I should add that Mr. Fowler has glimpsed a line less refrangible than that at 500 in the spectrum of the ring nebula in Lyra. If this should turn out to be the carbon fluting at 517, it would seem that in that nebula we may have a state of condensation between those represented by the nebulæ of Orion and Andromeda, the carbon replacing the λ 500 fluting of magnesium in the nebulæ, as apparently happens in comets on their approach to perihelion.

III. "Some Observations on the Amount of Luminous and Non-luminous Radiation emitted by a Gas Flame." By Sir JOHN CONROY, Bart., M.A., Bedford Lecturer of Balliol College and Millard Lecturer of Trinity College, Oxford. Communicated by A. G. VERNON HARCOURT, LL.D., F.R.S. Received November 11, 1889.

[See page 55.]

IV. "On the Effects of Pressure on the Magnetisation of Cobalt." By C. CHREE, M.A., Fellow of King's College, Cambridge. Communicated by Prof. J. J. THOMSON, F.R.S. Received November 22, 1889.

(Abstract.)

It has long been known, from the classic researches of Dr. Joule, that a rod of iron free from stress increases in length when magnetised in a comparatively weak field. When, however, the strength of the field is continually raised, it has been found by Mr. Shelford Bidwell that the rod ceases to increase in length, and then shortens, so that in a sufficiently strong field the length becomes less than it was originally. It has also been found by Villari, Sir W. Thomson, and others that when a rod of iron is exposed to successive loadings and unloadings of a given weight in a magnetic field, there appears a corresponding cyclic change of magnetisation. In this cyclic change the maximum magnetisation occurs when the load is "on," or when the load is "off," according as the field is weaker or stronger than a certain critical field depending on the load, called by Sir W. Thomson the Villari critical field.

Cobalt has been found by Mr. Shelford Bidwell to shorten when magnetised in weak fields, but to lengthen in very strong fields. The field in which it ceases to shorten is very much higher than the field in which iron ceases to lengthen. Also in weak fields Sir W. Thomson has found the magnetisation of a cobalt rod under cyclic applications of tension to be least when the tension is "on."

Now Professor J. J. Thomson has shown that on dynamical principles the effect of changes of magnetisation on the length of a rod of magnetic metal, and the effect of changes in the length of the rod on the magnetisation, must be fundamentally connected. In his "Applications of Dynamics to Physics and Chemistry," he has arrived at mathematical equations connecting the two phenomena, such that from a knowledge of the one set of phenomena the character of the other set can be deduced.

The conclusions derived from the theory are in the case of iron in accordance with the results of experiment, at least in their general character. In cobalt there is also an agreement between theory and experiment, so far as Sir W. Thomson's experiments go. In the absence of further experiments it would, however, be impossible to tell whether or not this agreement extended to the strong fields in which occurred the important phenomena observed by Mr. Shelford Bidwell. The application of Professor J. J. Thomson's formulæ to Mr. Shelford Bidwell's results led him to the conclusion that under cyclic applications of pressure a cobalt rod should experience cyclic change of magnetisation, and that the maximum magnetisation should answer to pressure "on," or to pressure "off," according as the magnetic field was weaker or stronger than a critical field, corresponding to the Villari field in iron. It was for the purpose of determining whether such a critical field did actually exist that the present investigation was commenced at Professor J. J. Thomson's suggestion.

Employing the magnetometric method, it was found that the agreement between theory and experiment was at least as satisfactory in cobalt as in iron. The application of pressure cycles in a magnetic field led to a cyclic change of magnetisation in a cobalt rod, in which the maximum magnetisation occurred when pressure was "on," or when it was "off," according as the strength of the field was below or above 120 C.G.S. units. This accordingly was the Villari critical field foreshadowed by theory.

Various phenomena which promised to throw light on the true character of the relations of strain and magnetisation having been noticed at an early period of the investigation, it was decided to make an attempt to isolate the phenomena, and examine them exhaustively.

In weak fields the first pressure applied after the introduction of the cobalt rod into the magnetising coil caused a large increase in the induced magnetisation. As the strength of the field was raised this change in the magnetisation attained a maximum, then diminishing vanished in a field considerably stronger than the Villari field for the cyclic effect, and in all stronger fields consisted in a diminution of magnetisation. The fields in which the cyclic effect of pressure and the effect of the first pressure were absolutely greatest occurred in the

neighbourhood of the "wende-punkt," or point where the coefficient of magnetic induction is a maximum. Relatively, however, to the intensity of the pre-existing induced magnetisation both the effects continually diminished in importance, as the strength of the field was raised from zero. In the weakest experimental field the first pressure increased the induced magnetisation by over 50 per cent., and fully 4 per cent. of the magnetisation took part in the cyclic change accompanying the pressure cycles. In some respects these results present a close resemblance to those observed by Professor Ewing in iron.

It was found that the existence of pressure previous to and during the introduction of the rod into a coil traversed by a current had an effect of the same general character, though not exactly of the same magnitude, as the first application of pressure when the rod on its introduction into the coil was free from pressure. Also on the break of a current during which pressure cycles had been applied, the rod manifested a polar character, in that, when exposed a second time without intermediate demagnetisation to the same strength of current, it possessed a greater intensity of magnetisation when the current passed in one direction than when it passed in the other. Both these effects had critical fields where they vanished and changed sign, and these fields were close to, if not identical with, the field in which the effect of the first pressure vanished. In fields below the critical the magnetisation of the rod when exposed a second time, without intermediate demagnetisation, to a current of the same strength as one in which pressure cycles had just been applied was greatest when the direction of the current was unchanged; but in fields above the critical the reverse was the case.

Both Villari and Professor Ewing observed that after the break of the magnetising current cyclic changes of tension produced eventually in iron wires cyclic changes of the residual magnetisation. In these the maximum magnetisation answered, as in the induced magnetisation in fields below the Villari point, to tension "on." Professor Ewing apparently examined the effect only in weak fields, but he does not seem to have anticipated that it would change its character in stronger fields.

In the present investigation the existence of a cyclic change in the residual magnetisation of cobalt accompanying cyclic changes of pressure has been established, and the magnitude of the effect examined in a large number of fields, extending from 0 to 400 C.G.S. units. It was found that not only the magnitude but the sign even of the effect depended largely on the condition of the rod during the break of the current. When the rod was under pressure during the break, the residual magnetisation in the cyclic state showed a maximum under pressure, whatever was the strength of the pre-existing field. When, however, the rod was free from pressure during

the break of the current, it was only in the residual magnetisation left after the weakest fields that the maximum answered to pressure "on." When the strength of the pre-existing field was raised, the effect passed through the value zero and changed sign. In the absence of all pressure during the flow of the current this critical field was only about 18 C.G.S. units. The application of pressure cycles during the flow of the current raised the critical field to about 30 C.G.S. units, but in fields over 60 C.G.S. units seemed to have extremely little effect. The intensity of the residual magnetisation when the cyclic effect of pressure vanished was of course in either case only a small fraction of the intensity of the induced magnetisation in the Villari critical field.

In the absence of all pressure the residual magnetisation left after the break of weak fields was very small, but in the weakest experimental fields its amount was increased in the ratio of 4 or 5 to 1 by the application of pressure cycles during the flow of the current. In fields over 30 C.G.S. units this effect of pressure cycles became extremely small.

The application of the first pressure subsequent to the break of the magnetising current and the removal of a pressure existing during the break of the current were found to shake out a considerable amount of the residual magnetisation. The percentage shaken out by the application of the pressure was decidedly the higher in strong fields, but in weak fields the reverse was the case when pressure cycles had been applied during the flow of the current.

Various other kindred phenomena were observed, and the laws of their variation examined. Most of the results obtained are given in tables, and curves are drawn showing the dependence of the more important effects on the strength of the field.

All the observations were made on a single specimen of cobalt, and by repeating certain of the observations at intervals it was proved that the condition of the specimen must have remained essentially unaltered while the different phenomena were being examined. Thus the several effects can be directly compared, and their mutual relationships are not masked by those differences of condition which are sure to exist between different specimens. An attempt has thus been made from an analysis of the phenomena to attain some knowledge of the true character of the magnetic changes effected by the application of pressure.

The experiments were all conducted in the Cavendish Laboratory, and the author is much indebted to Professor Thomson for the facilities afforded him, and for suggestions as to the form of the apparatus and the methods employed.