seen. That the vesicular structure is not owing to any especial affinity of melted copper for carbonic oxide, is shown by the fact that when copper is fused under charcoal or a flux of salt, and carbonic oxide passed through it, the metal, on cooling, is found to be entirely devoid of all porous structure, as proved by its specific gravity, which we found to be 8·943.

That carbon can exercise an influence of the kind attributed to it in the foregoing experiments, is shown by its action on melted silver; for if silver be fused under a layer of charcoal, and oxygen gas passed through it for any length of time, still no spitting will take place on the cooling of the metal. Again, when silver is fused in air, if charcoal be thrown on the melted surface no spitting occurs, a fact well known to assayers: sand or any other body of that kind does not exercise a similar influence on the silver*.

We next tried the action of sulphur on suboxidized copper, and found that it also produced the vesicular structure, and even caused the copper to vegetate to a very considerable extent. In fact, when sulphur is thrown on copper which has been melted with access of air, results are obtained similar to those which carbon produces under the same circumstances.

Two specimens of copper which had been rendered vesicular by the action of sulphur, were found to have respectively the specific gravities of 6·6 and 5·1. It is a somewhat curious fact, that the phenomenon of copper rain is caused to a much greater extent by the action of sulphur than it is by carbon. The sulphur, of course, acts on the suboxide of copper in the same kind of way as the carbon; and the vesicular structure and copper rain are in this case owing to the evolution of sulphurous acid.

We also tried the action of iodine and of phosphorus on suboxidized copper, but they did not produce any appearance of vesicular structure.

The foregoing experiments were carried out partly in Professor Percy's, and partly in Professor Williamson's laboratory.

* While engaged on this subject, we also made a series of experiments upon silver, to ascertain whether any other gas than oxygen was absorbed by it. The melted silver was treated in precisely the same way as the copper, and the gases oxygen, hydrogen, air, nitrogen, carbonic acid, and carbonic oxide passed through it. The spitting of the silver we found to be caused only by oxygen or air, and, further, that, as mentioned above, this was entirely prevented by the presence of charcoal. In Gmelin's 'Chemistry' (vol. vi. p. 139) it is stated that, when silver is fused under nitrate of potash, the spitting takes place: this statement we believe to be incorrect; for we always found that when silver was carefully fused, so that the air did not come in contact with it, under a layer of either nitrate or chlorate of potash, no spitting took place. As both these salts are decomposed below the melting-point of silver, this result is what might be expected.

XIV. *On Physical Lines of Force.* By J. C. Maxwell, *F.R.S., Professor of Natural Philosophy in King's College, London**.

Part IV.—*The Theory of Molecular Vortices applied to the Action of Magnetism on Polarized Light.*

THE connexion between the distribution of lines of magnetic force and that of electric currents may be completely expressed by saying that the work done on a unit of imaginary magnetic matter, when carried round any closed curve, is proportional to the quantity of electricity which passes through the closed curve. The mathematical form of this law may be expressed as in equations (9)†, which I here repeat, where α, β, γ are the rectangular components of magnetic intensity, and p, q, r are the rectangular components of steady electric currents,

$$\left.\begin{aligned} p &= \frac{1}{4\pi}\left(\frac{d\gamma}{dy}-\frac{d\beta}{dz}\right), \\ q &= \frac{1}{4\pi}\left(\frac{d}{dz}-\frac{d\gamma}{dx}\right), \\ r &= \frac{1}{4\pi}\left(\frac{d\beta}{dx}-\frac{d\alpha}{dy}\right). \end{aligned}\right\} \quad . \quad . \quad (9)$$

The same mathematical connexion is found between other sets of phenomena in physical science.

(1) If α, β, γ represent displacements, velocities, or forces, then p, q, r will be rotatory displacements, velocities of rotation, or moments of couples producing rotation, in the elementary portions of the mass.

(2) If α, β, γ represent rotatory displacements in a uniform and continuous substance, then p, q, r represent the *relative* linear displacement of a particle with respect to those in its immediate neighbourhood. See a paper by Prof. W. Thomson "On a Mechanical Representation of Electric, Magnetic, and Galvanic Forces," Camb. and Dublin Math. Journ. Jan. 1847.

(3) If α, β, γ represent the rotatory velocities of vortices whose centres are fixed, then p, q, r represent the velocities with which loose particles placed between them would be carried along. See the second part of this paper (Phil. Mag. April 1861).

It appears from all these instances that the connexion between magnetism and electricity has the same mathematical form as that between certain pairs of phenomena, of which one has a *linear* and the other a *rotatory* character. Professor Challis‡

* Communicated by the Author.

† Phil. Mag. March 1861.

‡ Phil. Mag. December 1860, January and February 1861.

conceives magnetism to consist in currents of a fluid whose direction corresponds with that of the lines of magnetic force; and electric currents, on this theory, are accompanied by, if not dependent on, a rotatory motion of the fluid about the axes of the current. Professor Helmholtz* has investigated the motion of an incompressible fluid, and has conceived lines drawn so as to correspond at every point with the instantaneous axis of rotation of the fluid there. He has pointed out that the lines of fluid motion are arranged according to the same laws with respect to the lines of rotation, as those by which the lines of magnetic force are arranged with respect to electric currents. On the other hand, in this paper I have regarded magnetism as a phenomenon of rotation, and electric currents as consisting of the actual translation of particles, thus assuming the inverse of the relation between the two sets of phenomena.

Now it seems natural to suppose that all the direct effects of any cause which is itself of a longitudinal character, must be themselves longitudinal, and that the direct effects of a rotatory cause must be themselves rotatory. A motion of translation along an axis cannot produce a rotation about that axis unless it meets with some special mechanism, like that of a screw, which connects a motion in a given direction along the axis with a rotation in a given direction round it; and a motion of rotation, though it may produce tension along the axis, cannot of itself produce a current in one direction along the axis rather than the other.

Electric currents are known to produce effects of transference in the direction of the current. They transfer the electrical state from one body to another, and they transfer the elements of electrolytes in opposite directions, but they do not† cause the plane of polarization of light to rotate when the light traverses the axis of the current.

On the other hand, the magnetic state is not characterized by any strictly longitudinal phenomenon. The north and south poles differ only in their names, and these names might be exchanged without altering the statement of any magnetic phenomenon; whereas the positive and negative poles of a battery are completely distinguished by the different elements of water which are evolved there. The magnetic state, however, is characterized by a well-marked rotatory phenomenon discovered by Faraday‡—the rotation of the plane of polarized light when transmitted along the lines of magnetic force.

When a transparent diamagnetic substance has a ray of plane-polarized light passed through it, and if lines of magnetic force

* Crelle, *Journal*, vol. lv. (1858) p. 25.
† Faraday, 'Experimental Researches,' 951–954, and 2216–2220.
‡ Ibid., Series XIX.

are then produced in the substance by the action of a magnet or of an electric current, the plane of polarization of the transmitted light is found to be changed, and to be turned through an angle depending on the intensity of the magnetizing force within the substance.

The direction of this rotation in diamagnetic substances is the same as that in which positive electricity must circulate round the substance in order to produce the actual magnetizing force within it; or if we suppose the horizontal part of terrestrial magnetism to be the magnetizing force acting on the substance, the plane of polarization would be turned in the direction of the earth's true rotation, that is, from west upwards to east.

In paramagnetic substances, M. Verdet* has found that the plane of polarization is turned in the opposite direction, that is, in the direction in which negative electricity would flow if the magnetization were effected by a helix surrounding the substance.

In both cases the absolute direction of the rotation is the same, whether the light passes from north to south or from south to north,—a fact which distinguishes this phenomenon from the rotation produced by quartz, turpentine, &c., in which the absolute direction of rotation is reversed when that of the light is reversed. The rotation in the latter case, whether related to an axis, as in quartz, or not so related, as in fluids, indicates a relation between the direction of the ray and the direction of rotation, which is similar in its formal expression to that between the longitudinal and rotatory motions of a right-handed or a left-handed screw; and it indicates some property of the substance the mathematical form of which exhibits right-handed or left-handed relations, such as are known to appear in the external forms of crystals having these properties. In the magnetic rotation no such relation appears, but the direction of rotation is directly connected with that of the magnetic lines, in a way which seems to indicate that magnetism is really a phenomenon of rotation.

The transference of electrolytes in fixed directions by the electric current, and the rotation of polarized light in fixed directions by magnetic force, are the facts the consideration of which has induced me to regard magnetism as a phenomenon of rotation, and electric currents as phenomena of translation, instead of following out the analogy pointed out by Helmholtz, or adopting the theory propounded by Professor Challis.

The theory that electric currents are linear, and magnetic forces rotatory phenomena, agrees so far with that of Ampère and Weber; and the hypothesis that the magnetic rotations exist wherever magnetic force extends, that the centrifugal force of these rotations accounts for magnetic attractions, and that the inertia of

* *Comptes Rendus*, vol. xliii. p. 529; vol. xliv. p. 1209.

the vortices accounts for induced currents, is supported by the opinion of Professor W. Thomson*. In fact the whole theory of molecular vortices developed in this paper has been suggested to me by observing the direction in which those investigators who study the action of media are looking for the explanation of electro-magnetic phenomena.

Professor Thomson has pointed out that the cause of the magnetic action on light must be a real rotation going on in the magnetic field. A *right-handed* circularly polarized ray of light is found to travel with a different velocity according as it passes from north to south, or from south to north, along a line of magnetic force. Now, whatever theory we adopt about the direction of vibrations in plane-polarized light, the geometrical arrangement of the parts of the medium during the passage of a right-handed circularly polarized ray is exactly the same whether the ray is moving north or south. The only difference is, that the particles describe their circles in opposite directions. Since, therefore, the *configuration* is the same in the two cases, the forces acting between particles must be the same in both, and the motions due to these forces must be equal in velocity if the medium was originally at rest; but if the medium be in a state of rotation, either as a whole or in molecular vortices, the circular vibrations of light may differ in velocity according as their direction is similar or contrary to that of the vortices.

We have now to investigate whether the hypothesis developed in this paper—that magnetic force is due to the centrifugal force of small vortices, and that these vortices consist of the same matter the vibrations of which constitute light—leads to any conclusions as to the effect of magnetism on polarized light. We suppose transverse vibrations to be transmitted through a magnetized medium. How will the propagation of these vibrations be affected by the circumstance that portions of that medium are in a state of rotation?

In the following investigation, I have found that the only effect which the rotation of the vortices will have on the light will be to make the plane of polarization rotate in the *same* direction as the vortices, through an angle proportional—

(A) to the thickness of the substance,
(B) to the resolved part of the magnetic force parallel to the ray,
(C) to the index of refraction of the ray,
(D) inversely to the square of the wave-length in air,
(E) to the *mean radius* of the vortices,
(F) to the capacity for magnetic induction.

* See Nichol's *Cyclopædia*, art. "Magnetism, Dynamical Relations of," edition 1860; Proceedings of Royal Society, June 1856 and June 1861; and Phil. Mag. 1857.

A and B have been fully investigated by M. Verdet*, who has shown that the rotation is strictly proportional to the thickness and to the magnetizing force, and that, when the ray is inclined to the magnetizing force, the rotation is as the cosine of that inclination. D has been supposed to give the true relation between the rotation of different rays; but it is probable that C must be taken into account in an accurate statement of the phenomena. The rotation varies, not exactly inversely as the square of the wave-length, but a little faster; so that for the highly refrangible rays the rotation is greater than that given by this law, but more nearly as the index of refraction divided by the square of the wave-length.

The relation (E) between the amount of rotation and the size of the vortices shows that different substances may differ in rotating power independently of any observable difference in other respects. We know nothing of the absolute size of the vortices; and on our hypothesis the optical phenomena are probably the only data for determining their relative size in different substances.

On our theory, the direction of the rotation of the plane of polarization depends on that of the mean moment of momenta, or *angular momentum*, of the molecular vortices; and since M. Verdet has discovered that magnetic substances have an effect on light opposite to that of diamagnetic substances, it follows that the molecular rotation must be opposite in the two classes of substances.

We can no longer, therefore, consider diamagnetic bodies as being those whose coefficient of magnetic induction is less than that of space empty of gross matter. We must admit the diamagnetic state to be the *opposite* of the paramagnetic; and that the vortices, or at least the influential majority of them, in diamagnetic substances, revolve in the direction in which positive electricity revolves in the magnetizing bobbin, while in paramagnetic substances they revolve in the opposite direction.

This result agrees so far with that part of the theory of M. Weber† which refers to the paramagnetic and diamagnetic conditions. M. Weber supposes the electricity in paramagnetic bodies to revolve the same way as the surrounding helix, while in diamagnetic bodies it revolves the opposite way. Now if we regard negative or resinous electricity as a substance the absence of which constitutes positive or vitreous electricity, the results will be those actually observed. This will be true independently of any other hypothesis than that of M. Weber about magnetism

* *Annales de Chimie et de Physique*, sér. 3. vol. xli. p. 370; vol. xliii. p. 37.
† Taylor's 'Scientific Memoirs,' vol. v. p. 477.

and diamagnetism, and does not require us to admit either M. Weber's theory of the mutual action of electric particles in motion, or our theory of cells and cell-walls.

I am inclined to believe that iron differs from other substances in the manner of its action as well as in the intensity of its magnetism; and I think its behaviour may be explained on our hypothesis of molecular vortices, by supposing that the particles of the *iron itself* are set in rotation by the tangential action of the vortices, in an opposite direction to their own. These large heavy particles would thus be revolving exactly as we have supposed the infinitely small particles constituting electricity to revolve, but without being free like them to change their place and form currents.

The whole *energy* of rotation of the magnetized field would thus be greatly increased, as we know it to be; but the *angular momentum* of the iron particles would be opposite to that of the ætherial cells and immensely greater, so that the total angular momentum of the substance will be in the direction of rotation of the iron, or the reverse of that of the vortices. Since, however, the angular momentum depends on the absolute size of the revolving portions of the substance, it may depend on the state of aggregation or chemical arrangement of the elements, as well as on the ultimate nature of the components of the substance. Other phenomena in nature seem to lead to the conclusion that all substances are made up of a number of parts, finite in size, the particles composing these parts being themselves capable of internal motion.

Prop. XVIII.—To find the angular momentum of a vortex.

The angular momentum of any material system about an axis is the sum of the products of the mass, dm, of each particle multiplied by twice the area it describes about that axis in unit of time; or if A is the angular momentum about the axis of x,

$$A=\Sigma dm\left(y\frac{dz}{dt}-z\frac{dy}{dt}\right).$$

As we do not know the distribution of density within the vortex, we shall determine the relation between the angular momentum and the energy of the vortex which was found in Prop. VI.

Since the time of revolution is the same throughout the vortex, the mean angular velocity ω will be uniform and $=\frac{\alpha}{r}$, where α is the velocity at the circumference, and r the radius. Then

$$A=\Sigma dmr^2\omega,$$

and the energy

$$E=\tfrac{1}{2}\Sigma dmr^2\omega^2=\tfrac{1}{2}A\omega,$$

$$=\frac{1}{8\pi}\mu\alpha^2V \text{ by Prop. VI.*},$$

whence

$$A=\frac{1}{4\pi}\mu r\alpha V \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (144)$$

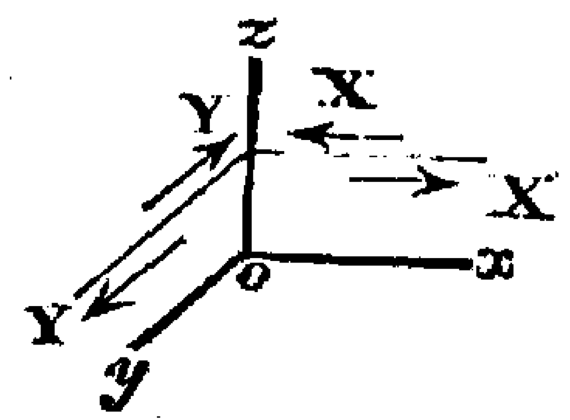
for the axis of x, with similar expressions for the other axes, V being the volume, and r the radius of the vortex.

Prop. XIX.—To determine the conditions of undulatory motion in a medium containing vortices, the vibrations being perpendicular to the direction of propagation.

Let the waves be plane-waves propagated in the direction of z, and let the axis of x and y be taken in the directions of greatest and least elasticity in the plane xy. Let x and y represent the displacement parallel to these axes, which will be the same throughout the same wave-surface, and therefore we shall have x and y functions of z and t only.

Let X be the tangential stress on unit of area parallel to xy, tending to move the part next the origin in the direction of x.

Let Y be the corresponding tangential stress in the direction of y.



Let k_1 and k_2 be the coefficients of elasticity with respect to these two kinds of tangential stress; then, if the medium is at rest,

$$X=k_1\frac{dx}{dz}, \quad Y=k_2\frac{dy}{dz}.$$

Now let us suppose vortices in the medium whose velocities are represented as usual by the symbols α, β, γ, and let us suppose that the value of α is increasing at the rate $\frac{d\alpha}{dt}$, on account of the action of the tangential stresses alone, there being no electromotive force in the field. The angular momentum in the stratum whose area is unity, and thickness dz, is therefore increasing at the rate $\frac{1}{4\pi}\mu r\frac{d\alpha}{dt}dz$; and if the part of the force Y which produces this effect is Y′, then the moment of Y′ is $-Y'dz$, so that $Y'=-\frac{1}{4\pi}\mu r\frac{d\alpha}{dt}$.

The complete value of Y when the vortices are in a state of

* Phil. Mag. April 1861.

varied motion is

$$Y = k_2 \frac{dy}{dz} - \frac{1}{4\pi}\mu r \frac{d\alpha}{dt}.$$

Similarly,

$$X = k_1 \frac{dx}{dz} + \frac{1}{4\pi}\mu r \frac{d\beta}{dt}. \quad \ldots \quad (145)$$

The whole force acting upon a stratum whose thickness is dz and area unity, is $\frac{dX}{dz}dz$ in the direction of x, and $\frac{dY}{dz}dz$ in direction of y. The mass of the stratum is ρdz, so that we have as the equations of motion,

$$\left.\begin{aligned} \rho\frac{d^2x}{dt^2} &= \frac{dX}{dz} = k_1\frac{d^2x}{dz^2} + \frac{d}{dz}\frac{1}{4\pi}\mu r\frac{d\beta}{dt}, \\ \rho\frac{d^2y}{dt^2} &= \frac{dY}{dz} = k_2\frac{d^2y}{dz^2} - \frac{d}{dz}\frac{1}{4\pi}\mu r\frac{d\alpha}{dt}. \end{aligned}\right\} \quad . \quad (146)$$

Now the changes of velocity $\frac{d\alpha}{dt}$ and $\frac{d\beta}{dt}$ are produced by the motion of the medium containing the vortices, which distorts and twists every element of its mass; so that we must refer to Prop. X.* to determine these quantities in terms of the motion. We find there at equation (68),

$$\delta\alpha = \alpha\frac{d}{dx}\delta x + \beta\frac{d}{dy}\delta x + \gamma\frac{d}{dz}\delta x \ldots (68).$$

Since δx and δy are functions of z and t only, we may write this equation

$$\frac{d\alpha}{dt} = \gamma\frac{d^2x}{dz\,dt};$$

and in like manner,

$$\frac{d\beta}{dt} = \gamma\frac{d^2y}{dz\,dt}; \quad \ldots\ldots \quad (147)$$

so that if we now put $k_1 = a^2\rho$, $k_2 = b^2\rho$, and $\frac{1}{4\pi}\frac{\mu r}{\rho}\gamma = c^2$, we may write the equations of motion

$$\left.\begin{aligned} \frac{d^2x}{dt^2} &= a^2\frac{d^2x}{dz^2} + c^2\frac{d^3y}{dz^2\,dt}, \\ \frac{d^2y}{dt^2} &= b^2\frac{d^2y}{dz^2} - c^2\frac{d^3x}{dz^2\,dt}. \end{aligned}\right\} \quad \ldots \quad (148)$$

These equations may be satisfied by the values

$$\left.\begin{aligned} x &= A\cos(nt - mz + \alpha), \\ y &= B\sin(nt - mz + \alpha), \end{aligned}\right\} \quad \ldots \quad (149)$$

* Phil. Mag. May 1861.

provided

$$(n^2 - m^2a^2)A = m^2nc^2B,$$

and

$$(n^2 - m^2b^2)B = m^2nc^2A. \quad \ldots \quad (150)$$

Multiplying the last two equations together, we find

$$(n^2 - m^2a^2)(n^2 - m^2b^2) = m^4n^2c^4, \quad \ldots \quad (151)$$

an equation quadratic with respect to m^2, the solution of which is

$$m^2 = \frac{2n^2}{a^2 + b^2 \mp \sqrt{(a^2 - b^2)^2 + 4n^2c^4}}. \quad \ldots \quad (152)$$

These values of m^2 being put in the equations (150) will each give a ratio of A and B,

$$\frac{A}{B} = \frac{a^2 - b^2 \mp \sqrt{(a^2 - b^2)^2 + 4n^2c^4}}{2nc^2},$$

which being substituted in equations (149), will satisfy the original equations (148). The most general undulation of such a medium is therefore compounded of two elliptic undulations of different eccentricities travelling with different velocities and rotating in opposite directions. The results may be more easily explained in the case in which $a = b$; then

$$m^2 = \frac{n^2}{a^2 \mp nc^2} \text{ and } A = \mp B. \quad \ldots \quad (153)$$

Let us suppose that the value of A is unity for both vibrations, then we shall have

$$\left.\begin{aligned} x &= \cos\left(nt - \frac{nz}{\sqrt{a^2 - nc^2}}\right) + \cos\left(nt - \frac{nz}{\sqrt{a^2 + nc^2}}\right), \\ y &= -\sin\left(nt - \frac{nz}{a^2 - nc^2}\right) + \sin\left(nt - \frac{nz}{\sqrt{a^2 + nc^2}}\right). \end{aligned}\right\} \quad (154)$$

The first terms of x and y represent a circular vibration in the negative direction, and the second term a circular vibration in the positive direction, the positive having the greatest velocity of propagation. Combining the terms, we may write

$$\left.\begin{aligned} x &= 2\cos(nt - pz)\cos qz, \\ y &= 2\cos(nt - pz)\sin qz, \end{aligned}\right\} \quad \ldots \quad (155)$$

where

$$p = \frac{n}{2\sqrt{a^2 - nc^2}} + \frac{n}{2\sqrt{a^2 + nc^2}},$$

and

$$q = \frac{n}{2\sqrt{a^2 - nc^2}} - \frac{n}{2\sqrt{a^2 + nc^2}}. \quad \ldots \quad (156)$$

These are the equations of an undulation consisting of a plane vibration whose periodic time is $\frac{2\pi}{n}$, and wave-length $\frac{2\pi}{p}=\lambda$, propagated in the direction of z with a velocity $\frac{n}{p}=v$, while the plane of the vibration revolves about the axis of z in the positive direction so as to complete a revolution when $z=\frac{2\pi}{q}$.

Now let us suppose c^2 small, then we may write

$$p=\frac{n}{a} \text{ and } q=\frac{n^2c^2}{2a^3}; \quad . \quad . \quad . \quad . \quad . \quad (157)$$

and remembering that $c^2=\frac{1}{4\pi}\frac{r}{\rho}\mu\gamma$, we find

$$q=\frac{\pi}{2}\frac{r}{\rho}\frac{\mu\gamma}{\lambda^2 v}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (158)$$

Here r is the radius of the vortices, an unknown quantity. ρ is the density of the luminiferous medium in the body, which is also unknown; but if we adopt the theory of Fresnel, and make s the density in space devoid of gross matter, then

$$\rho=si^2, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (159)$$

where i is the index of refraction.

On the theory of MacCullagh and Neumann,

$$\rho=s \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (160)$$

in all bodies.

μ is the coefficient of magnetic induction, which is unity in empty space or in air.

γ is the velocity of the vortices at their circumference estimated in the ordinary units. Its value is unknown, but it is proportional to the intensity of the magnetic force.

Let Z be the magnetic intensity of the field, measured as in the case of terrestrial magnetism, then the intrinsic energy in air per unit of volume is

$$Z^2=\frac{1}{8\pi}, \quad \frac{\pi s\gamma^2}{8\pi},$$

where s is the density of the magnetic medium in air, which we have reason to believe the same as that of the luminiferous medium. We therefore put

$$\gamma=\frac{1}{\sqrt{\pi s}}Z. \quad . \quad . \quad . \quad . \quad . \quad . \quad (161)$$

λ is the wave-length of the undulation in the substance. Now if Λ be the wave-length for the same ray in air, and i the index of refraction of that ray in the body,

$$\lambda=\frac{\Lambda}{i}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (162)$$

Also v, the velocity of light in the substance, is related to V, the velocity of light in air, by the equation

$$v=\frac{V}{i}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (163)$$

Hence if z be the thickness of the substance through which the ray passes, the angle through which the plane of polarization will be turned will be in degrees,

$$\theta=\frac{180^\circ}{\pi}qz; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (164)$$

or, by what we have now calculated,

$$\theta=90^\circ\frac{1}{\sqrt{\pi}}\cdot\frac{r}{s^{\frac{1}{2}}}\frac{\mu i Z z}{\Lambda^2 V}. \quad . \quad . \quad . \quad (165)$$

In this expression all the quantities are known by experiment except r, the radius of the vortices in the body, and s, the density of the luminiferous medium in air.

The experiments of M. Verdet* supply all that is wanted except the determination of Z in absolute measure; and this would also be known for all his experiments, if the value of the galvanometer deflection for a semirotation of the testing bobbin in a known magnetic field, such as that due to terrestrial magnetism at Paris, were once for all determined.

XV. *On the Composition, Structure, and Formation of Beekite.* By Arthur H. Church, *B.A. Oxon, F.C.S.*†

[With a Plate.]

THERE occurs in the triassic red conglomerate of Torbay and its neighbourhood, an interesting siliceous substance (generally considered to be a variety of hornstone), which offers a problem not only to the geologist and palæontologist, but also to the chemist. The Beekite is, in fact, not a mineral merely, but a fossil which has been more or less completely mineralized, the mineralization having, however, been effected in a way not very easy to understand. In the present paper, after having quoted some authorities in order to show the geological character and position of Beekites, I shall endeavour to throw some light,

* *Annales de Chimie et de Physique*, sér. 3. vol. xli. p. 370.

† Communicated by the Author.