MAGNETISM AND DIAMAGNETISM.

Diamagnetism is a term introduced by Faraday in connection with his discovery of the influence of magnetic force upon all bodies. By a diamagnetic is meant any substance which, when placed in a field of magnetic force, does not conduct itself in the same way as the magnetic bodies, iron, nickel, and cobalt. Before Faraday's discovery in 1845, the known properties of almost all the diamagnetics in relation to magnetic action were merely negative. It was known, indeed, long previously, that masses of bismuth and antimony act in a remarkable way upon a neighboring magnet, repelling the nearest pole, instead of attracting it as iron does; but this remained an isolated and barren fact, and seems to have received little attention till it was reduced by Faraday's discovery to a case of general magnetic action.

It was in the course of experiment in relation to circular magnetic polarization that Faraday first observed the new mechanical action of magnets upon bodies placed in the field of force. A bar of heavy glass was suspended centrally between the poles of a powerful horse-shoe electro-magnet. When the force of the magnet was developed, the bar no longer swung indifferently, but moved round its point of suspension into a direction at right angles to the lines of force, or at right angles to the direction that would be taken by a bar of soft iron placed in the same part of the field. Round this position the bar made a few vibrations, and finally settled in it. If displaced from it by the hand, it returned to it and settled as before, showing that this position of the bar, which Faraday calls the equatorial, was a position of stable equilibrium.

When the bar was placed originally, at rest, in the axial position, or in the position of stable equilibrium of an iron bar, it did not move out of this position under the action of the magnet; but if displaced a little in either direction it moved on into the equatorial position and settled there as before; showing that the axial is a position of unstable equilibrium.

It was observed further, that if the bar was placed near one of the poles, it was not only *directed* round its point of suspension, as above-mentioned, but was also repelled as a whole by the nearest pole, the center of gravity of the bar sensibly receding from that pole, and so remaining while the magnet was retained excited. The effects are simplified by the employment of. one electro-magnetic pole instead of two. In this case, the bar is always repelled by the pole in the direction of the lines of magnetic force passing through it; and it moves at the same time into a position perpendicular to the lines of force.

The effects are further simplified by using a cube or ball of heavy glass instead of an oblong bar. When such a body is acted on by one pole, it moves constantly outwards in the direction of the lines of magnetic force. When subjected to the action of two poles, the effects are more complex; but there is a simple law that explains them all. It is this, that a particle of heavy glass or other diamagnetic tends constantly to move outwards, or into the positions of weakest magnetic action. The directive tendency of an oblong diamagnetic across the lines of force when one or two poles are employed can be easily accounted for by this law. It is a simple result of the joint tendency of all the particles towards the positions of weakest force.

The property of being repelled by magnetic poles is not peculiar to heavy glass; it is, on the contrary, common to the most of natural and artificial bodies. It may be said, without exception, that every known substance, when subjected to electro-magnetic forces of sufficient power, will give some positive result, either of the magnetic or the diamagnetic character. And it is in comparatively few cases that the results are of the common magnetic kind presented by iron and nickel. Faraday himself tested a great number of bodies taken from all classes, amorphous and crystalline, liquid and solid, organic and inorganic. In this examination the liquids were experimented on by being inclosed in glass tubes, the action of the glass under the magnetic forces being taken into account.

Some of the results may be stated. Transparent bodies were the first examined, as was natural in the circumstances of the discovery. And it was found that even such transparent bodies as the singly and doubly refracting crystals, whose magnetic rotary action upon light is too feeble to be observed, are yet subjected to directive and repulsive actions by magnetic poles in their neighborhood, as other diamagnetics are. Of opaque bodies again, whose condition under magnetic action could not be tested by means of light, some are found to act very powerfully. Phosphorus may be mentioned as equal, if not superior, in its mechanical indications, to heavy glass. Sulphur and india-rubber are also well directed and repelled. Among liquids, alcohol and ether are evidently diamagnetic, and water still more so. Of organic bodies, the most are clearly diamagnetic. Wood, starch, sugar, leather, beef, mutton, apple, bread, and blood are instances; they are all repelled by the magnetic poles, and, when in oblong volumes, directed equatorially.

With regard to the gases, Faraday obtained no positive result in the first series of his experiments in this field. It was discovered, however, by Bancalari, that flames are mechanically affected by magnetic forces; and the subject was resumed by Faraday and other philosophers with success. It was found in the first place, that a current of heated air ascending between the poles of an electro-magnet conducts itself as a diamagnetic, separating under the magnetic action into two streams which ascends on different sides of the axial line. On the other hand, a descending current of cold air is not divided under the action of the poles, but keeps to the axial line. A descending stream of oxygen acts as a powerful magnetic body; if its proper line of descent is on either side of the axial line, its direction is changed by the action of the magnet, so as to intersect the latter line. All the other gases, when treated similarly are found to be diamagnetic, with the exception, perhaps, of nitrous gas.

To render the effects of the magnetic action more evident, Faraday inclosed the gases in soap-bubbles, and set them afloat in the magnetic field; and this test was found to be very delicate. Oxygen in these circumstances was powerfully attracted, and the other gases gave results in accordance with previous experiments. By employing glass tubes as the envelopes of the gases, in connection with a delicate torsion-balance, Faraday has even compared the gases magnetically with each other, and with themselves in different states of density and temperature. The contrast brought out by this method between the two principal components of our atmosphere is very interesting, and highly important also from its bearings on the theory of terrestrial magnetism.

The magnetic power of oxygen suffers evident diminution by a diminution of density, and also by an increase of temperature; though the gas cannot be rarefied or heated to such an extent as to lose all magnetic power. Nitrogen, on the other hand, which is a diamagnetic, undergoes no sensible change in its magnetic relations by the utmost attainable changes in density and temperature. In this brief view of the natural bodies in their magnetic relations, we have to refer finally to the metals.

Iron, nickel, and cobalt, have been long known as magnetic metals, though the second is far inferior in power to iron. To these metals Faraday has added the following: Platinum, palladium, titanium, manganese, cerium, chromium, and perhaps osmium. Some of these are inferred to be magnetic from direct observations of their actions in the field of force, while the character of others has been determined by the actions of their chemical compounds. The rest of the metals appear to be non-magnetic in the common sense of the term. They are found to be all subject to the influence of the magnetic force, and they produce the same general effects as heavy glass and the other diamagnetics already referred to.

The repulsive forces are manifested on the diamagnetic metals in very different degrees. Some of the metals, as gold, copper, silver, are inferior as diamagnetics, even to water; and with the exceptions of antimony and bismuth, they are all inferior to heavy glass. The last-mentioned metal has been characterized by Faraday as one of the best substances for the exhibition of the entire diamagnetic phenomena of the mechanical kind. The conduct of the various compounds of the metals under magnetic action has been studied with great attention. We may merely state the general law which has been arrived at upon this point by a very extensive induction; that the decidedly magnetic and the decidedly diamagnetic metals preserve their magnetic characters throughout all changes of mixture and chemical composition and solution.

By inference from this law, Faraday has determined the magnetic character of some of the metals, whose indications in the magnetic field could not be depended upon. It need hardly be observed that it is not meant by the above statement, that a solution of salt of iron, for example, will act evidently under magnetic force in the same way as iron itself does; for it may or may not so act, according to circumstances. The magnetic action of a mixture or chemical compound of different matters is the resultant of the actions of all its constituent parts; and the law is, that the action of each part is proper in kind and quantity to the part itself, and independent of the circumstances of mixture and chemical composition into which the part may enter. A solution of iron then will be magnetic or diamagnetic according to the strength of the solution—that is, according to the proportion of water or other diamagnetic matter with which it is diluted.

It is interesting to observe generally in this connection that the magnetic and diamagnetic properties of the parts of any mixed body, while they oppose each other in their effects, appear to interfere in no degree with each other in their proper actions. The delicacy of the experimental researches that have been conducted in this field is well illustrated by the phenomena of mixed bodies.

Glass in a pure state is evidently diamagnetic, but in the common forms of green-bottle and crown it is as evidently magnetic, in virtue of the small quantity of iron present in its mass. Wood in a pure state is diamagnetic; but to obtain a chip that will conduct itself as a magnetic body we have only to detach it with a common knife. Common paper again has been sometimes found to possess magnetic properties; and the fact has been explained by the contact of iron with the paper in the process of manufacture.

In the previous part of this article, bodies have been considered in their magnetic relations without reference to the *enveloping matter*, and they have been spoken of as absolutely magnetic or diamagnetic. This view has preserved us from unnecessary complication in the statement of elementary facts, but it now requires an important correction. The conduct of a body in the magnetic field depends as much, in fact, upon the nature of the enveloping matter as upon the nature of the body itself. As a simple instance: There are certain substances which set equatorially and are repelled in air, while in water they set axially, and are attracted; in other terms, they act as diamagnetics in a magnetic field which is occupied by air, while in the same part of a precisely similar field which is occupied by water, they act as magnetics. Phenomena of the same kind are presented by other media.

There are certain remarkable experiments of Faraday's that are worthy of notice in this connection. Glass tubes were filled with solutions of iron of different strengths, and were hermetically sealed. Vessels were also filled with the solutions, and placed successively in the magnetic field. The tubes in succession were immersed movably in the vessels when occupying the field of force; and though all the tubes were magnetic they sometimes pointed equatorially. The phenomena presented this constant law—that if the solution in the tube were stronger than that which enveloped it, the tube conducted itself as a magnetic body; if, on the other hand, the internal solution were the weaker, the tube was repelled and directed equatorially, and could be distinguished in no way from a diamagnetic. These facts have an evident bearing upon the nature of the distinction between bodies as magnetic and diamagnetic. But we consider them at present merely with an inductive view, and without reference to theoretical questions that may be raised in connection with them.

From the above statements it is evident that we cannot properly speak of a body as magnetic or diamagnetic without reference to the medium in which it is placed. But in practice we can dispense with the reference without any danger of mistake, by agreeing that where no medium is mentioned the air is understood. After this, the action of media, as far as determined, may be easily described. A magnetic body will act as a magnetic in every diamagnetic medium, and in every medium of less magnetic power than itself, but as a diamagnetic in every medium of greater magnetic power.

A diamagnetic will act as a diamagnetic in every magnetic medium, and in every medium of less diamagnetic power than itself; but as a magnetic in every medium of greater diamagnetic power than itself.

In conclusion, we may observe, that these and other facts are powerfully in favor of the idea, that bodies differ from one another as magnetic and diamagnetic only in virtue of the difference of degrees in which they possess the one common magnetic property. And that therefore a mass of bismuth or heavy glass recedes from the magnetic pole, not because of a repulsive action of the pole upon the diamagnetic, but because of a greater attraction exerted upon the surrounding medium; just as smoke ascends in air, and light solids in water, in opposition to the proper attractions exerted upon them.

This view was stated by Faraday as probably the true one, in connection with his singular experiments on solutions of iron already described; but he has seen reason to question it, and to speak of the movements of diamagnetics in the field of force as due to a proper repulsive action of the poles, an action therefore entirely different from the common and long-known action of magnetic force.

Whatever view be taken upon this point, there can be only one opinion as to the importance of the discovery of "the new magnetic condition." Magnetic science has received from it a very great extension. Those subtile forces that were formerly known only as exerted upon iron and two other metals are now recognized as acting effectively upon all bodies, and as exercising, in all probability most important functions in various departments of the great system of nature.—*Prof. Nichol.*

The Philosophy of the Earth Circuit.

It was at one time imagined that the earth completed the circuit precisely in the same manner as a return wire; this opinion is now considered incorrect. Gavarret explains the action thus:

"The poles of a battery, when disconnected, have equal and contrary tensions.

"When insulated conductors are placed in contact with them, they themselves become the poles of the battery, the battery having furnished a current sufficient to charge them, but not of *sufficient duration* to move a galvanometer needle.

"If the conductors are enlarged, the time occupied in charging them will increase, until, as they are still further enlarged, a limit will be reached at which the flow of electricity into them will last long enough to affect the galvanometer; and when the conductors become infinitely long or infinitely large, the time occupied in charging them also becomes infinite, or, in other words, the current will pass precisely as if the poles were connected.

"Thus, when the extremities of a circuit are connected to the earth, which is an infinitely large conductor, their respective tensions are diffused in all directions without producing any appreciable tension in the earth itself, so that the current will continue to flow.

"The earth acts as an ordinary conductor and opposes some resistance to this diffusion."

Another view is, that as whenever one kind of electricity is produced, an equal quantity of the opposite is also produced; and as both these tensions are ultimately transferred to the earth, its tension remains unaltered, the opposite tensions neutralizing one another through the earth's conductibility.

When a layer of soil placed in a box is compared with a similar layer forming part of the earth's surface, it is found that the isolated portion offers the greater resistance. Its resistance follows the same laws as that of any other substance, depending on its dryness or dampness, its nature, and its length and section.—*Culley's Handbook of Telegraphy.*

Mr. U. B. VIDAL, of Philadelphia, proposes to provide the street cars with strong skirts or nets, supported on frames to extend from the flooring down to or near the ground. The object of the improvement is to save persons who fall from being run over by the car. The frame which supports the net is to be elastic, vertically, so as to yield when any portion touches the ground. Such an improvement is greatly needed.

IT is stated on excellent authority that a constant current runs through the central portion of the Suez Canal, from the side of the Mediterranean to that of the Red Sea.