manufacture of the rheostats, they hope to retain and extend the markets opened to them by the temporary paralysis of German export trade. Messrs. Isenthal also inform us that they find "by careful organisation, by manufacturing the component parts of these rheostats in very large quantities, *i.e.* practically making the whole rheostat except the winding in very large quantities," the instruments do lend themselves to mass production. Before the war they did not consider themselves justified in incurring the expense and work required for such methods of manufacture, and therefore purchased the apparatus from abroad. But they add:—"The closing of our relations with the central Continent has given just that impetus which was needed for us to set aside *ordinary* commercial considerations, hence our present facilities for manufacturing this apparatus."

OUR ASTRONOMICAL COLUMN.

ASTRONOMICAL OCCURRENCES.—Mars, now nearly as bright as Sirius, will be in opposition early on Friday. Jupiter and Venus, so conspicuous in the western twilight, reach conjunction about 3 a.m. on February 14. Their nearest approach takes place earlier, about midnight, Venus being 26′ S. Even at 7.30 p.m., February 13, they will be only 32′ apart. The moon occults a 3·2 mag. star, ε Geminorum, on February 14. As seen from Greenwich disappearance occurs at 11h. 3m. The moon is in conjunction with Neptune on the evening of February 16 at 6h. 24m. Geocentrically the planet will be 1° 2′ S. Comet 1915*e* (Taylor) can still be glimpsed with a 3-in., but is not a suitable object for such a small aperture. The following positions are from a continuation of the Copenhagen ephemeris for Greenwich midnight:—

		h. m. s.		° ′
Feb. 11	...	5 30 22	...	+24 21·3
15	...	36 45	...	25 39·0
19	...	43 48	...	26 50·8

SHIFTS OF WAVE-LENGTHS.—Modern measurement of wave-lengths, in striving successfully after an accurate third decimal figure, has begun to detect all kinds of causes that result in wave-length alterations. In solar spectroscopy, in addition to the well-known pressure and motion effects, the recondite theory of relativity and the ubiquitous anomalous dispersion championed by Freundlich and Julius respectively have afforded explanations of the observed displacements. In the one case it is an intense gravitational field that is adduced as competent; in the other the mutual effect of neighbouring lines. In the laboratory length of arc, its internal pressure, distance from pole, impurities, change of electrical conditions, have been described as the source of displacement by Royds, Albrecht, St. John, Burns, and Bilham. The latter, working in Prof. Fowler's laboratory at South Kensington, has now studied the special case where the adventitious element itself gives rise to strong lines (*Astrophysical Journal*, December, 1915). A number of iron lines in the regions of H and K were measured in the spectrum given by a carbon arc fed with Fe filings, and also when the arc was fed with a mixture of filings and calcium chloride, the calcium lines being measured in both cases. The results obtained in this very interesting research indicate that some lines are susceptible, whilst others have constant wave-lengths. The K line of calcium is found to differ by 0·008 Å. in the two sources. One hesitates to think of the array of conditions it will become necessary to introduce into the specification of standard lines.

FURNACE SPECTRA OF COBALT AND NICKEL.—To the metals (Fe, Ti, V, and Cr) whereof the electric furnace spectra have already been investigated in such painstaking and accurate manner by Dr. King, must now be added Co and Ni (*Astrophysical Journal*, vol. xlii., No 4). Fourteen pages are given up to tabular matter similar to that for the elements previously studied. Attention may be directed to some results of an unexpected character; thus not only is the violet end found relatively rich in lines, but all the enhanced lines of cobalt (except only λλ 3878·90 and 3904·23) in the region of shorter wave-lengths than λ 4077·56 have been classified as furnace lines. Another peculiarity is the fact that each of the classes I., II., and III. contain some lines that attain a maximum in the furnace and are weaker in the arc, thus affording, as regards the lines of Class III. A, a group of lines special, perhaps, to a range of temperature of some 500° C.—a feature worthy of further attention.

THE ELECTRO-THERMIC SMELTING OF IRON ORES.

THE rapid growth of the application of the electric furnace to the metallurgy of iron and steel is certainly the most noteworthy feature of the development of this industry during the last decade. Ten years ago "electric steel" was largely a novelty. To-day there is scarcely a branch of this highly diversified and complex industry in which electrothermic heating has failed to secure a footing and to justify itself. This progress is all the more remarkable when it is remembered that the steel manufacturing industry "owing to its age and importance, and also to the capital invested in it, is one of the most conservative and settled of all industries."[1]

The earliest uses to which electric furnaces were applied were to the production of (1) ferro-alloys, containing iron, carbon, and such elements as tungsten, molybdenum, vanadium, etc., which indeed cannot be made in fuel-fired furnaces; and (2) of the highest classes of carbon and alloy tool steels, where they competed successfully with crucible furnace products. Having "made good" up to this point, they were next developed, not in direct competition with Bessemer and open-hearth furnaces, but as important adjuncts to them, and within the last seven years a great variety of products—*e.g.*, gun, tyre, and axle steel, wire and plate billets, and rail and girder steel—are manufactured with their aid. Such processes may be classed as electrothermic refining, for they take the metal as delivered by the Bessemer or open-hearth furnace, and, owing to their high temperature and more neutral atmosphere, permit the formation of refractory basic and even reducing slags, *e.g.*, calcium carbide, which carry the refining of the steel to a further stage, and produce a purer and more trustworthy metal. Especially has this been the case with the manufacture of rail steel in Germany and America, where it has been found that the trustworthiness of the steel is so much increased by electrothermic refining that the railway companies are willing to pay considerably more for rails produced in this way. Mention must also be made of the application of the electric furnace to the production of mild steel castings—always a difficult operation—where a very fluid metal can be obtained, and a better separation of gaseous and other impurities. Heroult[2] recently quoted instances in which it had been found to be unnecessary to anneal such materials at all, since their properties were fully as good as those of the best rolled mild steel made in

1 "Electrothermal Methods of Iron and Steel Production." By J. B. C. Kershaw, p. 3.
2 Transactions of the Eighth International Congress of Applied Chemistry. New York. September, 1912.

fuel-fired furnaces. These are only some of the most important branches of steel production where the electric furnace is firmly established.

It has always been recognised that the most serious competitor the electric furnace had to meet was the blast furnace. In this case the coke performs two functions. It has to supply not only the necessary heat, but also the carbon for the reduction of the ore and the carburisation of the metal. It is only the former which can be replaced by electric heat, and the horse-power year would have to be supplied at the extraordinarily low figure of about *1l.* if it is to compete with the modern coke-fired blast furnace. It is not surprising, therefore, that there are few localities which have been found to provide the necessary conditions for electrothermic iron-ore smelting. In fact, there are only two countries where the conditions have permitted headway in this direction to be made, viz., Sweden and California, and of these Sweden is in a much stronger position. Of unusual interest, therefore, is the recent publication of Bulletin No. 344 of the Canadian Department of Mines, entitled "The Electrothermic Smelting of Iron Ores in Sweden," by Dr. Alfred Stansfield, who visited Sweden in 1914, inspected the principal smelting works, and made a careful study of the economic operation of the furnaces, reporting on the general position as it affected the possibility of establishing a similar industry in Canada.

Two main types of furnace exist: (1) the Elektrometall furnace, in which the ore is preheated and partially reduced in a shaft before it reaches the smelting chamber; the heating of the ore in the shaft and the chemical reduction of the iron in the ore being materially assisted by the circulation of the furnace gases, which is characteristic of this furnace; (2) furnaces of the Helfenstein, Californian, and Tinfos type, in which there is no provision for preheating the ore. Any shafts employed are merely for the purpose of introducing the ore charge conveniently, and the main object of the design is to obtain a large and substantial furnace for smelting iron ores by electrical heat.

In Sweden the Elektrometall furnace has been largely used, and is in regular commercial operation at Domnarfvet, Hagfors, and Trollhättan, but experiments are being made with a modified Helfenstein furnace. In Norway, which Dr. Stansfield also visited, the Tinfos furnace is in operation on a moderate scale at Notodden. At Domnarfvet there is one 4000-h.p. furnace, producing about 30 tons of charcoal iron daily, and the output of the furnaces at the other places mentioned varies for the most part between 20 and 25 tons per diem. A considerable variety of irons, open-hearth and Bessemer, acid and basic, are produced. On June 4, 1915, seven furnaces were in operation and ten others in course of construction. The output of the furnaces is not large—compared with the 400 to 500 tons daily output of the hard-driven American coke blast furnace it is small—but it is as large as that of the charcoal blast furnaces which they replace. Dr. Stansfield concludes (p. 7):—"The electric furnace has now become a dependable and economic appliance for regular commercial use. The iron obtained from it is even better than that from the charcoal-iron blast furnace using the same ores and fuel. *The cost of making the iron, using cheap Swedish water-power, is somewhat less than in the charcoal blast furnace.* The amount of iron that can be made with a definite supply of charcoal is three times as much in the electric furnace as in the blast furnace. These considerations appear to represent the foundation of the present electric iron-smelting industry in Sweden." In fact, in this country the electric furnace is ousting the blast furnace.

That section of Dr. Stansfield's report which deals with the heat distribution and technical efficiency of the Trollhättan Elektrometall furnace is of particular importance. The large shaft of furnaces of this type depends for its effectiveness on the circulation of the gases which ascend from the hearth, as otherwise the contents would not be sufficiently heated, so that the question to be investigated resolves itself into the *desirability of the gas circulation system.* Does the circulation of the gases cause a large enough economy to justify the expense and inconvenience of the large stack and the circulation apparatus? From calculations made by Messrs. Leffler and Myström, as well as himself, Dr. Stansfield draws the following conclusions.

"(1) The heat utilised in the reduction of the iron, melting the pig-iron and slag, and in other necessary parts of the smelting operation, amounts to from 63 to 74 per cent. of the whole electrical supply, this figure increasing in the later periods.

"(2) The principal source of loss is the radiation of heat from the roof and other parts of the furnace and the heat lost in the cooling water supplied to electrode holders, collars, and other parts. These losses varied from 31 to 19 per cent. in these tests, decreasing in the later periods.

"(3) The amount of the potential energy or calorific power of the gases escaping from the furnace top varies from 84 to 74 per cent. of the heat equivalent of the electrical supply, and is in each case *more than the whole heat utilised in the smelting operation.* The object of the gas circulation is to utilise as far as possible, *in the furnace stack*, the reducing and heating power of the carbon monoxide in the furnace gases; but even when this has been done to the greatest extent that is practicable, the remaining gas has a heat value greater than the net heat requirements of the smelting operation, or about 75 per cent. of the whole electrical supply.

"(4) The sensible heat carried out of the furnace by the escaping gases is unimportant . . . and no considerable loss of heat is occasioned in the same manner by the gas circulation system."

Collecting the results of all the calculations it appears:—"(1) That without circulation the escaping gases have a heat value about equal to the net heat requirements of the furnace; (2) that with the gas circulation about one-fourth the value of the escaping gases is utilised in the furnace, thus saving about 11 per cent. of the coke and 7 per cent. of the electrical energy." It is evident, therefore, that if the calorific power of the escaping gases could be perfectly utilised the furnace could be run with a small fraction of the power that is needed at present, and that the circulating system only effects about one-fourth of the large saving that is theoretically possible. At present it scarcely looks as though this increased the efficiency of the smelting furnace to an extent commensurate with the complication and expense entailed, particularly when it is remembered that the escaping gases could be utilised for converting the pig-iron into steel. Dr. Stansfield's calculation leads him to conclude that the gas produced in making one ton of pig-iron in the electric furnace would almost suffice for the production of one ton of steel in the open-hearth furnace.

H. C. H. CARPENTER.

GEOLOGICAL WORK IN CANADA.

THE Museum Bulletins of the Geological Survey of Canada include a number of papers on natural history and anthropology, and afford a rapid means for the publication of scientific work. No. 4 ("The Crowsnest Volcanics," by J. D. MacKenzie, 1914) describes igneous rocks from south-west Alberta, and