PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

On the Photographic Arc Spectrum of Iron Meteorites

J. Norman Lockyer

Phil. Trans. R. Soc. Lond. A 1894 **185**, 1023-1028
doi: 10.1098/rsta.1894.0019

XIX. *On the Photographic Arc Spectrum of Iron Meteorites.*

By J. Norman Lockyer, *C.B., F.R.S.*

Received December 22, 1893,—Read February 15, 1894.

In a communication to the Royal Society in 1887,* I gave an account of certain experiments which I had made in connection with the spectra of various meteorites at various temperatures. The spectra were observed at the temperature of the oxy-hydrogen flame and the electric spark without jar, and when glowed in vacuum tubes. Some larger specimens of the iron meteorites, Nejed and Obernkirchen, cut so that they were of a size and shape suitable for forming the poles of an arc lamp, having afterwards been kindly placed at my disposal by the Trustees of the British Museum, it became possible to study the arc spectra of these meteorites under very favourable conditions, all impurities introduced by the use of the carbon poles being thus avoided.

The region of the spectrum photographed extends from K to D, in the case of each meteorite, and in addition to the solar spectrum, that of electrolytic iron, prepared by Professor Roberts-Austen, referred to in a previous communication, has been used as a comparison spectrum in one case.

The photographs obtained are as follows :—

	Comparison spectrum.
(1) Nejed Meteorite	Sun
(2) Obernkirchen Meteorite	,,
(3) ,, ,, ...	Iron
(4) Composite Meteorites on Nejed poles	Sun
(5) ,, ,, ,, Silver poles (region 393 421)	Composite meteorites on carbon poles

The instruments and arrangements used for photographing the spectrum were exactly the same as those which I have described in the case of the iron spectrum in the communication referred to above. The spectrum was photographed in three sections, λλ 39–42, 42–47, and 47–59. The photographic plates employed were also

* 'Roy. Proc. Soc.,' vol. 43, p. 117.

similar to those used in the case of iron for corresponding regions, the first two sections being taken on the ordinary "Mawson and Swan Castle Plates," and the third on plates which had been stained with a solution of erythrosin.

In the present paper, the first three series of photographs are discussed, the consideration of the composite meteorite spectra being reserved for a subsequent communication.

The lines in the spectrum due to iron were found to agree so closely with those in the photographic arc spectrum of Electrolytic Iron, on which a paper was communicated to the Royal Society, in October 27, 1893, that all lines due to iron have been omitted from the tables, and only the lines due to other metals dealt with. The results are given in the appended table. The first column gives the wave-length of all the lines, other than those due to iron, which appear in the spectra, while the second and third indicate the approximate intensities of the lines in the Obernkirchen and Nejed meteorites respectively. The scale of intensities is such that 1 represents the strongest, and 6 the weakest lines.

In the fourth column are given the probable origins of the lines. The evidence for the origins of some of the lines rests on the new map of the spectra of the elements which is in progress at Kensington.

The last column is reserved for occasional remarks.

General Conclusions.

1. The spectra of the two meteorites agree very closely both as regards the number and intensities of the lines. The slight difference in the number of lines seen in the two spectra may be in all probability due to the difference in exposures of the plates. In the first section of the spectrum (λ 390–421) the lines correspond exactly in number; in the next section (λ 420–470) the spectrum of the Obernkirchen meteorite was evidently under-exposed in relation to the other, so that it contains fewer lines; in the third section, the Nejed spectrum was relatively under exposed, and all the lines which are not common to the two in this region are absent from the spectrum of the Nejed.

2. There is a very considerable similarity between the spectrum of the meteorites and that of the sun. The iron lines in the meteorites have the same relative intensity as those in the solar spectrum, and this is an indication that the temperature of the iron vapour, in the most valid iron vapour absorbing region of the sun, is about the same as that of the electric arc.

3. The results of the enquiry into the origins of the lines, in addition to those of iron, may be thus summarised :—

Substances certainly present.	Substances probably present.
Manganese	Strontium
Cobalt	Lead
Nickel	Lithium
Chromium	Molybdenum
Titanium	Vanadium
Copper	Didymium
Barium	Uranium
Calcium	Tungsten
Sodium	Yttrium
Potassium	Osmium
	Aluminium

It is probable that the presence of the lines of copper in the arc spectrum of the meteorites is due to the fact that copper wire was used to bind the meteorites to the poles of the arc lamp. I have not yet had an opportunity of repeating the photographs with specimens of the meteorites which have not come in contact with copper in this way, but observations of the spark and flame spectra of other portions of the same meteorite have not confirmed the presence of copper.

4. Of the 43 lines in the tables for which no origins have been suggested, from the Kensington maps of metallic arc spectra, 29 are apparently coincident with lines mapped by KAYSER and RUNGE in the iron spectrum, but which do not appear in the Kensington photographs. These are indicated in the tables by the letters K. and R. (KAYSER and RUNGE), in the column for remarks.

As I pointed out in my paper on the Iron Spectrum, these are very probably due to iron, as no other origins have been determined for them, their absence from the Kensington photographs depending upon the short exposure necessarily given, as explained in the paper. Accepting these as due to iron, there are only 14 lines for which no origins have been found. Their wave-lengths are 3963·8, 3972·2, 3992·0, 3993·2, 4010·3, 4036·5, 4037·3, 4132·7, 4171·2, 4495·8, 4551·4, 5099·5, 5510·2, 5669·2. The two lines at wave-lengths 3963·8 and 3972·2 are apparently coincident with lines in Mr. MCCLEAN'S photograph of the spectrum of iron, but are not recorded by any other observer. All these lines are very feeble, and it is therefore probable that they may ultimately be found to be faint lines in the spectra of some of the metallic elements, when photographs with longer exposures are available.

5. Bearing in mind the lengths and intensities of the lines, the qualitative spectroscopic analysis of the meteorites can be carried a step further, and we can roughly approximate to the relative quantities of the different substances present. Thus, it will be gathered by a reference to the tables, that the chief chemical difference between the two meteorites is that there is a preponderance of calcium in the Nejed meteorite, and of nickel, barium, and strontium in the Obernkirchen meteorite.

The original negatives were taken by Sergeant KEARNEY, R.E.; the enlargements

have been made by Corporal HASLAM, R.E.; the reductions to wave-lengths have been made by Mr. BAXANDALL, and Mr. FOWLER has checked the work generally, and has assisted in the identification of the lines.

LINES due to other Metals than Iron in the Arc Spectra of the Nejed and Obernkirchen Meteorites.*

Wave-length (ROWLAND).	Intensity, Obern-kirchen.	Intensity, Nejed.	Origin.	Remarks.	Wave-length (ROWLAND).	Intensity, Obern-kirchen.	Intensity, Nejed.	Origin.	Remarks.
3905·7	6	Absent	Co ?		4038·9	5	5	Mn ?	
3907·6	6	6	Fe ?	K. and R.	4041·5	5	5	Mn ?	
3925·3	6	6	Fe ?	K. and R.	4045·2	4	4	Mn	
3934·0	4	2	Ca	K. line	4047·5	6	6	K	
3938·2	6	6	Fe ?	K. and R.	4050·8	6	6	Cu ?	
3940·1	6	6	Fe ?	K and R.	4052·8	5	5	Fe ?	K. and R
3941·9	6	6	Co ?		4054·3	6	6	Yt ?	
3944·2	6	6	Al ?		4061·2	6	6	Di ?	
3949·2	6	6	Ti ?		4062·1	6	6	(Pb or Mo) ?	
3954·8	6	6	Fe ?	K. and R.	4066·7	5	5	Os ?	
3957·8	Absent	6	Fe ?	K. and R.	4076·1	6	6	Cu	
3958·5	6	6	Fe ?	K. and R.	4076·4	6	6	Co ?	
3961·6	Absent	5	Al ?		4078·5	3	3	Ti ?	
3962·4	6	6	Fe ?	K. and R.	4079·4	6	6	Mn	
3963·8	6	Absent	Unknown		4079·7	6	6	Mn	
3965·6	6	6	Fe ?	K. and R.	4081·0	6	6	Cu ?	
3968·5	Absent	4	Ca	H line	4083·7	6	6	Mn	
3969·8	5	4	Cr ?		4083·9	6	6	Mn	
3972·2	6	6	Unknown		4086·5	6	6	Co	
3973·0	6	6	Di ?		4090·2	6	6	Mn ?	
3976·0	6	6	Mn ?		4091·1	6	6	Fe ?	K. and R.
3981·2	6	6	Fe ?	K. and R.	4092·5	3	3	Co ?	
3991·3	6	Absent	Cr ?		4099·9	6	6	Di ?	
3992·0	6	6	Unknown		4110·5	5	5	Co	
3993·2	6	6	Unknown		4112·5	6	6	V ?	
3995·4	3	3	Co ?		4115·1	6	6	V ?	
4002·8	6	6	Ti		4118·0	6	6	(V or W) ?	
4009·0	6	6	Ti or W		4119·1	3	3	Co ?	
4010·3	6	6	Unknown		4119·6	6	6	V ?	
4011·1	6	6	Cu ?		4121·4	3	3	Co	
4011·6	6	6	Mn		4130·2	6	6	Fe ?	K. and R.
4011·8	6	6	Fe ?	K. and R.	4132·7	5	5	Unknown	
4018·2	4	4	Mn ?		4134·6	5	5	Fe ?	K. and R.
4019·2	6	6	W ?		4136·7	5	5	Fe ?	K. and R.
4020·6	6	6	Fe ?	K. and R.	4140·6	6	6	Fe ?	K. and R.
4021·0	6	6	Co		4152·1	6	6	Fe ?	K. and R.
4022·9	6	6	Cu		4158·6	6	6	Co ?	
4026·0	6	6	U ?		4171·2	6	6	Unknown	
4027·2	6	6	Co		4190·9	6	6	Co	
4030·9	5	5	Mn		4198·8	5	5	Fe ?	K. and R.
4031·4	6	6	Fe ?	K. and R.	4215·7	4	4	Sr ?	
4033·2	6	4	Mn		4226·9	Absent	6	Ca	
4035 8	6	6	Mn		4254·5	3	4	Cr	
4036·5	6	6	Unknown		4275·0	4	4	Cr	
4037·3	6	6	Unknown		4289·9	5	5	Cr	

* K. and R. signifies KAYSER and RUNGE.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

LINES due to other Metals than Iron in the Arc Spectra of the Nejed and Obernkirchen Meteorites (continued).

Wave-length (ROWLAND).	Intensity, Obern-kirchen.	Intensity, Nejed.	Origin.	Remarks.	Wave-length, (ROWLAND).	Intensity, Obern-kirchen.	Intensity, Nejed.	Origin.	Remarks.
4296·0	Absent	6	(Cr or Ti) ?		4732·8	5	6	Ni ?	
4302·7	6	6	Ca		4749·8	6	6	Co	
4306·1	5	Absent	Ti		4754·9	5	6	Ni ?	
4321·1	6	6	Ti		4756·7	2	4	Ni or Co	
4322·0	6	5	Ti ?		4762·5	5	Absent	Mn	
4331·8	6	4	Ni ?		4764·1	4	6	Ni or Co	
4344·7	5	6	Cr ?		4792·7	6	Absent	Co	
4359·8	6	5	Cr or Ni		4807·2	4	6	Ni	
4425·6	6	6	Ca		4808·8	6	6	(Mn or Ti) ?	
4435·2	6	5	Ca		4821·3	6	Absent	Ni ?	
4455·2	Absent	6	Mn		4829·2	3	6	Cr ?	
4461·4	Absent	6	Mn ?		4831·3	3	6	Ni	
4462·2	6	6	Mn		4836·0	6	6	Ti ?	
4462·6	Absent	5	Ni ?		4838·7	5	6	Mn ?	
4464·9	6	5	Mn		4840·5	5	6	Co ?	
4470·7	4	3	Ni ?		4855·8	2	4	Ni	
4472·9	6	5	Mn		4866·6	3	5	Ni	
4490·3	5	5	Mn		4868·0	6	6	Co	
4495·8	6	6	Unknown		4873·7	4	6	Ni	
4496·2	6	6	Ti ?		4878·3	1	1	Ca ?	
4512·9	6	6	Ti		4885·6	4	5	Ti ?	
4522·8	6	6	Ti ?		4904·6	3	6	Ni	
4534·1	Absent	6	Co ?		4914·1	6	Absent	Ti	
4540·9	6	Absent	Cr ?		4925·7	6	Absent	(Ti or Ni) ?	
4544·0	6	6	Co		4934·2	5	5	Ba	
4546·1	6	Absent	Fe ?	K. and R.	4936·0	4	Absent	Ni	
4547·2	5	5	Ni ?		4937·5	6	Absent	Ni ?	
4549·6	5	5	Ti ?		4953·4	5	6	Ni ?	
4551·4	6	6	Unknown		4962·8	3	4	Sr ?	
4552·7	5	5	Ti ?		4968·1	6	6	Sr ?	
4554·2	5	5	Ba ?		4978·8	6	6	Ti ?	
4565·8	5	5	Co ?		4980·3	4	6	Ni	
4587·3	5	4	Cu ?		4984·3	3	3	Ni	
4600·5	4	4	Ni ?		4989·2	5	6	Ti ?	
4605·2	2	2	Ni		4991·5	5	6	Ti ?	
4606·4	6	6	Fe ?	K. and R.	4998·3	6	Absent	Ni ?	
4616·3	5	6	Cr		5000·5	6	Absent	Ni	
4629·6	6	6	Co ?		5007·4	5	6	Ti ?	
4646·3	5	Absent	Cr ?		5017·8	3	6	Ni ?	
4648·9	2	2	Ni		5035·7	2	5	Ni	
4652·3	6	Absent	Cr ?		5065·2	3	5	Ti ?	
4663·4	6	6	Co ?		5072·3	6	Absent	Ti ?	
4664·0	6	6	Co ?		5072·8	6	Absent	Cr ?	
4682·1	6	6	Ti ?		5080·6	2	4	Ni ?	
4686·5	4	4	Ni		5081·3	2	Absent	Ni ?	
4698·6	6	6	Ti ?		5099·5	5	Absent	Unknown	
4701·2	5	5	Mn ?		5100·1	5	Absent	Ni	
4704·0	5	5	Ni		5105·7	6	6	Cu ?	
4710·4	4	3	Ti ?		5115·6	4	6	Ni	
4714·6	1	1	Ni ?		5127·5	5	6	Ti ?	
4716·0	3	3	Ni		5129·4	6	6	Ti	
4727·6	4	3	Mn		5129·6	6	6	Ti	

LINES due to other Metals than Iron in the Arc Spectra of the Nejed and Obernkirchen Meteorites (continued).

Wave-length (ROWLAND).	Intensity, Obern-kirchen.	Intensity, Nejed.	Origin.	Remarks.	Wave-length (ROWLAND).	Intensity, Obern-kirchen.	Intensity, Nejed.	Origin.	Remarks.
5137·2	3	4	Ni		5533·0	6	6	Mo ?	
5142·7	3	4	Ni ?		5535·6	3	6	Ba	
5146·7	4	6	Ni		5543·4	3	4	Sr ?	
5151·0	5	5	Mn		5567·6	6	6	Mn ?	
5152·1	5	6	Ti		5592·5	4	6	Fe ?	K. and R.
5156·0	3	6	Ni		5594·7	5	5	Ca	
5159·3	6	6	Cu		5598·5	3	3	Ca	
5177·4	6	Absent	Ba ?		5600·4	6	6	Fe ?	K. and R.
5188·1	6	Absent	U ?		5603·2	2	2	Ca	
5204·7	4	6	Cr		5650·2	5	6	Mo ?	
5206·2	4	6	Cr		5662·7	2	3	Ti ?	
5266·7	1	1	Co ?		5669·2	6	Absent	Unknown	
5270·5	1	1	Ca ?		5682·9	4	6	Na	
5288·7	6	Absent	Ti or Mn		5695·2	5	6	Ni ?	
5298·5	6	Absent	Cr		5698·5	6	Absent	Cr ?	
5316·8	6	6	Co ?		5715·3	4	6	Ti ?	
5330·2	5	6	Sr ?		5754·9	5	6	Ni ?	
5341·3	1	1	Mn ?		5780·8	6	6	(Mn or Cr) ?	
5353·6	3	5	Co ?		5782·4	6	6	Cu	
5363·0	6	Absent	Co ?		5785·5	6	6	(Cr or Ti) ?	
5391·7	4	6	Cu ?		5794·1	6	6	Fe ?	K. and R.
5436·5	6	Absent	Ni ?		5804·6	6	6	Fe ?	K. and R.
5481·6	3	4	(Mn or Ti) ?		5806·9	6	6	Fe ?	K. and R.
5483·3	5	6	Co ?		5815·0	6	Absent	Fe ?	K. and R.
5510·2	6	Absent	Unknown		5857·6	6	Absent	Ca	
5513·2	6	6	Ti		5890·0	6	5	Na	
5519·8	6	Absent	Ba ?		5893·1	6	Absent	Ni	D lines
5522·6	6	6	Co ?		5896·1	6	5	Na	

In the above tables the wave-lengths are those corresponding to ROWLAND'S second series of photographic maps of the solar spectrum. An origin stated without further comment signifies that there is a long line at that wave-length in the spectrum of the substance named; but when a ? is added the coincident line of the substance is not one of the longest. Coincidencies with lines of cerium have not been considered.