

interior, so that as the carbon burnt away in the arc the calcium in the interior became manifest.

"Again, we found that when we used a perforated pole and passed a stream of hydrogen into the arc through it, H and K could be both entirely obliterated; but by then reducing the current of gas they gradually reappeared, and H always came out first and afterwards K; and H remained stronger than K, until they had both resumed their ordinary appearance. This observation was repeated several times.

"Both sets of observations, those with the purified carbon poles and those with the perforated pole, seem to me to confirm your conclusions.

"In the case of those with the perforated pole, the stream of hydrogen diluted the calcium vapour, and the degree of dilution was controlled by the rate at which the gas was introduced. The mass of gas passing was too small to reduce the temperature by any considerable amount, or even, I should think, to any sensible amount.

"We found also that metallic lithium, introduced into the arc, produced effects similar to those produced by hydrogen, that is, that it reduced very much the strength of the H and K lines. If more than a very minute piece of lithium were introduced, the arc was invariably broken, so that we did not notice the complete obliteration of H and K with the lithium.

"The reduction of the strength of H and K, in this case, I attribute to the dilution of the calcium vapour by that of lithium."—June 25.]

"Further Observations of Enhanced Lines." By J. NORMAN LOCKYER, C.B., F.R.S. Received May 12,—Read June 17, 1897.

In a recent paper I gave an account of a series of experiments having for their object the determination of the lines which were enhanced in the spectra of iron, magnesium, and calcium, on passing from the arc to a high temperature spark, and I pointed out the presence of these lines in the spectra of the hotter stars and in the solar chromosphere.

The spectra of the following additional elements have since been investigated in a similar manner, and the enhanced lines have been tabulated and compared with chromospheric and stellar spectra.



## List of Additional Elements examined for Enhanced Lines.

Aluminium.	Lead.	Sulphur.
Antimony.	Lithium.	Tantalum.
Barium.	Manganese.	Tellurium.
Beryllium.	Molybdenum.	Thorium.
Bismuth.	Nickel.	Titanium.
Carbon.	Niobium.	Tin.
Cadmium.	Palladium	Tungsten.
Cerium.	Potassium.	Uranium.
Chromium.	Rhodium.	Vanadium.
Cobalt.	Silicium.	Yttrium (and
Copper.	Silver.	Erbium).
Erbium (and	Sodium.	Zinc.
Yttrium).	Strontium.	Zirconium.
Lanthanum.		

The list of lines is not given here for the reason that so far the series of comparisons with a Rowland grating of 21 ft. radius is not complete. Nevertheless the approximate wave-lengths already determined are of the same order of accuracy as those of the chromospheric and stellar lines, and the supposed coincidences depend upon the occurrence of several lines of a given substance rather than upon an absolute agreement in the deduced positions of any single line.

In the former paper I drew attention to the fact that while the enhanced lines of magnesium (4481.3) and calcium (H and K) remained feebly visible in the hottest stars included in the discussion, the enhanced lines of iron vanished entirely in such stars, and were thinner than those of magnesium and calcium in stars which are approaching the highest temperature as determined by the length of the spectrum in the ultra-violet. Similar differences of behaviour have also been noted among the substances which have since been investigated.

These differences in the case of metals of the iron and calcium groups are shown in the following table, in which the stars are arranged in the order of temperature previously deduced from the discussion of the lines of iron, magnesium, and calcium, and the name of each substance considered is placed opposite that of the hottest star in which its enhanced lines remain visible.

It thus appears that while calcium remains visible up to the highest temperatures, the enhanced lines of strontium probably cease to be visible at temperatures higher than that of  $\gamma$  Cygni, while those of barium have not yet been certainly traced in any of the stars. The order of appearance of the metals of the calcium group thus conforms with the chemical order. Of the metals of the iron group,



Name of Star.	Calcium group.	Iron group.
Bellatrix	Ca	Fe, Mn. Co, Ni.
ζ Tauri	—	
Rigel	—	
η Leonis	—	
α Cygni	—	
γ Cygni	Sr	
α Tauri	—	
α Orionis	[Enhanced lines of barium probably do not ap- pear]	

iron and manganese show their enhanced lines at temperatures as high as ζ Tauri, while cobalt and nickel do not extend higher than Rigel. Among the substances recently examined, the case of silicium is of special interest. The enhanced lines of this substance, two of which have wave-lengths about 4128·6 and 4131·4, are amongst the most conspicuous lines in α Cygni and remain distinctly visible even in Bellatrix, after the lines of iron, manganese, nickel, and cobalt have vanished. In its stellar behaviour then, this substance resembles Ca and Mg.

So far as the work has gone, the comparison of the enhanced lines with the spectrum of the chromosphere reveals several facts of importance. In the case of iron, I have already pointed out\* that the enhanced lines were all present in the chromosphere during the eclipse of 1896, and most of them in that of 1893, their intensities being greater than those of the corresponding Fraunhofer lines. Many of the characteristic arc lines of iron also appear in the chromosphere, but the presence of the enhanced lines with such great intensities indicates that at least in some parts of the chromosphere the temperature of the iron vapour is considerably higher than that of the iron vapour which is most effective in producing the Fraunhofer lines. A similar result is obtained when other substances are considered. The special importance of the enhanced lines in the chromosphere is shown by the following figures relating to substances which have been most completely studied:—

No. of enhanced lines of Fe, Mg, Ca, Mn, Ni, Co, Ti, so far tabulated in the region F to K .....	63
No. of these lines photographed in eclipse of 1893 .....	28
Percentage of enhanced lines of Fe, &c., in eclipse lines of 1893.....	44
No. of enhanced lines photographed in eclipse of 1896 ....	41
Percentage of enhanced lines of Fe, &c., in eclipse of 1896..	65

\* 'Roy. Soc. Proc.,' vol. 60, p. 475.



These numbers show that the chromospheric spectrum is largely composed of enhanced metallic lines in addition to the lines of hydrogen and the cleveite gases.

In the Fraunhofer spectrum enhanced lines may be regarded as wanting, for in the case of iron and magnesium, at least, they only appear with the feeble intensities which they have in the arc spectrum, while the characteristic arc lines are strong. Here then we find the cause of the dissimilarity of the chromospheric and Fraunhofer spectrum which is indicated by the following figures:—

No. of Fraunhofer lines tabulated by Rowland in the region F to K.....	5694
No. of lines photographed in the same region, eclipse 1893 .....	164
Percentage of Fraunhofer lines .....	3
No. of lines photographed in the same region, eclipse 1896.....	464
Percentage of Fraunhofer lines .....	8

Clearly then, the chromosphere as photographed in the eclipses of 1893 and 1896, is a region of high temperature in which there is a corresponding simplification of spectrum as compared with the cooler region in which the Fraunhofer absorption is produced.

“The Total Solar Eclipse of August 9, 1896. Report on the Expedition to Kiö Island.” By J. NORMAN LOCKYER, C.B., F.R.S. Received May 15,—Read June 17, 1897.

(Abstract.)

The observing party consisted of Mr. Fowler, Dr. W. J. Lockyer, and myself, and the selection of Kiö Island as an observing station was rendered possible by the grant of the services of H.M.S. “Volage.” Although the expedition failed in its main objects, because of unfavourable weather, it is considered desirable to put on record an account of the arrangements which had been made to secure observations, more especially as a new feature was introduced in the training of a large number of officers and men to take part in the observations.

Profiting by the experience gained in previous eclipses, prismatic cameras of the highest available powers were taken out, as well as a powerful integrating spectroscope. To supplement the work of these photographic instruments, a number of prisms and small slit spectroscopes were provided for use by such assistants as were available. The voluntary services of 74 officers and men of H.M.S.