a question of time when every university will recognize the fact that it must adapt itself to the possibilities of the schools, and that ancient or artificial standards can be maintained only so long as they approve themselves to the experience of the schoolmaster. The mountain will never come to Mahomet. To compel schools to differentiate early a small and select and expensive class for entrance to the universities is unfair both to school and to the university, and seriously checks the diffusion of higher education. To deny the privilege of breathing the university atmosphere to any product of a good secondary school involves such a narrow conception of education that one dislikes to associate it with the university. It has always seemed an anomaly that universities are inclined to rate themselves more upon the basis of their raw material than their finished product. A fine-meshed screen is set up at the beginning of the university career, when it would seem far more logical to set it up at the other end. This matter of entrance has much to do with the opportunity given to science to express itself in education. If its most promising and best trained material is turned back or handicapped when attempting to enter the university, a certain kind of educational theory may command the result, but it is a blockade against the general progress of education, in so far as it cuts off a great agency from operating upon the legitimate material.

A statement summarizing the claims set forth in this paper may be formulated as follows: The introduction of science among the subjects used in education has revolutionized the methods of teaching, and all subjects have felt the impulse of a new life; it has developed the scientific spirit, which prompts to investigation, which demands that belief shall rest upon a foundation of adequate demonstration, which recognizes that the sphere of influence surrounding facts may be speedily traversed and that everything beyond is as uncertain as if there were no facts; it has introduced a training peculiar to itself, in that it teaches the attitude of self-elimination, an attitude necessary in order to reach ultimate truth, and thus supplements and steadies the other half of life, which is to appreciate. To obtain these results, there must be teachers who can teach, whose background and source of supply is the investigator. Moreover, the results are immensely desirable, inasmuch as they do not interfere with anything that is fine and uplifting in the old education, but simply mean that the possibilities of high attainment and high usefulness are open to a far greater number.

JOHN M. COULTER.

THE ZEEMAN EFFECT.

EARLY in the year 1897 a paper was published in several journals by Dr. P. Zeeman, describing a series of experiments to determine the effect of magnetism upon the spectrum of a source of light placed in the magnetic field. The electromagnetic theory of light indicated in a general way that there would probably be some effect, and several investigators had already sought for it without success. The most noteworthy of these was Faraday, who made it the object of one of his last researches, and in this country Rowland made an examination with a Rutherford grating, before he had himself begun to rule the more perfect gratings of the present day. Zeeman himself had made an earlier unsuccessful attempt, and Fievez really observed what may have been the same phenomenon which Zeeman finally discovered, but he failed to understand its true character.

With the aid of a strong magnet and better spectroscopic apparatus than any of his predecessors had used, Zeeman attacked the problem the second time with success. He placed a Bunsen flame containing common salt between the poles of the electromagnet and focused the light on the slit of his spectrometer, arranging the flame so that the D-lines were sharply defined. As soon as the magnet was excited both lines widened out very much. By a careful series of subsidiary experiments he showed that the widening was due directly to the action of the field and was not a secondary effect such as might be caused by changes of density in the flame.

These results were communicated before publication to Professor Lorentz, who showed Dr. Zeeman that the widening could be predicted from Lorentz's theory that light is generated by the vibrations of electrically charged particles or ions; and that the same theory indicated that the edges of the widened lines should be plane-polarized or circularly-polarized according as the light falling upon the slit came from the source in a direction perpendicular or parallel to the lines of magnetic force, and that the amount of the widening would give the ratio of the charge to the mass of the luminous particles. Zeeman was able to verify fully the predictions as to polarization, and deduced from Lorentz's equations, as a rough value for the ratio e/m, the value 10^7.

The substance of the reasoning which led Lorentz to his conclusions is this: the motion of any ion can be resolved into a rectilinear component along the lines of force and two circular components in opposite senses in a plane normal to the same lines. These moving charges constitute currents, and consequently there are electromagnetic forces acting on the particles carrying the charges, owing to the presence of the magnetic field. The component along the lines of force is unaffected, while one of the circular components is accelerated and the other retarded by an equal amount. Hence we have present three distinct vibrations: one linear, along the lines of force, with the same period as the undisturbed motion; and two circular, in opposite senses, having periods, one a little longer and the other a little shorter than the original. Hence if the difference of periods introduced is sufficient to resolve the three lines in the spectrometer, and the light falling upon the slit comes from the source in a direction parallel to the lines of force, two lines instead of one will appear in the spectrum, one composed of right-handed and the other of left-handed polarized light; for the linear vibration can send no wave in its own direction. On the other hand, if the light proceeds directly across the lines of force to the slit, a triplet will be seen, consisting of a central component polarized in a plane normal to the lines of force and two lateral components polarized in a plane through the lines of force (bearing in mind that on the electromagnetic theory of light the direction of electric force is normal to the plane of polarization). But, if the difference of period is smaller, the lines of the doublet in the one case and of the triplet in the other, being streaks of finite width and not lines in the mathematical sense, will overlap, forming a single widened line whose edges alone show any definite polarization. Lorentz's mathematical treatment, which we will omit here, leads to the expression

$$\frac{\Delta\lambda}{\lambda^2} = \frac{e}{m} \cdot \frac{H}{2\pi V},$$

where λ is the wave-length of the original line, $\Delta\lambda$ is the difference in wave-length introduced between the extreme components of the triplet by the external magnetic force H, e is the charge on the moving ion, m its mass, and V the velocity of light.

It follows from this that if e/m is the same for all the luminous ions which give the spectrum of any one substance, the separation $\Delta\lambda$ is proportional to the square of the wave-length; but it became evident as soon as the experimental study was extended that no such general law could be laid down. For the same region in the spectrum of an element the separation may vary from apparently nothing up to an Angström unit or more for a moderately intense field.

The high value of e/m indicated by this phenomenon is significant. It is of about the same order as that found for the cathode ray particles and the ions caused by uranium and Röntgen rays and ultraviolet light; but the value for electrolytic ions is only about 400.

Zeeman's experiments were soon repeated by other investigators, including Lodge, Michelson, Preston and Cornu; and it was not long before magnetic fields were used of strength sufficient to fully resolve the several components. It then became known that the phenomenon was not nearly so simple as the first observations would indicate. Lodge* first noticed indications of a quadruplet in the case of the D-lines instead of a triplet, and later Preston† and Cornu‡ observed unmistakable quadruplets both in the case of D_1 and in the spectra of cadmium and magnesium. A little later Becquerel and Deslandres§ discovered in the iron spectrum a new type of triplet in which the states of polarization of the inner and outer components were interchanged. In February, 1898, Michelson published in the *Astrophysical Journal* a paper giving results obtained with the interferometer, some of which are not in accord with those obtained before and since then with the grating. Among other things he said that all lines are divided into what may provisionally be called triplets of approximately the same width, each member of a so-called 'triplet,' however, being itself complex, making the whole magnetic group formed from a single natural line quite complicated. As has already been stated, other investigators have found the degree of separation to vary quite strikingly even for neighboring lines, and although researches with the grating have discovered many complicated lines, the number of these is very small compared to those that appear as simple triplets. Professor Michelson maintains in defense of his methods that the resolving power of a grating is not sufficient to reveal the finer structure of the line as indicated by the interferometer. This last is no doubt true, but on the other hand the interferometer method is exceedingly indirect, and one hesitates before accepting conclusions drawn from an estimated visibility-curve as to the distribution of intensity in such a complicated source as he advocates. In any case, the assumption is involved that the source is symmetrical, and this certainly is not always true. An example is found in the cadmium group 4678, 4800, 5086, and the similar group in the spectrum of zinc. Each of these lines in the spark-spectrum shows a decided shading on the red side, which is retained by each component when they are separated by the magnetic field, making the whole group quite asymmetrical. It has also been shown* that many triplets and quadruplets are asymmetrical in separation. It is quite possible that such cases may account for some of Professor Michelson's results.

It cannot be denied, however, that, although most lines become simple triplets in the field, many are more complicated than the simple theory would indicate, many being fourfold and some at least sixfold, while some seem not to be affected by the field. Several theories have been de-

The Electrician, June 18, 1897.

†*Proc. Roy. Soc.*, vol. 63, p. 26.

‡*Comptes Rendus*, vol. 126, p. 181.

§*Comptes Rendus*, April, 4, 1898, p. 997.

*Zeeman, *Proc. Roy. Amst. Acad. Sci.*, Dec. 30, 1899. Reese, J. H. U. Circulars, June, 1899; June, 1900.

vised to account for these variations, which will be discussed later.

Some attempts to classify the spectral lines according to the character and extent of their magnetic separation have met with partial success. Preston* found that in the spectra of magnesium, cadmium and zinc corresponding lines of the homologous groups of three at the head of Kayser and Runge's second subordinate series act in exactly the same way in the magnetic field. That is, the most refrangible line in each group becomes a sharp triplet with the value 10 (relatively speaking) for the ratio $\lambda^2/\Delta\lambda$, the middle line a sextuplet with the value 11.5, and the least refrangible a rather diffuse triplet with the value 18.

A magnetic effect has been noticed on some of the air-lines,† but, with the possible exception of nitrogen peroxide, no effect has been observed on band-spectra, either by emission or absorption methods.

On the continent of Europe most of the work has been done with absorption spectra, particularly with that of the sodium flame; and in this field several most important discoveries have been made.

Egoroff and Géorgiewsky ‡ noticed that the light from a sodium flame in a magnetic field is partially polarized as a whole, *i. e.*, without being dispersed. Lorentz § showed that this phenomenon can be explained by absorption even when the field is uniform.

Righi || and Cotton ¶ have shown how the Zeeman effect may be demonstrated without a spectroscope by passing a plane-polarized beam of white light through a magnetized sodium flame or absorbing gas.

* *Phil. Mag.*, vol. 47, p. 165.

† Becquerel and Deslandres, *Comptes Rendus*, vol. 127, p. 18.

‡ *Comptes Rendus*, vol. 124, pp. 748, 949.

§ *Proc. Roy. Amst. Acad. Sci.*, vol. 6, p. 193.

|| *Comptus Rendus*, vol. 127, p. 216.

¶ *Comptus Rendus*, vol. 125, p. 865.

By this method, which is very sensitive, nitrogen peroxide was shown to be subject to magnetic separation.

Macaluso and Corbino* discovered that a magnetized sodium plane rotates the plane of polarization to a very great extent for light whose wave-length is nearly that of one of the *D*-lines. Very close to the absorption-lines the rotation amounts to as much as 315 degrees. The immediate dependence of this phenomenon upon the Zeeman effect is shown in a very beautiful way in Cotton's little book 'Le Phénomene de Zeeman,' although I believe the more general principle that magnetic rotation of the plane of polarization is dependent upon the optical dispersion of the medium combined with a sort of generalized Zeeman effect, is due to Fitzgerald.†

An analogous effect of the magnetized flame upon light passed through it *across* the lines of force was discovered independently by Voigt ‡ and Cotton §. They found that the flame acts like a uniaxial crystal; that is, it introduces a phase-difference between waves polarized parallel and perpendicular to the lines of force. This phase-difference increases very rapidly as the wave-length approaches that of one of the *D*-lines. The explanation of this is also given in Cotton's book.

When we review the experimental facts concerning the effect of magnetism upon light we find many things inconsistent with the elementary theory first given by Lorentz. The equation which he obtained indicated that all spectral lines should become triplets under the influence of the field, and that the separation should vary as the square of the wave-length and as the strength of the field. On the contrary we find a considerable number of lines which

* *Comptus Rendus*, vol. 127, p. 548.

† *Proc. Roy. Soc.*, vol. 63, p. 31.

‡ *Wied. Annal.* No. 2, 1899, p. 345.

§ *Comptus Rendus*, vol. 128, p. 294.

become more complicated than triplets as well as some that are apparently unaffected; moreover the separation is very far from varying as the square of the wave-length, and recent work has shown that in some cases at least it is not proportional to the strength of the field.* In spite of these inconsistencies, however, we do not feel called upon to abandon the theory of electrified ions, for we must bear in mind that Lorentz's expression was deduced from assumptions which can hardly be realized in nature. He assumed a molecule of the simplest possible kind, consisting of a single positive or a negative ion acted upon by a central force proportional to its displacement and an electromagnetic force due to the external field equal in magnitude and direction to that which would act on a conductor carrying a current equal to the product of the velocity of the ion by the charge which it carries. Now it seems reasonable to suppose that the central force varies directly as the first power of the displacement because if it varied as any other power the period of vibration would change with the amplitude, and the spectral lines would change their position when the source of light became brighter, which has never been observed. The assumption that the same forces act on a particle carrying a charge e with a velocity v as would act on a conductor carrying a current of strength ev in the same direction is justified for comparatively low velocities by Rowland's experiment in Berlin in 1876. It seems utterly impossible, however, that a molecule should consist of a single ion, for in very few cases does the spectrum of an element contain less than twenty lines in the visible spectrum, and in the iron-spectrum there are thousands of them. A molecule which can vibrate in so many different periods must be exceedingly complicated. It is not surprising, then, that our simple theory is inadequate to account for the facts. Lorentz, in fact, knew this and instituted* a theoretical research on more general grounds before its insufficiency had been shown by the discovery of the quadruplet and other complications. He found that if the molecule naturally possessed more than three equivalent modes of vibration—that is, if it could vibrate in more than three ways with the same period—then the single spectral line corresponding to this period would become more than three-fold under the influence of magnetic force. Professor Lorentz does not regard this explanation as satisfactory, owing to the difficulty in conceiving a system having this property.

More recently Voigt† has proposed a theory which accounts for all the observed phenomena and is especially interesting in that by it he predicted cases of asymmetry found by Zeeman and others. Unfortunately the theory does not give any mechanical conception of the subject, merely consisting of the introduction into the equations of motion of terms of arbitrary form, which have no apparent justification.

It is comparatively easy to treat the case of a molecule composed of two ions carrying equal charges of opposite signs, and, in fact, Professor Rowland has lately given such a treatment before his students at Johns Hopkins University, but it leads to no new results as regards the Zeeman effect. Any case more general than this is very difficult.

HERBERT M. REESE.

* Shedd, *Phys. Rev.*, July, 1899, p. 1; Aug., 1899, p. 86. Reese, J. H. U. Circulars, June, 1900.

* *Wied. Annal.*, vol. 63, p. 278. *Astroph. Jour.*, vol. 9, p. 37.

† *Wied. Annalen*, No. 2, 1899, p. 345; No. 6, 1899, p. 352; No. 9, 1899, p. 290; No. 2, 1900, p. 376, and p. 389.

EUROPEAN APPLE TREE CANKER IN AMERICA.

SHORTLY after bulletin No. 163 of this station, entitled 'A New York Apple Tree