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XXXII. *On the general Magnetic Relations and Characters of the Metals. By* MICHAEL FARADAY, *D.C.L. F.R.S., &c.**

GENERAL views have long since led me to an opinion, which is probably also entertained by others, though I do not remember to have met with it, that *all* the metals are magnetic in the same manner as iron, though not at common temperatures or under ordinary circumstances†. I do not refer to a feeble magnetism‡, uncertain in its existence and source, but to a distinct and decided power, such as that possessed by iron and nickel; and my impression has been that there was a certain temperature for each body, (well known in the case of iron,) beneath which it was magnetic, but above which it lost all power; and that, further, there was some relation between this *point* of temperature, and the *intensity* of magnetic force which the body when reduced beneath it could acquire. In this view iron and nickel were not considered as exceptions from the metals generally with regard to magnetism, any more than mercury could be considered as an exception from this class of bodies as to liquefaction.

I took occasion during the very cold weather of December last, to make some experiments on this point. Pieces of various metals in their pure state were supported at the ends of

* Communicated by the Author.

† It may be proper to remark that the observations made in par. 255 of my "Experimental Researches," have reference only to the three classes of bodies there defined as existing at ordinary temperatures.

‡ *Encyclop. Metrop.*, 'Mixed Sciences,' vol. i. p. 761.

fine platinum wires, and then cooled to a very low degree by the evaporation of sulphurous acid. They were then brought close to one end of one of the needles of a delicate astatic arrangement, and the magnetic state judged of by the absence or presence of attractive forces. The whole apparatus was in an atmosphere of about 25° Fahr.: the pieces of metal when tried were always far below the freezing-point of mercury, and as judged, generally at from 60° to 70° Fahr. below zero.

The metals tried were,

Arsenic,	Lead,
Antimony,	Mercury,
Bismuth,	Palladium,
Cadmium,	Platinum,
Cobalt,	Silver,
Chromium,	Tin,
Copper,	Zinc,
Gold,	

and also Plumbago; but in none of these cases could I obtain the least indication of magnetism.

Cobalt and chromium are said to be both magnetic metals. I cannot find that either of them is so, in its pure state, at any temperatures. When the property was present in specimens supposed to be pure, I have traced it to iron or nickel.

The step which we can make downwards in temperature is, however, so small as compared to the changes we can produce in the opposite direction, that negative results of the kind here stated could scarcely be allowed to have much weight in deciding the question under examination, although, unfortunately, they cut off all but two metals from actual comparison. Still, as the only experimental course left open, I proceeded to compare, roughly, iron and nickel with respect to the points of temperature at which they ceased to be magnetic. In this respect iron is well known*. It loses all magnetic properties at an orange heat, and is then, to a magnet, just like a piece of copper, silver, or any other unmagnetic metal. It does not intercept the magnetic influence between a magnet and a piece of cold iron or a needle. If moved across magnetic curves, a magneto-electric current is produced within it exactly as in other cases. The point at which iron loses and gains its magnetic force appears to be very definite, for the power comes on suddenly and fully in small masses by a small diminution of temperature; and as suddenly disappears upon a small elevation, at that degree.

With nickel I found, as I expected, that the point at which it lost its magnetic relations was very much lower than with

* See Barlow on the Magnetic Condition of Hot Iron. Phil. Trans. 1822, p. 117, &c.

iron, but equally defined and distinct. If heated and then cooled, it remained unmagnetic long after it had fallen below a heat visible in the dark: and, in fact, almond oil can bear and communicate that temperature which can render nickel indifferent to a magnet. By a few experiments with the thermometer it appeared that the demagnetizing temperature for nickel is about 630° or 640°. A slight change about this point would either give or take away the full magnetic power of the metal.

Thus the experiments, as far as they go, justify the opinion advanced at the commencement of this paper, that all metals have similar magnetic relations, but that there is a certain temperature for each beneath which it is magnetic in the manner of iron or nickel, and above which it cannot exhibit this property. This magnetic capability, like volatility or fusibility, must depend upon some peculiar relation or condition of the particles of the body; and the striking difference between the necessary temperatures for iron and nickel appears to me to render it far more philosophical to allow that magnetic capability is a general property of all metals, a certain temperature being the essential condition for the development of this state, than to suppose that iron and nickel possess a physical property which is denied to all the other substances of the class.

An opinion has been entertained with regard to iron, that the heat which takes away its magnetic property acts somehow within it and amongst its electrical currents (upon which the magnetism is considered as depending) as flame and heat of a similar intensity act upon conductors charged with ordinary electricity. The difference of temperature necessary for iron and nickel is against this opinion, and the view I take of the whole is still more strongly opposed to it.

The close relation of electric and magnetic phænomena led me to think it probable, that the sudden change of condition with respect to the magnetism of iron and nickel at certain temperatures, might also affect, in some degree, their conducting power for electricity in its ordinary form; but I could not, in such trials as I made, discover this to be the case with iron. At the same time, although sufficiently exact to indicate a great change in conduction, they were not delicate enough to render evident any small change; which yet, if it occurred, might be of great importance in illustrating the peculiarity of magnetic action under these circumstances, and might even elucidate its general nature.

Before concluding this short paper, I may describe a few results of magnetic action, which, though not directly concerned in the argument above, are connected generally with the subject*. Wishing to know what relation that temperature which could take from a magnet its power over soft iron, had to that which could take from soft iron or steel its power relative to a magnet, I gradually raised the temperature of a magnet, and found that when scarcely at the boiling-point of almond oil it lost its polarity rather suddenly, and then acted with a magnet as cold soft iron: it required to be raised to a full orange heat before it lost its power as soft iron. Hence the force of the steel to *retain* that condition of its particles which renders it a permanent magnet, gives way to heat at a far lower temperature than that which is necessary to prevent its particles assuming the *same state* by the inductive action of a neighbouring magnet. Hence at one temperature its particles can of themselves retain a permanent state; whilst at a higher temperature that state, though it can be induced from without, will continue only as long as the inductive action lasts; and at a still higher temperature all capability of assuming this condition is lost.

The temperature at which polarity was destroyed appeared to vary with the hardness and condition of the steel.

Fragments of loadstone of very high power were then experimented with. These preserved their polarity at higher temperatures than the steel magnet; the heat of boiling oil was not sufficient to injure it. Just below visible ignition in the dark they lost their polarity, but from that to a temperature a little higher, being very dull ignition, they acted as soft ron would do, and then suddenly lost that power also. Thus the loadstone retained its polarity longer than the steel magnet, but lost its capability of becoming a magnet by induction much sooner. When magnetic polarity was given to it by contact with a magnet, it retained this power up to the same degree of temperature as that at which it held its first and natural magnetism.

A very ingenious magnetizing process, in which electro-magnets and a high temperature are used, has been proposed lately by M. Aimé†. I am not acquainted with the actual results of this process, but it would appear probable that the temperature which decides the existence of the polarity, and above which all seems at liberty in the bar, is that required. Hence probably it will be found that a white heat is not more advantageous in the process than a temperature just above or about that of boiling oil; whilst the latter would be much

* See on this subject, Christie on Effects of Temperature, &c. Phil. Trans. 1825, p. 62, &c.

† *Annales de Chimie et de Physique*, tome lvii. p. 442.

more convenient in practice. The only theoretical reason for commencing at high temperatures would be to include both the hardening and the polarizing degrees in the same process; but it appears doubtful whether these are so connected as to give any advantage in practice, however advantageous it may be to commence the process above the depolarizing temperature.

Royal Institution, Jan. 27, 1836.

XXXIII. *On the Effects of the Earthquake Waves on the Coasts of the Pacific.* By Woodbine Parish, *Esq., F.R.S., Secretary to the Geological Society.**

AT one of our meetings last season, in a discussion which arose out of the discovery of recent shells and other marine deposits on several parts of the coasts of Chile and Peru above the present level of the sea, I ventured to throw out the opinion that a great part of those appearances might, perhaps, be referred to violent upheavings of the *sea* under the influence of earthquakes. I had then only in my recollection the earthquake waves which burst over Scylla and Lisbon in Europe, and Callao in America; but upon looking into the early writers upon the countries bordering on the Pacific, I have found so many recorded instances of these disruptions of the great ocean, and in some cases attended with such remarkable effects, that I have thought it might interest the Society to have them collectively before it, particularly upon any new discussion of such phænomena as first gave rise to my observations upon the subject.

Under that impression I have put them together in this paper.

Historical Notices of the Effects of the Earthquake Waves on the Coasts of Chile and Peru.

Acosta in his *Historia Natural y Moral de las Indias*, written in 1590, gives us a chapter upon the earthquakes of his time, from which the following is a translation: he says, "On the coast of Chile, I do not remember precisely the year, there took place a very terrible earthquake, which overthrew whole mountains, stopping up with them the courses of rivers and turning them into lakes, destroying towns, and a vast number of people." *It caused the sea to rise out of its bed some leagues, leaving ships dry far inland.*

* Read before the Geological Society Dec. 2, 1835; and now communicated by the Author.