

4. On a New Form of Mariner's Compass.
By Sir William Thomson.

Monday, 6th April 1874.

SIR WILLIAM THOMSON, President, in the Chair.

The following Communications were read :—

1. Further Note on Spectra under exceedingly Small Pressures. By Professor Tait and James Dewar, Esq.

2. On the After-glow of Cooling Iron at a Dull-Red Heat. By George Forbes, Esq.

The facts to be explained were observed by Messrs Gore and Barrett, and were described by the latter gentleman in the "Philosophical Magazine" for 1873.

The experiments are performed on an iron or steel wire of no great thickness. When this is heated to an intense white heat and allowed to cool, the following facts appear at the instant it has cooled down to a dull-red heat :—

1. The wire expands for an instant, and then continues its normal contraction.

2. The glow from the wire is at the same instant seen to increase.

3. The temperature of the air round the wire is at the same instant increased.

4. The same facts are seen when the wire is in an atmosphere of hydrogen.

5. If the wire be very thin the cooling is so rapid that the effects are not observed.

6. If the iron be massive the effects are not observed.

7. If the wire be not originally heated up to an intense white heat the effects are not observed.

That iron should increase its temperature at a dull-red heat

while it is cooling from an intense white heat, and that it should not do so when cooling from a temperature a little over a dull-red heat, is a hypothesis so inconsistent with all known facts as to make it desirable to find some explanation more in accordance with known principles. Iron is a very bad conductor, and Professor Tait has shown (R. S. E. Proceedings, 1873) that the conductivity is much worse above than below a dull-red heat. Now, the cooling of such an iron wire as that used is effected so rapidly that the temperature falls through an enormous range of temperature in a few seconds. This is effected by convection and radiation from the surface. It is quite possible that the internal heat cannot be conducted outwards with sufficient rapidity to compensate this outer loss. Thus the temperature of the interior of the wire is greater than that of the exterior. At very high temperatures the rapidity of cooling is enormous. But as the cooling proceeds, the deviation from the Newtonian law of cooling is much less. Hence the cooling by radiation becomes less, and the heat which has been stored up in the interior of the wire has a tendency to show itself on the surface. At a dull-red heat the wire becomes a better conductor, and this tendency is assisted, so that about this stage the temperature throughout the wire is nearly equalised. The second experimental fact is explained by this raising of the external temperature. The third fact is explained in the same way. And it must be noticed, that a difference in temperature between the interior and exterior is the only means of explaining the rise in temperature of the external air, unless we suppose that, while cooling, the wire increases in temperature. And even then it would be difficult to understand why the effect is not produced by cooling from a temperature a little above a dull-red heat. If the wire be massive, or if a poker be used, the cooling is not rapid enough to produce the effects; apparently, because the convection currents are not nearly so strong in proportion to the surface which has to be cooled. Other causes come into play in this case, all tending to prevent the effect from being apparent. The explanation I have given shows why the effect is observed only when the wire has been originally heated to an intense white heat; for it is only then that a great difference of temperature can exist between the interior and exterior.

It only remains now to explain the first experimental fact, *i.e.*, the expansion of the wire at the critical instant. This follows from what has already been said, when we consider certain experiments made by Colonel Clarke, communicated to the Royal Society of London in 1863, and the explanation of them which was given by Professor Stokes. A hollow cylinder of iron was heated in a furnace, and plunged into water, so that half of it was buried in the water, the axis of the cylinder being vertical. After cooling, the cylinder was found to be permanently indented at the water-level, so that its diameter was there diminished. The explanation is as follows:—When plunged in water the lower part immediately contracts and cools. The upper part remains expanded. At this instant there is at the water-line a conflict between the upper, hot, expanded portion and the lower, cool, contracted portion. Now iron is much stronger when cool than when hot. Hence the cool iron has the advantage, and at the water-line the iron is at first forcibly shrunk, and afterwards cooled, and hence at that line the cylinder is contracted.

Now, exactly the same thing may happen in the cooling wire. Before cooling down to the dull-red heat, the hot inner part is expanded, and the cooler outer part contracted, and owing to the greater strength of the cooler iron, the wire is on the whole unduly contracted. But at the moment of after-glow the internal heat is driven out, and the contraction is no longer maintained. Hence the expansion at that temperature.

The hypothesis I have now given explains all the facts observed; but it cannot be stated to be proved. An alternative, and only one remains, which is to consider that *when iron is heated to an intense white heat it becomes different in its nature from cold iron, and that the iron in the hot state has a certain amount of latent heat, which is given out when, by cooling, the iron changes its nature.*

In the absence of any data for determining between these two, I prefer the former hypothesis, as it does not involve a new property of iron quite unlike that of any other substance yet examined. The apparently opposite phenomena observed when the iron is massive can be explained equally well on either hypothesis. But the second hypothesis is favoured by certain experiments made by Professor Barrett while heating the iron.