GEOGRAPHICAL NOTES

AT the meeting of the Royal Geographical Society on Monday night Sir Henry Rawlinson read the following telegram, forwarded by the Eastern Telegraph Company from Zanzibar, with regard to the movements of Mr. Joseph Thomson:—"Thomson reached Dgare na Erobi, in Masai country, long. 37°, lat. 3·5, on May 5. Was compelled to flee during night to evade what could only have been a disastrous fight, through troubles raised by Fischer's caravan in front. Got safely back to Taveta, where he camped his men, and has come down to Mombasa with small party in seven marches to replenish his goods, which has become necessary in consequence of his retreat from Masai and prolonged detention at Taveta. Returns in a few days to Taveta 'to proceed by Arusha, probably in compauy of another caravan. Is in good health. Details by post."

THE Russian Geographical Society has awarded its great gold medal to H. W. Abich, Member of the Academy of Sciences, for his researches into the Geology of the Caucasus. The gold medal of Count Lütke has been awarded to W. K. Döllen, astronomer of the Pulkova Observatory, for his new improved instrument for the determination of latitudes and longitudes. Two other gold medals, for ethnographical and statistical works, have been awarded to M. Barsoff, for collections of songs of Northern Russia, and to M. Krasnoperoff for a statistical description of the Government of Perm. Small gold medals have been awarded to MM. Eklon and Roborovsk, who both accompanied M. Prshevalsky in his travels; to M. Oshanin, zoologist, for travels in Karategin, Darvaz, and Turkestan; and to M. Vitkovsky, for exploring graves of the Stone period about Irkutsk. Silver medals have been awarded to M. Lessar for levelling operations between Askabad and Seraks; to M. Schultz for the same between Orenburg and Lake Aral; to M. Brounoff, for researches on cyclones and anticyclones in Europe; to M. Gladysheff, for determinations of latitudes and longitudes in the Akhal-tekke oasis; to M. Kiseleff, for a journey to the Bi-shan; to M. Rodionoff, for surveys in Karategin; to M. Slovtsoff, for a description of the district of Kokchetan; also four other medals for smaller ethnographical and statistical works.

M. LESSAR, who made so interesting a journey from Askabad to Mash-had, continues to make a series of excursions in the same region. He went a second time to Mash-had *viâ* Khelat, and thence to Zurabad, Saraks, Merv, Charjui, and Khiva; then he made a barometric levelling from Askabad to Tejent, visited Merv a second time, and in December last journeyed in the mountain region of Khelat, Daraghez, and Attek, thus covering about 3300 miles from April to December.

THE proprietors of the *Melbourne Age* have despatched an exploring expedition to New Guinea.

WE mentioned in a preceding volume the late Barbot de Marny's theory as to the formation of the dunes (*barkhans*) in the steppe of Kyzyl-kum and the influence of the wind as a powerful agency in modifying the earth's surface in the steppes. We find now, in the *Zapiski* of the Kieff Society of Naturalists, several objections to this theory by M. Borschoff. Without denying the partial influence of the wind, he reduces it to a quite secondary agency, and decidedly opposes the wind-theory of the formation of *barkhans*. Wind may increase the *barkhans* to a certain amount, but their primary origin must be sought for elsewhere, and the *rôle* of the wind is far below what has been assumed. So hard a rock as the sandstone, permeated with iron and lime, of the Kara-kum and Kyzyl-kum steppes cannot be disintegrated by wind, unless it has been disintegrated beforehand by rains and rapid changes of temperature —both which conditions are missing in the steppes. Therefore on the Emba, the Ilik, the Irghiz, where the same sandstones occur—as devoid of vegetation as in the Kyzyl-kum, there are no such surfaces covered with *barkhans* as in the neighbourhood of Lake Aral. As a rule the dunes appear only where there are remains of former lakes, and in such cases they assume the directions of the shores of these former basins. Far from being dependent on the direction of the prevailing winds, the direction of the *barkhans* varies, even within short distances, and it follows the windings of the coast of Lake Aral. Thus, they inclose the Sary Cheganak bay, like the parallel steps of an amphitheatre, the same directions being also taken by the rocky ledges of the terraces of sandstone, even beneath the water of the bay. The close connection of these ridges with the former action of the interior sea is the more obvious, as these dunes—sometimes stratified in their interior—often contain remains of Aral mollusks, such as *Cardium rusticum*, *Dreissena polymorpha*, as also *Adacna vitrea*. Whole banks, from a quarter to half a foot thick, of these shells are found in the *barkhans*, and they are met with at distances of 27 miles from Lake Aral, and 70 feet above its level (at Sopak), or even 80 miles north of it, and 100 to 120 feet above its level (at the Toulagai hill), whilst the depressions between the *barkhans* contain deposits of salt, with the same shells, or with an alga similar to the Aralian *Zostera*. The primary origin of the *barkhans*, M. Borschoff says, can be discovered even now in the low coast ridges. These ridges once formed slowly increase afterwards by the accumulation of vegetation on their summits, and vegetation plays a most important part in their growth. Several Solaneæ, such as *Caroxylon*, or *Halostachys*, and Gramineæ, such as *Ærulops lævis*, grow on their summit, which is covered subsequently with various species of *Tamarix* and *Calligonum*. When deeply covered with vegetation, their further increase is due to the sand brought by the wind, the organic life still remaining a powerful agency of increase. But their original appearance must be sought for, it is contended, in the agency of water. M. Severtsoff's remarks on the influence of vegetation on the growth of the dunes, and those of the Turkestan railway expedition on the immobility of the dunes (already analysed in NATURE), go far to sustain M. Borschoff's conclusions.

AN expedition, under the direction of Col. Prshevalsky, is being organised for the purpose of scientific researches in Central Asia and Thibet. The expedition is expected to start in August next.

A SERIES of valuable papers on the island of Yezo now appearing in the *Japan Gazette* deserve the attention of geographers. They are from the pen of Capt. Blakiston, who received the gold medal of the Royal Geographical Society in 1861 for exploration on the Yang-tsze, and who has for many years resided at Hakodate, the principal port of Yezo. The papers, which have reached their fifteenth part, are so varied and complete that they may fairly be called an encyclopædia of the island. The geography, geology, fauna and flora, the progress made during the past twenty years by the Japanese administrators, the Ainos, the mineral productions are all treated, and in addition the records of numerous journeys over all parts of the island are given. It is to be hoped that these valuable papers will be published in a collected form, for no future account of Yezo will be complete in which copious reference is not made to them. The numerous reports of the *employés* of the Japanese Government to the Colonisation Department in Tokio, which are now so difficult to obtain, are largely quoted in notes.

ACCORDING to a new survey of the rapids of the Dnieper, the total fall of the river, on a stretch of forty-six miles, from Ekaterinoslav to the Khortitsa Island at Alexandrovsk, is 106·5 feet. The aggregate fall of the nine rapids is 60·3 feet, and their aggregate length is 5335 yards, the greatest rapid being that of Nenasytetsky (the Insatiable) which has a fall of 19·5 feet and a length of 1867 yards. The discharge of water at the head of the rapids has been found, at a level 2·5 feet below the average, to be 27,934 cubic feet per second.

THE CAUSE OF EVIDENT MAGNETISM IN IRON, STEEL, AND OTHER MAGNETIC METALS [1]

THE extreme sensitiveness of the induction balance to all molecular changes in the structure of metals was remarked in my first paper on this subject to the Royal Society; [2] and in the case of iron and steel it is most remarkable, as the addition or subtraction of 1/500,000th part, or the addition of the smallest iron filing to an already large balanced mass of iron, is at once rendered evident and measurable.

Possessing such an invaluable instrument of research, I was desirous of investigating the molecular construction of iron and steel, but at once I met with a difficulty, viz. that magnetism itself completely changed the character of any piece of iron under investigation; consequently, finding no help or explanation of the effects produced from any accepted theories of magnetism, I was forced to investigate, by means of the induction balance, the

[1] Paper read before the Society of Telegraph Engineers and of Electricians, on May 24, 1883, by Prof. D. E. Hughes, F.R.S., Vice-President.

[2] "On an Induction Current Balance, and Experimental Researches made therewith."—*Proceedings Royal Society*, March 29, 1879, p. 56.

whole question of magnetism as existing in the interior of a magnet, and to determine the particular structure for each case, such as neutrality and polarity.

In a recent paper to the Royal Society, upon the theory of magnetism (*Proceedings Royal Society*, May 10, 1883), I described the use of and demonstrations obtained by the induction balance. In this paper I propose to confine myself to demonstrations that can be repeated without it, and whose effects can be observed by the aid of ordinary magnetic direction needles.

That magnetism is of a molecular nature has long been accepted, for it is evident that, no matter how much we divide a magnet, we still have its two poles in each separate portion, consequently we can easily imagine this division carried so far, that we should at last arrive at the molecule itself possessing its two distinctive poles, consequently all theories of magnetism attempt some explanation of the cause of this molecular polarity, and the reason for apparent neutrality in a mass of iron.

Coulomb and Poisson assume that each molecule is a sphere containing two distinct magnetic fluids, which in the state of neutrality are mixed together, but when polarised are separated from each other at opposite sides; and, in order to explain why these fluids are kept apart as in a permanent magnet, they had to assume, again, that each molecule contained a peculiar coercive force, whose functions were to prevent any change or mixing of these fluids when separated.

There is not one experimental evidence to prove the truth of this assumption; and as regards coercive force, we have direct experimental proof opposing this view, as we know that molecular rigidity or hardness, as in tempered steel, and molecular freedom of softness, as in soft iron, fulfil all the conditions of this assumed coercive force.

Ampère's theory, based upon the analogy of electric currents, supposes elementary currents flowing around each molecule, and that in the neutral state these molecules are arranged haphazard in all directions, but that magnetisation consists in arranging them symmetrically.

The objections to Ampère's theory are numerous. 1. We have no knowledge or experimental proof of any elementary electric currents continually flowing without any expenditure of energy. 2. If we admit the assumption of electric currents around each molecule, the molecule itself would then be electro-magnetic, and the question still remains, What is polarity? Have the supposed electric currents separated the two assumed magnetic fluids contained in the molecule, as in Poisson's theory? or are the electric currents themselves magnetic, independent of the iron molecule?

In order to produce the supposed heterogeneous arrangement of neutrali y, Ampère's currents would have either to change their position upon the molecule and have no fixed axis of rotation, or else the molecule, with its currents and polarities, would rotate, and thus be acting in accordance with the theory of De la Rive. 3. This theory does not explain why (as in the case of soft iron) polarity should disappear whenever the exciting cause is removed, as in the case of transient magneti ation. It would thus require a coercive force in iron to cause exactly one-half of the molecules to instantly reverse their direction in order to pass from apparent external polarity to that of neutrality.

The influence of mechanical vibrations and stress upon iron in facilitating or discharging its magnetism, as proved by Matteucci, 1847, in addition to the discovery by Page, 1837, of a molecular movement taking place in iron during its magnetisation, producing audible sounds, and the discovery by Dr. Joule, 1842, of the elongation of iron when magnetised, led De la Rive, in his remarkable "Treatise on Electricity," 1853, to give his theoretical views upon magnetism in the following remarkable words:—

"The whole of the magnetic molecular phenomena that we have been studying lead us to believe that the magnetisation of a body is due to a particular arrangement of its molecules, originally endowed with magnetic virtue, but which in the natural state are so arranged that the magnetism of the body that they constitute is not apparent. Magnetism would therefore consist in disturbing this state of equilibrium, or in giving to the particles an arrangement that makes manifest the property with which they are endowed, and not in developing it in them. The coercitive force should be the resistance of the molecules to change their relative positions."

Wiedemann, in 1861, gives a theory in which he admits the fluids of Poisson, or the elementary currents of Ampère, as the cause of polarity of the molecule, but believes that the molecules are turned in a general direction in the case of polarity, and that in neutrality, like Ampère's, the magnetic axes of the molecules are turned in all directions.

Maxwell, in his remarkable treatise on "Electricity and Magnetism," 1881, page 75, gives the following *résumé* of Weber's theory:—

"Weber's theory differs from Poisson's in assuming that the molecules of the iron are always magnets, even before the application of the magnetising force, but that in ordinary iron the magnetic axes of the molecules are turned indifferently in every direction, so that the iron, as a whole, exhibits no magnetic properties." And again, page 429, Maxwell says he agrees with Weber's views, and that neutrality, or unmagnetised iron, has the axes of its molecules placed indifferently in all directions, and that the act of magnetisation consists in turning all the molecules so that their axes are either rendered all parallel to one direction, or at least deflected in that direction.

I have quoted these several theories which admit of the inherent polarity of the molecule, and in that respect they entirely agree with my own; but the induction balance at once shows that they are erroneous in the most important part, for my researches have proved that neutrality is perfectly symmetrical, that there is no case of neutrality where the axes of the molecules are turned indifferently in all directions, and that we cannot obtain perfect neutrality except when the molecules form a complete closed circuit of attraction.

I believe that a true theory of magnetism should admit of complete demonstration, that it should present no anomalies, and that all the known effects should at once be explained by it.

From numerous researches I have gradually formed a theory of magnetism entirely based upon experimental results, and these have led me to the following conclusions:—

1. That each molecule of a piece of iron, steel, or other magnetic metal is a separate and independent magnet, having its two poles and distribution of magnetic polarity exactly the same as its total evident magnetism when noticed upon a steel bar-magnet.

2. That each molecule, or its polarity, can be rotated in either direction upon its axis by torsion, stress, or by physical forces such as magnetism and electricity.

3. That the inherent polarity or magnetism of each molecule is a constant quantity like gravity; that it can neither be augmented nor destroyed.

4. That when we have external neutrality, or no apparent magnetism, the molecules, or their polarities, arrange themselves so as to satisfy their mutual attraction by the shortest path, and thus form a complete closed circuit of attraction.

5. That when magnetism becomes evident, the molecules or their polarities have all rotated symmetrically in a given direction, producing a north pole if rotated in that direction as regards the piece of steel, or a south pole if rotated in the opposite direction. Also, that in evident magnetism we have still a symmetrical arrangement, but one whose circles of attraction are not completed except through an external armature joining both poles.

6. That we have permanent magnetism when the molecular rigidity, as in tempered steel, retains them in a given direction, and transient magnetism whenever the molecules rotate in comparative freedom, as in soft iron.

Experimental Evidences.—In the above theory the coercive force of Poisson is replaced by molecular rigidity and freedom; and as the effects of mechanical vibrations, torsion, and stress upon the apparent destruction and facilitation of magnetism is well known, I will, before demonstrating the more serious parts of the theory, cite a few experiments to prove that molecular rigidity fulfils all the requirements of an assumed coercive force.

The influence of vibrations, torsion, or stress of any kind upon a magnetised steel or iron rod may be seen by striking with a wooden mallet rods of hard and soft steel, also hard and soft iron previously magnetised to a known degree. The tempered steel, owing to its molecular rigidity, will lose but 5 per cent., the soft steel 60, hard iron 50, and soft Swedish iron 99 per cent. of its magnetism, the amount of loss depending not so much upon whether the metal be steel or iron, as upon its degree of hardness and softness; and as hard steel requires far more power to magnetise it to the same force than iron, it is possible to imagine a steel so hard that its molecules could not rotate, and that consequently no magnetism could be manifested from a given inducing cause, whilst a perfectly soft iron would give the maximum effect, and instantly return to its previous state. From this we might in error suppose that soft Swedish iron could not retain its magnetism, and that its natural state would be zero, or neutrality. The apparent disappearance of magnetism, however, is here due to the extreme freedom of motion of its molecules allowing them at once to follow the comparatively feeble directing force of the earth's magnetism. We can demonstrate this by feebly magnetising a rod of soft iron held vertically, so that its north pole is at the lower portion. Upon removing the inducing magnet, or electromagnetic coil, we find that the rod retains a powerful north polarity; but if magnetised in a contrary sense, then we have only *traces* of magnetism left upon the withdrawal of the inducing cause. To succeed in this experiment, as in all others where soft iron is mentioned, we should use the best Swedish charcoal iron, thoroughly annealed at high temperature.

We find, again, that rods of steel or iron will lose far less magnetism when vibrated in the magnetic dip, or vertically, when their north poles are at the lowest extremity, than when horizontal, or still less than when their poles are contrary to those of the earth's field, and also that they will acquire their maximum magnetism from a given exciting cause when held vertically as described, and the molecules allowed greater freedom of motion to obey the directing influence by vibrations, torsion, stress, or blows upon the iron. Any influence that would tend to give greater freedom of motion, such as heat or mechanical trepidations, gives a far higher magnetic force to the iron than could be obtained without these aids.

In order to render visible the effects of motion upon magnetism, we may take two glass tubes, or ordinary phials, of any length or diameter, say, 10 centimetres in length by 2 centimetres in diameter. If we now put iron filings in these tubes, leaving about one-third vacant, so as to allow complete freedom in the filings when shaken, we find that each tube, when magnetised, retains an equal amount of residual magnetism, and that this all disappears upon slightly shaking the tube. We are thus imitating the effects of vibration. But if in one of these tubes we pour melted resin (in fact, any slightly viscous liquid, such as petroleum, suffices), we then render these filings more rigid, and then we can no longer produce by shaking the disappearance of its residual magnetism. In pouring in petroleum we have apparently been introducing a strong coercitive force, but we know that it can only have the mechanical effect of rendering the iron filings less free to turn, and so comparatively rigid. If we desire to see the effect of torsion, we have only to shake the filings so that when the tube is held horizontally the vacant space is above, and rotate it slightly (but without shaking) about a horizontal axis. Its remaining magnetism instantly disappears upon rotation, although we evidently have not changed the longitudinal position of its particles. A similar effect takes place upon a soft iron rod, for if we magnetise it and observe its remaining magnetism, we find that upon giving a slight torsion to this wire its remaining magnetism instantly disappears—a similar effect to that in the rotating tube of iron filings. But if the iron is rendered more rigid by hammering, or steel rendered hard and rigid by tempering, torsions or vibrations have but little effect, as in the case of the filings rendered rigid as above mentioned. Thus we have no longer need of an assumed mysterious coercive force to account for the retention of magnetism, for once knowing the mechanical qualities of iron and steel and their degree of molecular rigidity or hardness, we can at once predict their retentive magnetic powers.[1]

Rotation of Inherent Polarised Molecules.—Torsion, as well as mechanical vibrations, has, as we have seen, a powerful influence in aiding the molecules to overcome their inertia, and thus aid them to rotate in the direction of the inducing influence; and we may thus polarise strongly a flat, soft iron rod by simply bending or vibrating it when held vertically, and if we measure the magnetic force obtained we shall notice that the force is strictly relative to the degree of softness of the iron. Thus, with hard steel we should obtain only *traces* of polarisation, whilst with extremely pure, soft Swedish iron we obtain the maximum of force. The bar of iron or steel, being held in the earth's magnetic field, of infinite size compared with the bar, and infinitely homogeneous, cannot deflect or weaken its surrounding field. Its lower portion, being north, apparently strengthens it by its reaction, whilst its upper, south, apparently weakens the field; but, as Maxwell has shown, "the two poles of each molecule are equal and opposite, consequently the sum of each molecule and the whole mass must be zero."

[1] "On the Molecular Rigidity of Tempered Steel," by Prof. D. E. Hughes, F.R.S. (*Proceedings Institution of Mechanical Engineers*, pp 72-79, January, 1883.)

We have a far greater induced polarity in iron or steel when the iron is in thin bars or small wires, and this we should expect, as the external molecules rotate directly under the influence of the earth's magnetism, whilst those forming the interior of the bar either rotate feebly, or, as in the case of very thick bars, actually act as an armature, preventing by their influence free rotation of the exterior molecules.

Thus, as the sum of the two and equal polarities in a bar of iron is zero, it is evident that its polarity must be inherent. I have some remarkably pure soft Swedish iron wire, one millimetre in diameter, and as its inherent polar force seemed great when held vertically in the earth's magnetic field, I measured in the induction balance this force compared with a similar column of the magnetic atmosphere which it displaced. The inherent polarity of this wire, simply rendered evident by the earth's magnetism, was 15,600 times greater than the column it displaced.

We cannot, either by induction, conduction, or concentration, produce a greater force in another body of similar displacement or size, otherwise we could easily create power from a feeble source. Thus the enormously greater magnetic power observed in iron than the same column of air which it displaces must be due to the *inherent* polarity of its molecules.

Amongst numerous bars of iron upon which I have experimented, one of ordinary hoop-iron, 2 centimetres wide, 40 centimetres long, and 1½ millimetre thick, not softened, possesses sufficient molecular rigidity to be apparently uninfluenced by the earth's magnetism. When this rod is rendered neutral we have but feeble polarity—mere traces when it is held vertically under the earth's magnetic influence; but if we apply a few successive torsions or vibrations to it when thus held, we have at once several thousand times greater polarity than before. Now, if iron had the power of deflecting or concentrating the earth's magnetism upon itself, it should not require the mechanical aid to molecular rotation given to it by these torsions or vibrations. Thus we are forced to conclude at least the existence of the inherent polarity of the molecules; and, if we admit this, we must also as a necessary consequence, admit the rotation of these molecules, else we cannot explain why mechanical vibrations allowing freedom of motion should always produce the polarity in accordance with the directing cause. I have already shown that torsion and vibrations *per se* are apparently destructive of magnetism; consequently in this case Poisson's two fluids and Ampère's parallel currents should, according to their theory, be mixed or heterogeneous, whilst, according to the views I am sustaining, the polarised molecules should obey, as compass needles, any magnetic directing cause whenever sufficient molecular freedom of motion allows free rotation.

The inherent polarity of iron may again be observed by drawing a flat rod of soft iron over one or both poles of a permanent magnet. This rod will then be powerfully magnetised, its remaining magnetism, when separated from the magnet, being sufficiently powerful to strongly deflect a suspended direction needle. A few slight torsions or vibrations will then completely discharge it. Now, suppose this operation repeated successively many thousand times, if there was no inherent polarity we should have gradually drawn all the polarity out of the magnet, and discharged it into the atmosphere. Nothing of the kind takes place. The molecules of the iron are simply rotated each time, and the only energy in work expended or lost comes from the arm of the experimenter, and the energy required would be strictly in accordance with the molecular freedom, or softness and hardness of the iron and steel; thus, whilst soft iron could be easily polarised and discharged by mechanical torsions, hard tempered steel would require a far greater amount.

Dr. Warren de la Rue, F.R.S., kindly aided me in this part of the research by passing a current from his well-known chloride of silver battery through iron and steel wires. A condenser of 42·8 microfarad capacity, charged by 3·360 cells, was used. We passed this enormous electric charge longitudinally through the wires, and observations were made as to whether any change whatever was produced in their quality or inherent polarity, the result being that these wires gave exactly the same magnetic polarity from a given directing or inducing cause as before, being similar in nature and degree, consequently this enormous electric force had not changed or destroyed the original inherent polarity.

If the molecules possess inherent polarity and rotate upon their axes, similar to a series of compass needles having a slight degree of frictional rigidity, then, upon passing one pole of a magnet above them, they would turn symmetrically in one direction, and drawing the same pole of the magnet in the contrary direction would rotate them, and they would then remain symmetrically in the opposite direction.

A precisely similar effect takes place in a soft iron rod, placed east and west a few inches above a direction needle. Upon drawing the south pole of a powerful natural magnet at a few centimetres distance above the wire from east to west, the north polarities of the molecules successively turn in the direction of west, following the attraction of the south pole, as previously seen on the small compass needles. The rod is now magnetised with its north pole west, as indicated by the direction needle below any portion of this rod. Upon passing the same south pole of the natural magnet in a contrary direction, the molecules all rotate, their north poles still turning successively to the south pole of the permanent magnet until its arrival at the end from which the first magnetisation commenced. The rod has now entirely changed its polarity, and its north pole is east.

This phenomenon is well known in the ordinary magnetisation of rods, where care is taken to draw the magnet always in a similar direction, or the poles would be reversed at each to and fro drawing. To account for this on Coulomb-Poisson's theory it would be requisite that, first, all the fluids be separated with their north fluids symmetrically in one direction, but on drawing back the magnet these fluids would have to mix together, the north fluid passing through its south fluid to be finally opposite to its previous position, its coercive force doing the double work of allowing both fluids to mix and pass through each other, and finally keep them entirely apart. Ampère's theory would require that from a haphazard arrangement the molecules should become symmetrically arranged upon the first passage of the magnet, then upon its reversed direction one-half of the electric elementary currents should successively revolve in a contrary direction to arrive at neutrality before, finally, the other half followed the direction of the first half, and now all these currents would be revolving in the opposite direction to that upon the first magnetisation. We thus see that both these theories, whilst resting altogether upon assumption, are extremely complicated and improbable.

We might suppose, from the theory which I am advocating, that upon the rotation of the molecules there would be some disturbance or mechanical trepidation; and such is found to be the case, as first observed by Page and afterwards verified by Dr. Joule and De la Rive, in the molecular sounds produced in iron upon its magnetisation. Reis's first telephone was founded upon these sounds, and Du Moncel has made numerous researches upon this subject.

In the last of my experiments cited the sounds are too feeble to be heard, but by the application of the microphone these trepidations at once become audible.

That molecules of iron and other metals rotate with time, whose period becomes shortened by mechanical vibrations, is well known in metallurgy, the ultimate result being generally the passage from a fibrous condition, as in iron wires, to a high degree of crystallisation. For many years I employed a circular vibrating spring as the regulator of speed of my printing telegraph instrument, and although this spring was so regulated by means of a frictional break, or "Frein," as not to surpass its limits of elasticity, these springs were constantly breaking after a few days' use, and as a matter of urgent necessity I made special researches into the cause of this breaking after a few days' constant vibratory action. I found at the point of rupture a high state of crystallisation. Fibrous iron would thus become thoroughly crystallised and break in one day; the number of vibrations for an instrument in constant use during 24 hours being 1,209,600. Thus we could roughly estimate the life of iron in the form of one of these springs at 1,000,000 vibrations. Copper crystallised in one hour, and all metals and alloys were inferior to steel, except aluminium bronze. The latter springs would stand six weeks' constant use, or some 50,000,000 of vibrations. I finally resolved this problem by spreading the amount of vibrating work over a spiral spring containing 3 metres of steel rod wound into the same space as previously held by the straight rod of 30 centimetres; by this means the average life of these springs has become five years. Evidently the molecules of these fibrous springs must have rotated under the vibrations, in order to produce crystals. The same phenomenon is observed in axles of carriages receiving constant trepidations, large crystals being always found at the point of fracture. Again, if we rapidly magnetise and demagnetise an iron rod, we have the production of evident heat, due to the constant motion of its molecules.

Maxwell describes an experiment of Beetz, in which an exceedingly small filament of iron was deposited by electrotype, under the influence of a strong magnetic field, in order to arrive at the inherent polarity of comparatively few molecules, and, as its magnetic force was very great, he regards the experiment as conclusive. My own experiments show that we have far less external magnetic force from a solid bar than from a thin tube or flat bar of the same surface exposed to a limited exciting cause. We know that magnetism does not penetrate to a very great depth, and we also know that, if to a thin steel permanent magnet we place another piece unmagnetised, or, better still, a rod of soft iron, its external polarity is greatly reduced, consequently the external evidence of polarity is not a direct measure of the degree of rotation, nor of the total inherent polarity of its mass. We may have a great superficial *external* rotation superposed upon rotations of an opposite nature, as will be seen later; and thus the internal molecules of a magnet often act more or less as an external armature in closing its circle of attractions.

I have stated my belief that the molecule itself possesses its inherent polarity, which, like gravity, is an endowed quality for which we have no more reason to suspect the cause to be elementary electric currents than that elementary currents should be the cause of gravity, chemical affinity, or cohesion, and its polar power of crystallisation, most of which are affected by an electric current. We have a certain analogy between electric currents and magnetism, but not so great as the analogy between the magnetic polarity of a molecule and its other endowed qualities.

Magnetism, like chemical affinity, cohesion, and crystallisation, has its critical points. Faraday discovered that at red-yellow heat iron instantly lost its apparent polar magnetic power, to be as instantly restored at red heat, the critical point varying in iron, steel, &c., and being the lowest in nickel. This would be difficult to explain upon Ampère's theory, as we should have to admit the instant destruction or cessation of the elementary currents, to be again restored at a few degrees less temperature. It would be equally difficult to explain under my view, if it did not belong to a whole class of phenomena due to the possession by the molecules of various endowed qualities, of which chemistry and all our means of research can only teach us their critical points, without attempting to explain why, for instance, iron has a greater affinity for oxygen than gold. We know that it is so; we know that the molecules of all matter are endowed with certain qualities having certain critical points, and I can see no reason for separating their magnetic inherent polarity from their numerous other qualities.

(*To be continued.*)

METERS FOR POWER AND ELECTRICITY[1]

THE subject of this evening's discourse, "Meters for Power and Electricity," is unfortunately, from a lecturer's point of view, one of extreme difficulty; for it is impossible to fully describe any single instrument of the class without diving into technical and mathematical niceties which this audience might well consider more scientific than entertaining. If then in my endeavour to explain these instruments and the purposes which they are intended to fulfil in language as simple and as untechnical as possible, I am not as successful as you have a right to expect, I must ask you to lay some of the blame on my subject and not all on myself

I shall at once explain what I mean by the term "meter," and I shall take the flow of water in a trough as an illustration of my meaning. If we hang in a trough a weighted board, then when the water flows past it the board will be pushed back; when the current of water is strong the board will be pushed back a long way; when the current is less it will not be pushed so far; when the water runs the other way the board will be pushed the other way. So by observing the position of the board we can tell how strong the current of water is at any time. Now suppose we wish to know, not how strong the current of water is at this time or at that, but how much water altogether has passed through the trough *during* any time, as for instance one hour. Then if we have no better instrument than the weighted board, it will be necessary to observe its

[1] Lecture at the Royal Institution, by Mr. C. Vernon Boys, March 2.