

XX. *Flame Spectra at High Temperatures.*—Part II. *The Spectrum of Metallic Manganese, of Alloys of Manganese, and of Compounds containing that Element.*

By W. N. HARTLEY, F.R.S., *Professor of Chemistry, Royal College of Science, Dublin.*

Received April 25, 1894,—Read June 14, 1894.

[PLATE 14.]

THE SPECTRUM OF METALLIC MANGANESE.

THE spectrum of manganese obtained in various ways has been the subject of much investigation. HUGGINS, THALÉN, and LECOCQ DE BOISBAUDRAN have studied the spark spectra of manganese compounds; ÅNGSTRÖM, THALÉN, CORNU, LOCKYER, also LIVEING and DEWAR, the arc spectrum; SIMMLER, VON LICHTENFELS, LECOCQ DE BOISBAUDRAN and LOCKYER have investigated the flame spectra, while MARSHALL WATTS has given us most accurate measurements of the wave-lengths of lines and bands observed in the spark and oxyhydrogen flame spectra of spiegel-eisen, manganese dioxide, and other compounds of this metal.

An account of the spectrum of manganese obtained by the oxyhydrogen flame was prepared for insertion in Part I. of this research, but it was omitted for the reason that when investigating the spectrum of the Bessemer flame, I found it necessary to compare the spectrum of elementary manganese under different conditions with that of its oxide. Comparative experiments were made with various alloys containing manganese, and with compounds of that substance ignited in the oxyhydrogen flame.

The results showed that the alloys invariably gave a more distinct and extensive series of bands than the compounds containing the same proportion of manganese as the alloys. Moreover, the bands were always accompanied by lines, and the lines were stronger in the spectra of the alloys than in the compounds. The principal lines were always distinctly visible when the conditions were such that the bands could barely be seen. For instance, when the spectrum of spiegel-eisen was photographed with a very short exposure, in fact by a mere flash of light, or when steel containing a very small amount of manganese was burnt in the oxyhydrogen flame and its spectrum photographed. The various materials used have been ferro-manganese, containing 80 per cent. of manganese, spiegel-eisen, containing 18 to 20 per cent., silico-spiegel, containing 10 per cent. of silicon and 18 to 20 per cent. of manganese, pig-iron, composition undetermined, and TURTON'S tool steel.

15.1.95

Ferro-manganese yielded a very fine spectrum after an exposure varying from 15 to 30 minutes, better in fact than any compound of that substance. It may thus be generally stated that manganese alloys containing iron yield a more distinctive spectrum of manganese than any compound containing the same proportion of that element. (See the upper spectra on Plate 14.)

Metallic manganese, deposited on platinum by the electrolysis of a perfectly pure solution of the chloride, was heated in the oxyhydrogen flame for half-an-hour and its spectrum photographed.

Pure manganic oxide was prepared from a solution of potassium permanganate by the action of alcohol and a small quantity of sulphurous acid. The precipitated oxide, washed and ignited, was heated on a support of kyanite in the flame of the oxyhydrogen blow-pipe for an hour and 20 minutes. It will be seen that as there is a considerable difference between 30 and 80 minutes in the exposure, a corresponding difference in the width and intensity of the bands common to the two spectra obtained from the metal and the oxide may be anticipated. Also bands invisible or barely discernible in the spectrum of the metal with 30 minutes' exposure will, it is possible, be clearly defined after an exposure of the oxide for 80 minutes. The same spectrum as regards its leading features as that yielded by metallic manganese, was obtained by deflagrating a mixture of finely-powdered potassium permanganate and lamp-black.

MANGANESE.

Metallic manganese, deposited on platinum by the electrolysis of a perfectly pure solution of the chloride, was heated in the oxy-hydrogen flame for half an hour. References: F. and T., FIEVEZ and THALÉN; V. and T., VOGEL and THALÉN; L. DE B., LECOCQ DE BOISBAUDRAN; K. and R., KAYSER and RUNGE; C., CORNU.

Description of Spectrum.	$\frac{1}{\lambda}$.	λ .	References.
More refrangible edge of band, weak . . .	17078	5855	5855.2, Fe, F. and T. 5800, Fe, F. and T., also L. DE B.
Line, doubtful	17202	5813	
" "	17242	5800	
More refrangible edge of very weak band, or a line.	17350	5764	Uncertain.
More refrangible edge of very weak band, or a line.	17451	5730	
More refrangible edge of very weak band, or a line.	17508	5712	
Edge of band, or a line	17568	5692	5623.5, Fe, F. and T. 5591, Fe, F. and T.
" " and apparently a line . . .	17786	5622	
Strongest part of band	17863	5598	
Edge of band hazy	17886	5591	

MANGANESE--(continued).

Description of Spectrum.	$\frac{I}{\lambda}$.	λ .	References.
Line, or less refrangible edge of band . .	17950	5571	5571·3, Fe, F. and T.
" more " " " " " " " " " " "	18000	5556	
Line	18077	5532	
" " " " " " " " " " " "	18180	5500	
" " " " " " " " " " " "	18255	5478	5478, Fe, F. and T.
" or edge of band	18298	5465	
" distinct, rather broad	18365	5445	5446, Fe, F. and T.
" sharper and weaker	18390	5438	
More refrangible edge of strong band . .	18510	5402	
Band	18548	5391	5392·3, Fe, F. and T.
Edge strong	18620	5370·5	5370·6, Fe, F. and T.
Fine line	18642	5364	
Edge of band doubtful	18703	5347	} 5316, Fe, F. and T.
" " " " " " " " " " " "	18815	5315	
More refrangible edge of band coincident with solar line E.	18973	5270	5269·5, Fe, F. and T.
More refrangible edge of band	19100	5235	5270·3, K. and R.
" " " " " " " " " " " "	19235	5199	5232·1, Fe, F. and T.
" " " " " " " " " " " "	..	5166	5198·2, Fe, F. and T.
Line	20702	4830	5167, Fe, F. and T.
" " " " " " " " " " " "	20870	4791·5	4831·8, Fe, F. and T.
" " " " " " " " " " " "	20998	4762	4761·3, Mn, THALÉN, ÅNGSTRÖM.
" " " " " " " " " " " "	24605	4064	4062·9, Mn, ÅNGSTRÖM.
" " " " " " " " " " " "	24656	4056	4063, Fe, V. and T.
" " " " " " " " " " " "	24694	4049·5	4048, Mn, ÅNGSTRÖM.
" " " " " " " " " " " "	24742	4041·3	4048·7, Mn, CORNU.
Strongest group of lines in the whole spectrum. These appear as two bands very closely adjacent, or, in the manganese oxide spectrum, as one band with the centre reversed, the less refrangible edge of the band being very strong and sharp, the more refrangible being degraded and diffuse. The measurement in brackets indicates the apparent reversal, but is probably the point of separation of two lines	24773	4036·5	4040·6, Mn, ÅNGSTRÖM.
Uncertain measurement	(24800)	4032)	4034·9, Mn, ÅNGSTRÖM; also CORNU.
	24817	4029·5	(4032·9) Mn, (4031·8) Mn, ÅNGSTRÖM.
	25683	3894	4029·4, Mn, ÅNGSTRÖM.
Line	25815	3874	In some photographs there are four lines discernible here. In the spectrum from MnO ₂ , 4036·5 widens out to 4037.
" " " " " " " " " " " "	25905	3860	3894·7, Fe, C.
" " " " " " " " " " " "	25992	3847	3895·75, Fe, K. and R.
" " " " " " " " " " " "	26077	3835	3859·3, Fe, C.
" " " " " " " " " " " "	26132	3827	3860·03, Fe, K. and R.
" " " " " " " " " " " "	26150	3824	3834, Fe, C.
" " " " " " " " " " " "	26262	3808	3834·37, Fe, K. and R.
" doubtful	26296	3803	3824·1, Fe, C.
" weak, doubtful	3764	3824·58, Fe, K. and R.
" feeble	27615	3621	3806·4, CORNU.
" doubtful	27685	3612	3805, Fe, C.
			3620·6, Fe, C.

THE SPECTRUM OBTAINED BY THE INTENSE IGNITION OF MANGANIC OXIDE.

The pure oxide was prepared from a solution of potassium permanganate by the action of alcohol and a small quantity of sulphurous acid. The precipitate being washed and ignited was heated on a support of kyanite in the flame of the oxy-hydrogen blow-pipe. Exposure one hour and twenty minutes. A similar spectrum is obtained by deflagrating a mixture of finely-powdered potassium permanganate and lamp-black. For comparison iron lines are indicated as follows:—F. and T., FIEVEZ and THALÉN; V. and T., VOGEL and THALÉN; C., CORNU; L. DE B., LECOCQ DE BOISBAUDRAN; K. and R., KAYSER and RUNGE.

Description of Spectrum.	$\frac{1}{\lambda}$	λ .	References.
Less refrangible edge of band, or a weak nebulous line	}	..	
More refrangible edge of weak band . . .			
Less refrangible edge of narrow band . . .			
More refrangible edge of band			
A band appears to commence here	17028	5873	5858, L. DE B. 5855·2, Fe, F. and T.
More refrangible edge of weak band . . .	17076	5856	
	17160	5827	5807, L. DE B. 5800, Fe, F. and T.
More refrangible edge of weak band . . .	17240	5800	
„ „ stronger band . . .	17385	5752	5759, L. DE B.
„ „ „ . . .	17490	5717	5719, L. DE B.
„ „ „ . . .	17603	5681	5683, L. DE B.
Edge of band very indistinct	17705	5645	5644, WATTS.
„ „ like a line	17787	5622	5623·5, F. and T.
Less refrangible edge of band	17835	5607	5607, WATTS.
More „ „ „	17885	5591	5591, Fe, F. and T.
More refrangible edge of last band of this series	17902	5586	5587, L. DE B.
Less refrangible edge of weak band . . .	17937	5575	5571·3, Fe, F. and T.
Edge of band, doubtful	5474	5473, L. DE B.
Nebulous line near edge of band	18370	5443·5	5473·6, Fe, F. and T.
„ „ but sharper	18388	5438	5443·1, Mn, THALÉN.
More refrangible edge of band	18409	5432	5433, WATTS.
Less „ „ „	18425	5427	5432, HUGGINS.
Line on edge of band, strong	18500	5405	5427, L. DE B.
Edge of band	18518	5400	5406·6, THALÉN.
„ „ and of this series	18627	5368·5	5398, L. DE B.
Less refrangible edge of band, very feeble .	18702	5347	5399·9, Mn, THALÉN.
More „ „ „	18800	5318	5367, L. DE B.
„ „ „ weak. „ Nearly	18970	5271	5348, Mn, HUGGINS.
coincident with the Solar line E			5316, Fe, F. and T.
			5269·5, Fe, F. and T.
			5270·43, Fe, K. and R.
			5269·65, Fe, K. and R.
More refrangible, stronger edge of band, edges sharp of this and the next two bands. Degraded towards the red	19105	5234	5233·8, THALÉN.
The same, stronger	19241	5197	5232·1, Fe, F. and T.
„ weaker	19367	5163	5198·2, Fe, F. and T.

SPECTRUM obtained by the Intense Ignition of Manganic Oxide—(continued).

Description of Spectrum.	$\frac{1}{\lambda}$.	λ .	References.
More refrangible edge of band, weak . . .	19780	5055	
" " " " . . .	19927	5018	
" " " " . . .	20095	4976	
Line on edge of band	20263	4935	
Edge of band, very doubtful	20423	4896	
" " " "	20605	4853	
Line, strong, not very sharp	20710	4828	4831·8, Fe.
" " " "	20875	4790	
Band, very weak	{ 20935	4776·5	
	20965	4770	
Line, fairly strong, not very sharp	20998	4762	4761·3, Mn, THALÉN.
More refrangible edge of band, weak . . .	21055	4749·5	
" " " very weak	21293	4696	
" " " "	21476	4656	
" " " doubtful	21740	4600	
" " " fairly strong and sharp	21857	4575	
More refrangible edge of band, very weak .	22267	4491	4491, Mn, ÅNGSTRÖM.
			Band peculiar to manganic oxide.
" " " stronger	22436	4457	4457·6, Mn, THALÉN.
" " " sharp	22713	4403	
" " " doubtful	23293	4293	Band peculiar to manganic oxide.
" " " distinct	23400	4273	4271·6, Mn, THALÉN.
" " " "	23520	4252	
There are some imperfect edges of band at intervals extending to	23664	4226	4227, Mn, ÅNGSTRÖM.
Three very doubtful lines, or edges of bands	{ 24180	4135	Band peculiar to manganic oxide.
	24196	4133	
	24215	4130	4132·15, Fe, K. and R.
More refrangible edge of band	24238	4125·5	
Line, nebulous, fairly strong, or edge of band	24264	4121	
" " but strong " "	24514	4079	4079·6, Mn, ÅNGSTRÖM.
Nebulous line, weak	24538	4075	
" " very weak	24600	4065	
" " "	24617	4062	
Line, possibly a pair, fairly strong	24664	4054·5	4062·9, Fe, C.
" or edge of narrow fluting, sharp . . .	24699	4049	4063, Fe, V. and T.
			4054·3, Mn, THALÉN.
" " " "	24750	4040	4048·7, Mn, C.
			4048, Mn, ÅNGSTRÖM.
			4040·6, Mn, C.
			Also ÅNGSTRÖM.
The above are both degraded slightly towards the more refrangible edge.	24770	4037	
Very strong band degraded towards the more refrangible edge. The band is more diffuse, stronger, and broader, at the lower part of the flame,	24845	4025	
Line, possibly a close pair, strong	25036	3994	
" " " "	25055	3991	3991·7, Mn, LOCKYER.

* This band appears as two groups of lines, in ordinary steel and spiegel-eisen, when photographed with short exposure. The less refrangible group consists of three lines, the more refrangible of two lines. They are very sharp and distinct. The two groups become merged into two broad lines in metallic manganese.

SPECTRUM obtained by the Intense Ignition of Manganic Oxide—(continued).

Description of Spectrum.	$\frac{1}{\lambda}$	λ .	References.
Line, weak	25077	3988	3988, Mn, ÅNGSTRÖM.
„ fairly strong	25682	3894	3894·7, Fe, C.
„ doubtful, very weak	25735	3886	3895·75, Fe, K. and R.
„ „ „	25760	3882	3886·38, Fe, K. and R.
„ „ „	25785	3878	Fe, 3878·5.
„ strong	25817	3873	
„ doubtful, very weak	25844	3869	
„ „ „	25865	3866	
„ or edge of band, weak	25907	3860	3859·3, Fe, C.
„ weak	26000	3846	3860·3, Fe, K. and R.
„ „	26030	3842	3841·19, Fe, K. and R.
„ stronger	26085	3833·5	3834, Fe, C.
„ still stronger	26151	3824	3834·37, Fe, K. and R.
„ doubtful, very weak	26250	3809	3824·1, Fe, C.
„ „ „	26270	3806·5	3824·58, Fe, K. and R.
Band weak, and with edges not well defined	26652	3752	3806·4, CORNU.
„ „ and very doubtful	26824	3728	{ 3727·78, Fe, K. and R.
Line, or edge of band, very weak	26875	3721	
„ very weak	26915	3715	
Very feeble band, edge	27250	3670	{ „ „ „
Edge of band, very weak, doubtful	27314	3661	
Line, „ hazy, weak „	27604	3623	
„ „	27615	3621	{ 3620·6, Fe, C.
„ „	27685	3612	
„ „	27708	3609	
„ sharp, weak	27753	3603	3608·3, Fe, C.
„ „	27808	3600	3608·99, Fe, K. and R.
„ very weak	27870	3588	3604·6, Fe, C.
„ „	27880	3587	
„ sharp, weak	27948	3578	
„ „ stronger	27965	3576	
„ „ fairly strong	28013	3570	3568·9, Fe, C.
More refrangible edge of band, very weak	28057	3564	3570·23, Fe, K. and R.
Band, very weak	{ 28080	3561·5	{ 3564·1, Fe, C.
Line, or more refrangible edge of band, very weak		3559·5	
Line, sharp, fairly strong		3553	
Two nebulous lines, very weak	28143	3548	3565·5, Fe, K. and R.
Line, very weak, sharp	28183	3548	
„ stronger, sharp	28236	3541·5	
„ still stronger, sharp	28254	3539	
„ very weak, sharp	28305	3533	
„ strong, sharp	28313	3532	
„ weak, „	28330	3530	
„ very weak, sharp	28339	3528·5	
„ strong, sharp	28358	3526	{ 3526·5, Fe, K. and R.
„ weak, „	28374	3524	
„ very weak, sharp	28383	3523	
Lines, equally weak and sharp	28400	3521	
	28408	3520	

SPECTRUM obtained by the Intense Ignition of Manganic Oxide—(continued).

Description of Spectrum.	$\frac{1}{\lambda}$.	λ .	References.
Line, very weak	28425	3518	3501·8, Fe, C.
„ fairly strong	28460	3513·5	
„ weak	28467	3513	
„ double, centre weak	28487	3510	
„ strong, sharp	28520	3506	
„ very strong, sharp	28552	3502	
The lines which follow are very weak and not in very sharp focus; the measurements, therefore, are less accurate.			
.	28590	3498	3496·8, Fe, C.
.	28600	3496·5	
.	28622	3494	
.	28632	3492·5	3490·65, Fe, K. and R.
.	28650	3490·5	
.	28665	3488·5	
.	28678	3487	
.	28694	3485	
.	28703	3484	
.	28715	3482·5	
.	28730	3481	
.	28749	3478·5	
.	28762	3477	
Fairly strong, a pair	{ 28774	3475	{ 3476·1, Fe, C.
Weak, but sharp	28787	3474	
„ „ „	28807	3471	{ 3476·75, Fe, K. and R.
Strong	28820	3470	
Very weak	28838	3468	3470·4, Fe, C.
Weak	28849	3466	
„	28860	3465	3468, Fe, C.
Very weak	28872	3463·5	
Weak.	28883	3462	3465·5, Fe, C.
Very strong	28897	3460·5	
Very weak	28935	3456	3461·5, Fe, C.
„ „ „	28978	3451	
Sharp, less refrangible edge	28994	3449	3457·8, Fe, C.
Weak band, less refrangible the stronger edge	29013	3447	
Weak, sharp line	29028	3445	3453·3, Fe, C.
„ „ „	29038	3444	
„ „ „	29059	3441	3441·07, Fe, K. and R.
„ „ „	29078	3439	
Nebulous group of lines, very close together	29096	3437	Coincident with Solar line O.
Edge of group	29125	3433·5	
More refrangible edge of group	29156	3430	
Very weak line	29260	3417·5	
Coincides with a solar line	29285	3415	
Very strong line	29302	3413	
Very weak line	29323	3410	
„ „ „	29332	3409	
Very strong line	29368	3405	
.	29410	3400	
.	29454	3395	3415·5, Fe, C.
.	29492	3391	
.	29516	3388	

MANGANIC OXIDE.

The following measurements appear to belong to bands peculiar to the manganic oxide spectrum; that it to say, on comparing the photographs of the spectra of metallic manganese and manganic oxide, they appear to consist of the same groups of lines and bands with the addition of these which at once strike the eye when the whole spectrum is viewed. Hence we may conclude that the spectrum obtained by intense ignition of manganic oxide consists of the bands and lines due to the element manganese, with the addition of those bands which are due to the oxide of manganese.

Ivory scale measurements.	Description of Spectrum.	$\frac{1}{\lambda}$.	λ
{ 66.5 70.3 70.3 75.5 75.5 }	Band	21155 21430 21430 21855 21855	4727 4667 4667 4575 4575
{ 82.0 82.7 86.3 86.3 97.5 97.5 109.0 }	Band Band, weak and not well defined Band Band A sharp line on this edge There is a continuous band of rays extending to	22360 22415 22694 22694 23490 23490 24274 ..	4472 4461 4406 4406 4257 4257 4120 3424
{ 148.5 154.0 160 161 119 119.5 161 167 }	Band, weak, and with edges not well defined A very feeble narrow band Narrow band. Band degraded towards the less refrangible edge	26652 26930 27250 27304 24917 24950 27304 27615	3752 3713 3670 3662 4013 4008 3662 3621

There are also the following narrow bands, or flutings, to be noted, not observable without a magnifier.

Ivory scale measurements.	Description of Spectrum.	$\frac{1}{\lambda}$.	λ
{ 115.5 116.3 151.0 153.3 }	Sharp edge of narrow fluting Both are "degraded" towards their more refrangible edges Fine sharp lines, apparently the edges of flutings	24699 24732 26783 26903	4049 4043 3734 3717

A broad diffuse band, which is to be seen on the Bessemer flame spectrum between M and N of the solar spectrum, belongs apparently to manganic oxide. There is one,

also overlying M, which is not visible, probably on account of the strong group of iron lines at this point. There is also a weak band beyond N, seen as diffused rays in the Bessemer spectrum, but which appears as two groups of very fine lines in the manganic oxide spectrum.

The following is a list of 87 lines and edges of bands which are common to the spectrum of metallic manganese and that obtained from manganese dioxide. The spectrum of the metal received only half-an-hour's exposure, that of the oxide an hour and twenty minutes. The bands of the one may be a little wider than those of the other owing to the longer exposure. The intense ignition of the oxide certainly causes its dissociation. It will be noticed that many lines have been measured as iron lines by FIEVEZ and THALÉN, VOGEL and THALÉN, KAYSER and RUNGE, and by CORNU. Some of these are unquestionably manganese lines, others may closely approximate, or coincide, in wave-length with iron lines. It is quite certain, after careful examination, that the photographs of the manganese spectrum, whether obtained from the metal or the pure oxide, contain no iron lines, since all the principal lines of this element are absent.

LIST of Lines and Bands Common to the Spectra Obtained from the Metal and from the Oxide of Manganese.

Manga- nese. λ.	Description of Spectrum, with Lines observed in other Spectra.	Manga- nese dioxide. λ.	Description of Spectrum, with Lines observed in other Spectra.
5855	Fe, 5855·2, FIEVEZ and THALÉN	5856	Fe, 5855·2, FIEVEZ and THALÉN
5800	Fe, 5800 FIEVEZ and THALÉN	5800	Fe, 5800, FIEVEZ and THALÉN
5712	m.r. edge of weak band	5717	m.r. edge of band
5622	Edge of band and apparently a line	5622	Edge of band like a line
	Fe, 5623·5, FIEVEZ and THALÉN		Fe, 5623·5, FIEVEZ and THALÉN
5591	Edge of band, hazy	5591	m.r. edge of band
	Fe, 5591, FIEVEZ and THALÉN		Fe, 5591, FIEVEZ and THALÉN
5571	Line or l.r. edge of band	5575	l.r. edge of weak band
	Fe, 5571·3, FIEVEZ and THALÉN		
5478	Line	5474	Edge of band, doubtful
	Fe, 5478		Fe, 5473·6, FIEVEZ and THALÉN
5445	Line, distinct, rather broad	5443·5	Nebulous line near edge of band
	Fe, 5446, FIEVEZ and THALÉN		Fe, 5446, FIEVEZ and THALÉN
5438	Line, sharper and weaker	5438	Nebulous line, but sharper
5402	Edge of strong band	5405	Line or edge of band, strong
5391	Fe, 5392, FIEVEZ and THALÉN	5400	} Band
5370·5	} Band	5368·5	
	Edge strong		Edge of band and of this series
	Fe, 5370·6, FIEVEZ and THALÉN		
5347	} Edge of band, doubtful	5347	} l.r. edge of band } very feeble
5315	} "	5318	
	Fe, 5316, FIEVEZ and THALÉN		
5270	m.r. edge of band	5271	m.r. edge of band, weak
	Fe, 5269·5, FIEVEZ and THALÉN		Nearly coincident with E
	Coincident with E		

LIST of Lines and Bands Common to the Spectra Obtained from the Metal and from the Oxide of Manganese—(continued).

Manga- nese. λ.	Description of Spectrum, with Lines observed in other Spectra.	Manga- nese dioxide. λ.	Description of Spectrum, with Lines observed in other Spectra.
5235	m.r. edge of band	5234	m.r. edge of band
5199	" Fe, 5198·2, FIEVEZ and THALÉN	5197	" " "
5166	m.r. edge of band	5163	" " "
	Fe, 5167, FIEVEZ and THALÉN		
4830	Line	4828	Line, strong, not very sharp
	Fe, 4831·8, FIEVEZ and THALÉN		
4791·5	Line	4790	" " " "
4762	"	4762	" fairly strong, not very sharp
4064	"	4062	Nebulous line, very weak
	Fe, 4063·63, KAYSER and RUNGE;		4062·9, CORNU
	Fe, 4063, VOGEL and THALÉN		4063·63, KAYSER and RUNGE
4056	Line	4054·5	Line, possibly a pair, fairly strong
4049·5	"	4049	" or edge of narrow fluting
4041·3	"	4040	" 4041·44, Fe, KAYSER and RUNGE
	Fe, 4041·44, KAYSER and RUNGE		
4036·5*	Strongest group of lines in the whole spectrum	4037	Very strong band, degraded towards the red. Band more diffuse, stronger, and broader at the lower part of flame
4032	4035·76 Fe, KAYSER and RUNGE		
4029·5	4033·16 Fe, " " "		
3894	4030·84 Fe, " " "	4025	
	Uncertain line	3894	Line, fairly strong
	Fe, 3894·7, CORNU		
	Fe, 3895·75, KAYSER and RUNGE		
3874	Line	3873	" strong
3860	"	3860	" or edge of band, weak
	Fe, 3859·3, CORNU		
	Fe, 3860·03, KAYSER and RUNGE		
3847	Line	3846	" weak
3835	"	3833·5	" stronger
	Fe, 3834, CORNU		
	Fe, 3834·37, KAYSER and RUNGE		
3824	Line	3824	" still stronger
	Fe, 3824·1, CORNU		
	Fe, 3824·58, KAYSER and RUNGE		
3808	Line	3809	" doubtful, very weak
3803	" doubtful	3806·5	"
	Fe, 3805, CORNU		
3621	Line, feeble	3621	" hazy, weak
	Fe, 3620·6, 3617·8, CORNU		
3612	Line, doubtful	3612	" " "
3607·5	"	3609	" " "
	Fe, 3606·0, CORNU		Fe, 3608·3, CORNU
3604	Line, doubtful	3603	Line, sharp, weak
	Fe, 3604·6, CORNU		
3600	Line, fairly strong	3600	" " "
3589	" very weak	3588	" very weak
3587	"	3587	" " "
3578	" weak	3578	" sharp, weak
3576	"	3576	" " stronger

* There are undoubtedly four lines here, but two of them are very close together, so that only at the extreme points can four lines be counted.

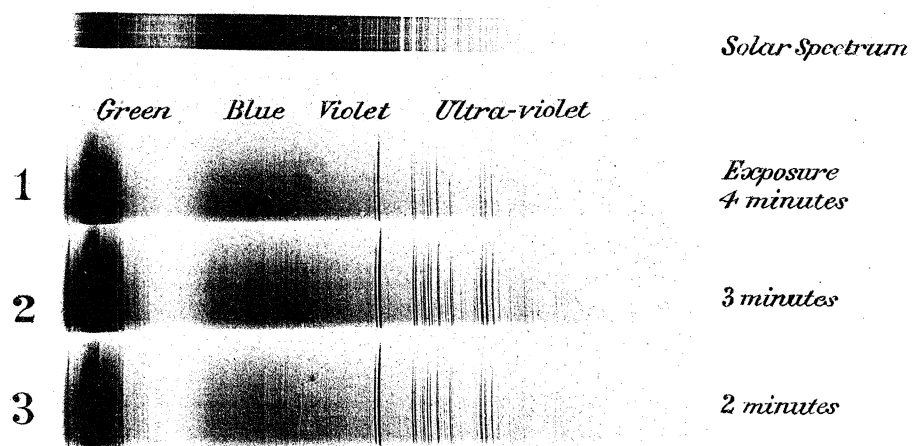
LIST of Lines and Bands Common to the Spectra Obtained from the Metal and from the Oxide of Manganese—(continued).

Manga- nese. λ.	Description of Spectrum, with Lines observed in other Spectra.	Manga- nese dioxide. λ.	Description of Spectrum, with Lines observed in other Spectra.
3571	Line Fe, 3568·9, CORNU	3570	Line, sharp, fairly strong
	Fe, 3570·23, KAYSER and RUNGE		
3566	Line Fe, 3564·1, CORNU	3564	m.r. edge of band, very weak
	Fe, 3565·5, KAYSER and RUNGE		
3562	Line, doubtful	3561·5	} Band, very weak
		3559·5	
3549	"	3548	Line, sharp, fairly strong
3543	"	3541·5	Nebulous line, very weak
3536	"	3539	" " "
3534	"	3533	Line, very weak, sharp
3533	"	3532	" stronger, sharp
3530·5	"	3530	" still stronger, sharp
3529·5	"	3528·5	" very weak, sharp
3528	"		
3525	"	3526	" strong, sharp
	Fe, 3526·51, KAYSER and RUNGE		
3524	Line	3524	" weak, sharp
3513	"	3513	" "
3511	"	3510	" double, centre weak
3507	"	3506	" strong, sharp
3503	"	3502	" very strong, sharp
	Fe, 3501·8, CORNU (reversed)		
3498	Line	3498	} Lines very weak and not in very sharp focus or hazy lines
	Fe, 3496·8, CORNU		
	Fe, 3497·92, Fe, K. and R.		
3497	Line	3496·5	
3493·5	"	3494	
3485	"	3485	
3476	"	3475	
	Fe, 3476·1, CORNU (reversed)		
3473·5	Line	3474	
3472	"	3471	
3470·5	"	3470	
3468	Fe, 3468, CORNU (reversed)	3468	
3467		3466	
3465	Fe, 3465·5, CORNU	3465	
3464·5		3463·5	
3461	Fe, 3461·5, "	3462	
3457	Fe, 3457·8, "	3456	
3453	Fe, 3453·3, "	3451	
3448		3449	
3442		3441	Solar line O
			3441·07, Fe, KAYSER and RUNGE
3437	Edge of band }	{ 3437	Nebulous group of lines very close
3434	" " }	{ 3433·5	together
3431	Line, nebulous }	3430	m.r. edge of group
3419	" " }	3417·5	Very weak line
3418	" " }	3415	Line coincides with with a solar line
3415	"		
	Fe, 3415·5, CORNU		
3413	Line	3413	Very strong line
3410	"	3410	" weak line



Manganese Spectra,

1, *Spiegeleisen*, 2, *Ferromanganese*, 3, *Manganic Oxide*.



Mn Bands

Fe

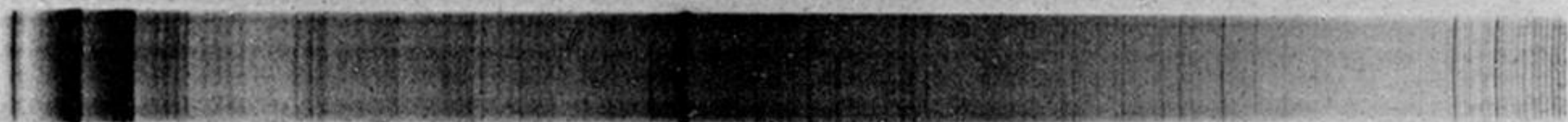
Bessemer Flame Spectra

Plate 8. Crewe

1



2



3



Manganese Spectra,

1, *Spiegeleisen*, 2, *Ferromanganese*, 3, *Manganic Oxide*.

Solar Spectrum

Green Blue Violet Ultra-violet

1

*Exposure
4 minutes*

2

3 minutes

3

2 minutes

Mr Bards

Fe

Bessemer Flame Spectra

Plate 8. Crewe