question now is, "How are we to determine if this is the case?"

It is clear that if the broadened line is really a triplet, then the components of this triplet must be so close together that they overlap each other, and so appear to the eye merely as one broad line, as illustrated by the model which is here before you. [Model illustrating the overlapping shown here.] We know that the spectral lines are not infinitely narrow lines, but are really narrow bands of light of finite width, and consequently we are quite prepared to regard the magnetically broadened line as an overlapping triplet, but we cannot remain satisfied until we have proved beyond all doubt that it really is a triplet, and not merely a single broad line. To do this, Dr. Zeeman made use of the second prediction of the theory—namely, that the constituents of the triplet must be plane polarised. If this is so, then the outer edges of the broadened line must be plane polarised, and therefore by introducing a Nicol's prism into the path of the light it must be possible to turn the Nicol so that the plane polarised edges shall be cut off, and the breadth of the line shall be reduced to its normal amount. In fact in this position of the Nicol the outside lines of the triplet are extinguished, and the central component alone remains. This component is, of course, the same in width as the original line, and consequently when the outer members of the triplet are extinguished all the magnetic broadening of the line is removed. When the Nicol is turned through a right angle the central component of the triplet is extinguished, while

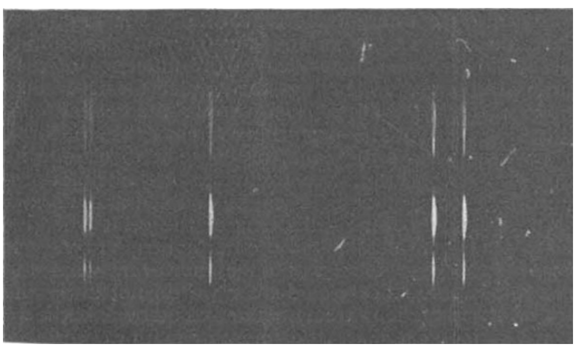

FIG. 2.—The lower row shows the lines uninfluenced by the magnetic field. The row next above shows the same lines broadened by the magnetic field. The top double row shows the analysation by a Nicol's prism. (Reproduced natural size.)

the side lines remain, and, if these side lines are sufficiently separated, so that they do not overlap, then, when the central line is removed, a narrow dark space will exist between the side components, which represents the space intervening between the outer members of the triplet, as illustrated by Fig. 2.

But even though we may be able to so increase the strength of the magnetic field that when the central component of the triplet is removed by a Nicol the side lines stand apart with a clearly defined interval between them, yet this in itself does not absolutely satisfy us that the broadened line is a triplet. It might be contended that the broadened line is not really a triplet, but is merely a band of light polarised in one plane along its edges, and in the perpendicular plane along its centre, and that increase of the magnetic field might never separate it into distinct constituents, but merely continue to broaden it. This contention, however, might be disposed of by a careful study of the facts, even though we might not be able to produce a magnetic field strong enough to completely separate the constituent lines of the triplet.

Actual Triplets Obtained.

But clearly the thing to be arrived at is to so arrange matters, in fact to so design our electro-magnet and to plan the conditions of our experiment, that the magnetic field acting on the source of light shall be strong enough to completely separate the members of the triplet if such exist. You will understand that this is no easy thing to do when you remember that it was only after repeated efforts and many failures that even a slight broadening of the spectral lines was obtained. Nevertheless, in spite of the great difficulty which besets this investigation, and which arises from our inability to obtain a magnetic field of unlimited strength, yet, with a properly designed magnet and other properly arranged conditions, it is possible to obtain a magnetic field strong enough to completely separate the constituents of the magnetic triplet, and thus to prove that the prediction of theory is verified by the actual facts.

Other Perturbations, Complex Types.

But with a magnetic field of great strength the facts as shown by these slides [photographs shown here] turn out to be more complicated and more interesting than the simple theory led us to expect. For while some of the spectral lines are split up into triplets as indicated by

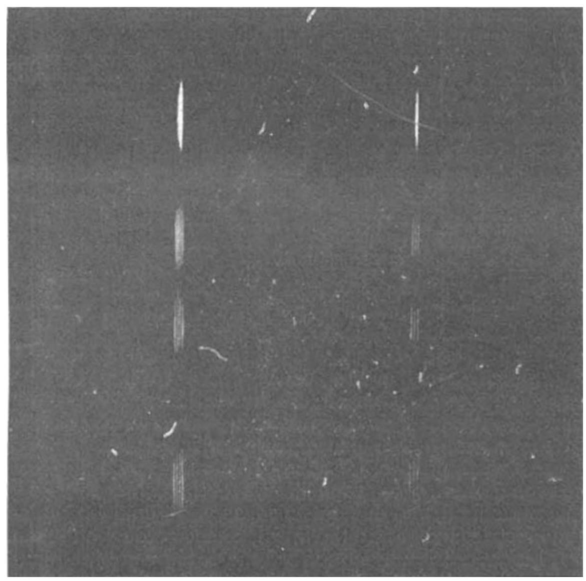

FIG. 3.—The top lines are not subject to the influence of the magnetic field. Underneath the same lines are shown affected by a magnetic field of increasing strength. The line on the right is resolved into a pure triplet, while that on the right appears at first as a quartet, and finally in a very strong field as a sextet (easily seen on the negative). (Reproduced natural size.)

theory, some, on the other hand, become resolved into sextets, or octets, or other complex types (see Fig. 3). Thus when the magnetic field becomes sufficiently intense, we realise to the full all the theoretical predictions and more. The reason of this surplus of realisation over expectation lies in the fact that the theory in its simplest form deals only with the simplest types of motion under the simplest conditions, and the conclusions arrived at are of course of corresponding simplicity. When more complicated types of motion are contemplated, the theory furnishes us with the dynamical explanation of the more complicated types of effect produced by the magnetic field. That tripling pure and simple should occur in the case of every spectral line (as predicted by the simplest form of theory) is not a result which we should expect from a broader consideration of the problem. In fact, if we reflect on the subject, we are forced to the conclusion that deviations from the pure triplet type should be expected, and, as we have seen, such deviations actually do occur. In this respect, therefore, the experimental investigation which yields more than the simple theory expected is not to be taken as in any way discordant with that theory, but on the contrary to be in harmony with it.

Theoretical Considerations.

In order that you may form some idea as to what it is that the theory supposes to be in operation in the production of these phenomena, I have had this elliptic frame constructed [model shown], which I ask you for the present to consider as the orbit described by one of those elements of matter which by their motions set up waves in the ether, and thereby emit what we call light. This white ball, which slides on the elliptic frame, is supposed to represent the element of matter. It is sometimes called an ion, which name is used to imply that the element of matter carries an electric charge inherently associated with it.

Now, under ordinary circumstances this ion revolving in its orbit with very great rapidity will continue to do so peacefully unless external forces come into play to disturb it. When external forces come into action, the orbit ceases in general to be the same as before. The orbit becomes perturbed, and the external forces are termed perturbing forces. But you now ask what is the character of the forces introduced by the magnetic field when the ion is moving through it. In answering this, we are to remember that the ion is supposed to be an element of matter charged with an electric charge—or, if you like, an electric charge possessing inertia. Now, if a charged body moves through a magnetic field, it is an experimental fact that it experiences a force arising from the action of the magnetic field on the moving electric charge. The direction of this force is at right angles both to the direction of motion of the charged body and to the direction of the magnetic force in the field. The effect of this force in our case is to cause the elliptic orbits of the ions to rotate round the lines of magnetic force; or to cause them to have a precessional motion [illustrated by model] instead of staying fixed in space, just as the perturbing forces of the planets in the solar system cause the earth's orbit to have a precessional motion. The angular velocity of this precessional motion is proportional to the strength of the magnetic field, and depends also, as you would expect, on the electric charge and the inertia associated with the ion.

This precessional motion of the orbit, combined with the motion of the ion around the orbit, gives the whole motion of the ion in space, and the result of this combined movement, of these two superposed frequencies—viz. the frequency of revolution of the ion in its orbit, and the frequency of rotation of the orbit around the lines of force—is that, in the case of the light radiated across the lines of force, each period becomes associated with two new periods, or, in other words, each spectral line becomes a triplet. A partial analogue to this, which may to some extent help you to understand the introduction of the two new periods, occurs in the case of sound, although the two phenomena at basis are quite different. The analogue (or quasi-analogue) is this. When two notes of given pitch, that is, of given frequency of vibration, are sounded together, their superposition produces two other notes of frequencies which are respectively the sum and the difference of the frequencies of the two given notes. These are known as the summation and the difference tones of the two given notes. Corresponding to these are the two side lines of the magnetic triplet. The frequency of the vibration in one of these lines is the sum, and the frequency of the other is the difference, of the two frequencies mentioned before—namely, the frequency of the revolution of the ion around its orbit and the frequency of the precessional revolution of the orbit round the lines of force. The centre line of the triplet has the frequency of the original vibration, and this frequency disappears completely when the light is viewed along the lines of force—that is, through axial holes pierced in the pole-pieces. In this direction, too, a further peculiarity arises, for not only does the triplet drop its central member and become a doublet, but each member of this doublet is not plane polarised, as the members of the triplet are. They are each, on the contrary, circularly polarised—that is, the vibration is circular instead of being rectilinear.

This all follows as the expectation of the simple theory which supposes that the ions are free to describe their elliptic orbits undisturbed by any forces other than the magnetic field. But it is only to be expected that other perturbing forces must come into play in the assemblage of ions which build up incandescent matter of the source of light. We know, for example, that the other members of the solar system perturb the earth's motion, so that it deviates from the simple elliptic motion predicted by the simple theory which did not take these perturbing forces into account. Hence, if any such perturbing forces exist, and we should be surprised if they did not exist, the tripling pure and simple of the spectral lines will be departed from, and other types will arise. From the character of these new types we may infer the nature of the perturbations which give rise to them, and hence by the study of these types we obtain a view of what is going on in matter when it is emitting light, which we should not possess if such perturbations did not occur. These deviations from pure tripling are consequently of more importance almost, in regard to our future progress, than the discovery of the tripling itself. To give you some idea of the influence of such perturbations in modifying the triplet form, I may mention that it follows, from simple theoretical considerations, that if the perturbing forces cause the orbit to revolve in its own plane, or cause it to change its ellipticity periodically, then each line of the triplet produced by the magnetic field will be doubled and a sextet will result, and other oscillations of the orbit will give rise to other modifications of the normal triplet type. It is not quite easy to see at once, however, what the perturbing forces are exactly, for we do not know the way in which the ions are associated in matter; but if we regard an ion as a charged element of matter describing an orbit, it will be analogous to a closed circuit, or to a magnetic shell, and will be urged to set in some definite way in the magnetic field. In coming into this position, it may oscillate about the position of equilibrium, and thus introduce an oscillation into the precessional motion of the orbit, which may have the effect of doubling or tripling the constituents of the pure precessional triplet.

Now, experimental investigation shows us that all the spectral lines do not become triplets when viewed across the lines of force in a magnetic field, for some lines show as quartets, or sextets, or octets, or in general as complex triplets derived from the normal triplet by replacing each component by a doublet or a triplet. We conclude, therefore, that the ions which give rise to these complex forms are not perfectly free in their motions through the magnetic field, but are constrained in some way by association with each other in groups, or otherwise, while they move in the magnetic field.

Law of the Magnetic Effect.

And now we come to a very important point in this inquiry. According to the simple theory, every spectral line, when viewed across the lines of force, should become a triplet in the magnetic field, and the difference of the vibration frequency between the side lines of the triplet should be the same for all the spectral lines of a given substance. In other words, the precessional frequency should be the same for all the ionic orbits, or the difference of wave-length $\delta\lambda$ between the lateral components of the magnetic triplet should vary inversely as the square of the wave-length of the spectral line under consideration. Now, when we examine this point by experiment, we find that this simple law is very far from being fulfilled. In fact, a very casual survey of the spectrum of any substance shows that the law does not hold even as a rough approximation; for, while some spectral lines show a considerable resolution in the magnetic field, other lines of nearly the same wave-length, in the same substance, are scarcely affected at all. This deviation is most interesting to those who concern themselves with the ultimate structure of matter, for it shows that the mechanism which produces the spectral lines of any given substance is not of the simplicity postulated in the elementary theory of this magnetic effect.

Grouping of Spectral Lines.

Our previous knowledge of the line spectra of different substances might indeed have led us to suspect some such deviation as this from the results predicted by the simple theory. For if we view the line spectrum of a given substance we find that some of the lines are sharp while others are nebulous or diffuse, and that some are long while others are short—in fact, the lines exhibit characteristic differences which lead us to suspect that they are not all produced by the motion of a single unconstrained ion. On closer scrutiny, they are seen to throw themselves into natural groups. For example, in the case of the monad metals sodium, potassium, &c., the spectral lines of each metal form three series of natural pairs, and again, in the case of the diad group, cadmium, zinc, &c., the spectrum of each shows two series of natural triplets, and so on.

Thus, speaking generally, the lines which form the spectrum of a given substance may be arranged in groups which possess similar characteristics as groups. Calling the lines of these groups A_1, B_1, C_1 . . . A_2, B_2, C_2 . . ., A_3, B_3, C_3 . . . we may regard the successive groups as repetitions of the first, so that the A's—that is A_1, A_2, A_3, &c.—are corresponding lines produced probably by the same ion; while the B's—namely, B_1, B_2, B_3, &c.—correspond to one another and are produced by another ion, and so on. This grouping of the spectral lines has been noticed in the case of several substances, and it has been a subject of earnest inquiry amongst spectroscopists for some time past. All such grouping, however, up to the present, has had to depend on the judgment of the observer as to certain similarities in the general character and arrangement of the lines, and similarities which indeed may or may not have any specific relation to the mechanism by which the lines are produced. In fact, such grouping has been effected by guess-work, or by empirical formulæ, and we need not be surprised if it is found that the groups so far obtained are more or less imperfect.

I introduce this grouping of the spectral lines to your notice in order that we may attack the problem of reducing to order the so far apparently lawless magnetic effect. As I have already mentioned, the lines in the spectrum of any given substance are not all resolved into triplets by the magnetic field, but some are resolved into triplets while others become sextets, &c.; and further, the magnitude of this resolution, that is, the interval $\delta\lambda$ between the lateral components, does not appear at first sight to obey any simple law.

Complex Atoms.

According to the prediction of the simple theory, the separation $\delta\lambda$ should be proportional to λ^2, and although this law is not at all obeyed, if we take all the lines of the spectrum as a single group, yet we find that it is obeyed for the different groups if we divide the lines into a series of groups. In other words, the corresponding lines A_1, A_2, A_3, &c., have the same value for the quantity e/m,* or, as we may say, they are produced by the motion of the same ion. The other corresponding lines, B_1, B_2, B_3, &c., have another common value for e/m, and are produced therefore by a different ion, and so on. We are thus led by this magnetic effect to arrange the lines of a given spectrum into natural groups, and from the nature of the effect we are led to suspect that the corresponding lines of these groups are produced by the same ion, and therefore that the atom of any given substance is really a complex consisting of several different ions, each of which gives rise to certain spectral lines, and these ions are associated to form an atom in some peculiar way which stamps the substance with its own peculiar properties.

In order to illustrate the meaning of this, let us consider the spectrum of some such metal as zinc. The bright lines forming the spectrum of this metal arrange themselves to a large extent in sets of three—that is, they group themselves naturally in triplets. Denoting these triplets in ascending order of refrangibility by A_1, B_1, C_1, A_2, B_2, C_2, &c., we find that the lines A_1, A_2, &c., show the same magnetic effect in character, and have the same value of e/m, so that they form a series obeying the theoretical law deduced by Lorentz and Larmor. In the same way, the lines B_1, B_2, B_3, &c., form another series, which also obeys the theoretical law, and possess a common value for the quantity e/m, similarly for the lines C_1, C_2, C_3, &c. The value of e/m for the A series differs from that possessed by the B series, or the C series, and this leads us to infer that the atom of zinc is built up of ions which differ from each other in the value of the quantity e/m, that each of these different ions is effective in producing a certain series of lines in the spectrum of the metal. When we examine the spectrum of cadmium, or of magnesium—that is, when we examine the spectra of other metals of the same chemical group—we find that not only are the spectra homologous, not only do the lines group themselves in similar groups, but we find in addition that the corresponding lines of the different spectra are *similarly* affected by the magnetic field. And further, not only is the character of the magnetic effect the same for the corresponding lines of the different metals of the same chemical group, but the actual magnitude of the resolution as measured by the quantity e/m is the same for the corresponding series of lines in the different spectra. This is illustrated in the following table, and leads us to believe, or at least to suspect, that the ion which produces the lines A_1, A_2, A_3, &c., in the spectrum of zinc is

Magnetic effect	Nonets or complex triplets	Sextets	Triplets
Cadmium ... ... $\lambda=$	5086	4800	4678
Zinc ... ... $\lambda=$	4811	4722	4680
Magnesium ... $\lambda=$	5184	5173	5167
Precessional spin ...	$\frac{e}{m}=55$	$\frac{e}{m}=87$	$\frac{e}{m}=100$

[This table shows the effect for the three lines which form the first natural triplet in the spectrum of cadmium compared with the corresponding lines in the spectra of zinc and magnesium. It will be seen that the corresponding lines in the different spectra suffer the same magnetic effect both in character and magnitude. Thus the corresponding lines 4800, 4722, 5173 are each resolved into sextets, and the rate at which the ionic orbit is caused to precess is the same for each (denoted by $e/m = 87$ in the table). Similarly for the other corresponding lines.]

* The quantity e is the electric charge of the ion, and m is its inertia, and the ratio e/m determines the precessional frequency, or spin, of the ionic orbit round the lines of magnetic force in a given field.

the same as that which produces the corresponding series A_1, A_2, A_3, &c., in cadmium, and the same for the corresponding sets in the other metals of this chemical group. In other words, we are led to suspect that, not only is the atom a complex composed of an association of different ions, but that the atoms of those substances which lie in the same chemical group are perhaps built up from the same kind of ions, or at least from ions which possess the same e/m, and that the differences which exist in the materials thus constituted arises more from the manner of association of the ions in the atom than from differences in the fundamental character of the ions which build up the atoms; or it may be, indeed, that all ions are fundamentally the same, and that differences in the value of e/m, or in the character of the vibrations emitted by them, or in the spectral lines produced by them, may really arise from the manner in which they are associated together in building up the atom.

This may be an unjustified speculation, but there can be no doubt as to the fascination which inquiry of this kind has always exerted, and must continue to exert, over the human mind. It is the speculation of the ignorant as well as of the philosophic and trained scientific mind, and even though it should never be proved to rest on any substantial basis of fact, it will continue to cast its charm over every investigator of nature.

It is ever the desire of the human mind to see all the phenomena of nature bound by one connecting chain, and the forging of this chain can be realised only gradually and after great labour in the laboratories of science. From time to time, the hope has been entertained that metals may be transmuted, and that one form may be converted into another; and although this hope has been more generally nurtured by avarice and by ignorance rather than by knowledge, yet it is true that we never have had any sufficient reason for totally abandoning that hope, and even though it may never be realised that in practice we shall be able to convert one substance into another, even though the philosopher's stone be for ever beyond our grasp, yet when the recent developments of science, especially in the region of spectrum analysis, are carefully considered, we have, I think, reasonable hope that the time is fast approaching when intimate relations, if not identities, will be seen to exist between forms of matter which have heretofore been considered as quite distinct. Important spectroscopic information pointing in this same direction has been gleaned through a long series of observations by Sir Norman Lockyer on the spectra of the fixed stars, and on the different spectra yielded by the same substance at different temperatures. These observations lend some support to the idea, so long entertained merely as a speculation, that all the various kinds of matter, all the various so-called chemical elements, may be built up in some way of the same fundamental substance; and it is probable that this protyle theory will, in one form or another, continue to haunt the domains of scientific thought, and remain a useful and important factor in our progress, for all time to come.

Even though it may be that a knowledge of the ultimate constitution of matter must for ever remain a sealed book to our inquiries, yet, framed as we are, we must for ever prosecute the extension of our knowledge in every direction; and in pursuing knowledge it frequently happens that vast acquisitions are made through channels which at first seem most unlikely to lead us any further. It has frequently happened that small and obscure effects, obtained after much labour and difficulty, have led to results of the highest importance, while very pronounced and striking effects which have forced themselves on the attention of the observer have proved comparatively barren. It was by a determined effort of this kind, founded on a correct appreciation of the importance of small outstanding differences—so small as to be despised or passed over by all other observers—that Lord Rayleigh discovered a new gas in our atmosphere, added argon to our list of elements, and initiated the attack which led to the brilliant capture by Prof. Ramsay of several new terrestrial substances.

Viewed from this standpoint, I hope I am to some extent justified in occupying your attention this evening with the consideration of the action of magnetism on light, for although the effect produced is small and not easy to observe, yet it is likely to prove an important instrument of research in the study of matter, and it is not inappropriate that a public account of what has been already achieved should be given in this Institution, in which the inquiry was first begun by Faraday, and in which his spirit still lives.

THE DOVER MEETING OF THE BRITISH ASSOCIATION.

THE meeting of the British Association in Dover on September 13 this year promises, on account of its international character, to be a memorable one in the history of the Association. Dover was selected, though it is a smaller town than is usually chosen for these meetings, on account of its nearness to the French coast, in order that an interchange of visits should take place between the British Association and its French counterpart, which meets this year at Boulogne. The French Government has taken a great interest in the arrangements for the meeting, rightly judging that the meeting cannot but promote friendship and good will between the two nations. A good illustration of the truth that science has no nationality will be found in the fact that one of the evening lectures in Dover will be delivered in French by Prof. Chas. Richet, of Paris, on "La vibration Nerveuse." This will take place on Friday, September 15, at 8.30 p.m. It is extremely probable that Prof. Fleming will find some way of imparting an international character to his lecture on the "Centenary of the Electric Current," to be delivered on Monday, September 18.

The preliminary arrangements for the meeting are well in hand. The usual handbook is being prepared under the editorship of Dr. Sebastian Evans, brother of the ex-President of the Association, and will deal with Dover both in its ancient and modern aspect. The historical part of the subject has been undertaken by the Rev. S. P. H. Statham, Chaplain to the Forces, who has recently written a history of the castle, town, and port of Dover. The geology of the district is in the able hands of Prof. Boyd Dawkins; the botany in those of Mr. Sydney Webb. Dr. Parsons undertakes the climate, health and meteorology of Dover; whilst the harbour and cross-Channel traffic is described by Mr. A. T. Walmisley, C.E., the Harbour Board Engineer. This portion of the handbook should be extremely interesting in view of the national harbour which has been undertaken by the Government after more than fifty years' delay, and which will turn Dover into one of our most important naval ports.

For a town of its size Dover possesses an unusually large number of rooms suitable for public meetings, so little difficulty has been experienced in providing for the Sections. The Town Hall, with its annexe, the ancient Maison Dieu, will serve for the President's address and the soirées. The School of Art, in which five of the Sections assemble, adjoins and communicates with the Town Hall. The reception rooms and offices have an ideal *locale* in the buildings and grounds of the Dover College. This institution was founded some thirty