"On the Arc Spectrum of Vanadium." By Sir NORMAN LOCKYER, K.C.B., F.R.S., and F. E. BAXANDALL, A.R.C.S. Received March 19,—Read March 28, 1901.

The spectrum of vanadium is so important, especially on account of the prominent part which lines of that element play in the spectra of sun-spots, and the existing records of vanadium lines differ so considerably, that it has been thought desirable to publish a list of the lines reduced some time ago from the Kensington photographs of the arc spectrum.

These photographs were obtained by Mr. C. P. Butler with a 6-inch Rowland concave grating of $21\frac{1}{2}$ feet focal length and 14,438 lines to the inch. The region of the spectrum investigated extends from λ 3887 to λ 4932, and occupies on the plates a length of $16\frac{1}{4}$ inches.

The sources of the spectra were (1) vanadium chloride, and (2) a pure sample of vanadium oxide supplied by Sir Henry Roscoe, to whom we wish to express our thanks. In each case they were volatilised in the arc between poles of the purest silver which could be obtained, and which were kindly placed at our disposal by Sir W. C. Roberts-Austen. These are used because the number of lines due to the poles themselves is so small compared with that produced when carbon poles are employed, that it is much easier to detect the lines really due to the substance under consideration.

Lists of lines in the arc spectrum of vanadium have been published by Rowland and Harrison,* and by Hasselberg.† The former investigators used some compound of vanadium (not stated in their paper) volatilised on carbon poles; the latter employed poles made of the metal itself.

The three records naturally contain a large number of lines in common, but there are many differences between any two of them for which it is difficult to account. To show these differences it has been considered best to give side by side in tabular form the lines in the three lists, and analyse the lines special to any one list, with the object of either properly establishing their claim to be accepted as true lines of vanadium, or possibly tracing them to their real origin. It may be safely assumed that lines common to any two of the lists really belong to vanadium.

To eliminate lines due to impurities, the vanadium spectrum has been directly compared with the arc spectra of all the other elements available at Kensington, photographed exactly on the same scale. If the "strongest" lines of an element are not represented in the vanadium spectrum, apparent coincidences with any of the "weaker" lines are

* 'Astro.-Phys. Jour.,' vol. 7, p. 273, 1898.

† 'Svenska Vetenskaps Akad. Handl.,' vol. 32, No. 2, 1899.

not accepted as furnishing any proof of the existence of that element as an impurity in the vanadium. This comparison shows that, in addition to those belonging to silver, the only lines which with any degree of probability can be attributed to other metals, are traces of the very strongest lines only of iron, manganese, chromium, cobalt, calcium, strontium, aluminium, and lead. Such lines (a list of which is given later in the paper) have been left out of the following table.

Although Rowland gives his wave-lengths to one-thousandth of a tenth-metre, for convenience of comparison with the other records his values are quoted, throughout the present paper, to the nearest hundredth of a tenth-metre. A brief reference must be made to Rowland's scale of intensities. In his paper he states that the scale he has adopted is from 1 to 15. There are, however, several intensities given which are beyond these limits; but they are probably due to typographical errors. Such cases are indicated in the column for remarks. It would seem rather difficult to reconcile his adoption of such a scale with the opinion expressed in the introduction to his "Preliminary Table of Solar Spectrum Wave-lengths" to the effect that "the ordinary scale from 1 to 10 or from 1 to 6 is far too limited for the spectral lines, especially for the metallic spectra; 1 to 1000 is hardly great enough for the enormous difference in intensity. The small range, 1 to 10, ordinarily used gives an entirely wrong idea to the worker in this subject, and many books with spectroscopic theories might have been saved by using a scale from 1 to 1000."

Vanadium Arc Lines.

Comparison of Kensington Records with Hasselberg's and Rowland's.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
3887·69	<1					
88·20	2	3888·23	1			
88·47	3	88·50	2			
89·36	1–2					
89·91	<1					
90·30	7	90·33	3	3890·30	4	
91·25	5	91·27	2			
91·88	1					
92·53	2–3			92·47	4	
92·95	6–7	93·03	3			
93·88	<1					
94·16	4–5	94·19	2			
95·86	2–3					
96·29	4	96·29	2	96·26	2	

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4-5.	λ.	Int. Max. =15.	
3896·83	2					
97·20	4	3897·22	2			
98·17	6	98·15	3	3898·08	1	
98·44	3					
99·23	3-4	99·30	1			
3900·29	4-5	3900·33	2-3			
01·28	4-5	01·30	2-3			
01·81	2					
02·45	10	02·40	3-4	3902·37	7	
		02·71	1			
03·32	3-4	03·42	1-2			
03·86	<1					
04·51	3-4	04·63	1			
06·92	4	06·89	2			
07·33	2					
08·46	3					
09·58	<1					
09·96	9	10·01	3	09·99	5	
10·57	<1					
10·92	4	10·95	2			
11·90	1					
12·35	5	12·36	2-3			
13·04	3	13·03	2			
13·71	1					
14·08	<1					
14·49	4			14·44	1	
15·30	1-2					
15·57	2					
16·57	3-4	16·55	1-2			
				19·60	1	
20·10	1	20·15	1			
20·67	4	20·65	1-2			
22·11	4	22·15	2	22·02	1	
22·57	5	22·58	2-3	22·55	3	
24·85	5	24·84	2-3	24·77	3	
25·36	5	25·36	2	25·35	3	
26·64	<1					
26·86	1-2					
28·07	5					
28·64	1-2					
29·93	1					
30·19	6	30·19	2-3			
31·46	5	31·40	1			
		31·50	2			
				33·77	3	Ca (K).
34·18	5-6	34·16	3-4			
35·28	4-5	35·28	2-3			
36·43	3-4	36·42	2			
37·65	3	37·68	2			
38·37	3	38·35	2			
39·04	1-2					
39·49	3	39·48	2			

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ	Int. Max. =15.	
3940·75	2	3940·75	1			
41·40	3	41·40	1–2			
42·18	4	42·16	2			
43·81	5	43·77	2–3			
				3944·13	3	Al.
45·36	1					
46·04	<1					
48·79	3					
50·38	4	50·37	2			
52·12	5	52·09	2	52·07	1	
				61·65	5	Al.
63·78	3	63·77	2			
64·64	1–2					
68·29	3	68·24	2			
				68·59	1	Ca (H).
72·12	2	72·10	1			
73·53	1	73·49	1			
73·79	3–4	73·79	2			
75·48	1–2					
77·88	2					
79·31	3	79·30	2			
79·61	3	79·59	2	79·54		
80·66	3	80·66	2			
81·78	4–5					
84·51	3					
84·78	3–4	84·75	2			
88·21	<1					
88·98	4	88·97	2			
89·95	1					
90·72	7	90·71	3	90·69	5	
91·22	1					
92·95	7	92·95	3	92·92	3	
95·08	2					
97·31	3–4	97·30	1–2			
98·91	7	98·87	3	98·85	3	
4000·24	2	4000·24	1			
03·12	3	03·10	1–2			
03·70	2–3	03·70	1–2			
05·90	4–5	05·86	2	4005·84	1	
08·33	<1					
09·99	1–2	09·94	1			
11·50	2–3	11·45	1			
13·69	<1					
15·26	1	15·20	1			
16·86	<1					
19·18	<1					
19·58	<1					
20·73	1					
22·07	2–3			22·04	1	
23·28	2–3					
23·48	3–4	23·50	2	23·51	1	
24·63	<1					

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4025·47	1	4025·46	1			
30·05	1–2	30·04	1–2			
31·36	2	31·37	1–2			
31·99	4	31·98	2	4031·96	1	
32·64	1–2	32·62	1–2			
33·00	1	33·01	1			
				33·19	3	Mn.
				34·62	2	Mn.
35·77	4	35·77	2			
36·93	2	36·93	1			
39·76	<1					
40·43	1–2	40·46	1			
41·66	2–3	41·72	2			
42·80	3–4	42·78	2	42·76	1	
46·99	1	47·05	1			
48·77	2–3	48·77	2			
51·10	5	51·11	2–3			
51·52	5	51·48	2–3			
52·60	1	52·60	1			
53·41	2–3					
53·81	<1					
57·21	5	57·21	3	57·21	2	
				57·96	1	Pb.
61·00	1	60·97	1			
61·76	1					
62·92	1					
64·11	4–5	64·09	2–3	64·06	2	
65·54	1–2					
67·96	2–3	67·90	1–2			
68·16	2–3					
70·94	2–3					
71·67	4–5	71·67	2–3	71·66	2	
72·28	2–3	72·30	2			
				77·85	1	Sr.
78·10	1					
83·07	3–4					
83·44	<1					
84·92	<1					
88·00	<1					
90 05	1					
90·74	8	90·70	3	90·70	5	
92·08	3	92·09	1–2			
92·55	4	92·54	2	92·53	2	
92·81	8	92·83	3			
93·61	3–4	93·65	2			
94·38	3	94·42	2			
95·60	7	95·64	3	95·61	5	
97·05	2–3	97·09	1–2			
98·50	3–4	98·54	2	98·51	1	
98·99	1					
99·94	9	99·93	3–4	99·92	7	
4101·99	1-2					

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4101·65	<1					
02·25	6–7	4102·32	3	4102·28		
03·54	1–2					
04·52	4	04·55	2	04·52	2	
04·93	3–4	04·92	2			
05·33	7	05·32	3			
06·08	1					
07·60	3	07·64	1–2	07·60	1	
08·32	4	08·36	2			
09·20	2					
09·89	8	09·94	3–4	09·91	7	
10·86	1					
11·22	<1					
12·00	10	11·92	4	11·92	5	
12·50	4	12·47	1–2			
13·62	5	13·65	2–3	13·64	3	
14·69	3	14·69	1–2			
15·33	9	15·32	3–4	15·31	7	
16·64	8	16·64	3	16·63	9	
		16·85	1·2			
18·34	4–5	18·34	2·3	18·32	1	
18·76	4–5	18·73	2			
19·23	1					
19·56	4–5	19·58	2	19·57	3	
20·65	4–5	20·69	2	20·65	2	
21·08	2	21·13	1			
21·75	2–3					
22·45	1					
22·94	<1					
23·30	3					
23·59	7	23·65	3			
24·15	3–4	24·23	2	24·20	1	
27·15	1					
27·56	<1					
28·20	9	28·25	3–4	28·15	7	
28·94	4	29·00	2			
30·28	<1					
30·44	1					
31·07	<1					
31·26	1	31·32	1	31·30	1	
32·08	9	32·13	3–4	32·13	6	
32·93	1					
33·86	3	33·92	2			
34·61	9	34·61	3–4	34·62	7	
35·40	1					
36·27	3	36·25	2			
36·55	2–3	36·52				
37·06	1					
37·36	<1					
38·17	2					
39·34	3–4	39·39	2			
41·50	3					

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4141·91	1–2	4141·96	1–2			
42·80	1–2	42·75	1–2			
43·02	1	43·02	1			
43·47	<1					
45·62	2					
46·15	<1					
47·90	2					
49·01	2–3	49·02	1–2			
50·22	<1					
50·80	2–3	50·84	2			
51·46	<1	51·52	1			
52·80	2–3	52·81	2			
53·47	2–3	53·49	1–2			
54·16	<1					
55·34	<1	55·39	1			
55·95	1	56·00	1–2			
56·65	<1					
58·11	1	58·14	1			
58·58	<1					
59·82	5	59·84	2–3	4159·82	2	
60·48	1	60·57	1			
62·48	<1	62·51	1			
66·86	1–2					
67·15	1					
69·08	<1					
69·37	2–3	69·40	1–2			
71·42	3–4	71·45	2			
74·13	4	74·18	2	74·16	1	
75·24	1	75·30	1			
76·85	<1	76·83	1			
77·00	<1	77·02	1			
77·19	3	77·25	1			
77·67	1					
78·53	1					
79·54	6	79·53	2–3			
80·12	1					
80·95	1	80·99	1			
82·21	2–3	82·23	1–2			
82·74	5–6	82·74	2–3	82·73	1	
				83·07	4	
83·45	1	83·43	1			
83·60	2–3	83·59	1			
84·55	<1					
86·91	1	86·95	1			
87·74	1	87·82	1			
89·95	5–6	89·99	2–3	90·01	2	
91·69	5–6	91·70	2–3			
94·13	1–2	94·17	1			
95·73	2–3					
97·43	1	97·45	1			
97·74	3–4	97·77	2			
98·74	3–4	98·78	2			

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4199·75	<1					
99·97	1					
4200·30	3	4200·35	2			
01·05	1–2					
02·50	2–3	02·52	1	4202·51	2	
04·34	<1					
04·67	<1	04·67	1			
05·28	2–3	05·23	1	05·20	2	
06·73	1					
10·00	4–5	09·98	2–3	10·00	5	
		10·55	1	..	..	Probably masked in Kensington photograph by a strong broad line of Ag at λ 4212·1
		11·02	1	..	..	
16·50	1	16·52	1			
18·89	3–4	18·86	2			
19·66	1–2	19·65	1–2			
21·22	1	21·17	1			
22·54	1–2	22·49	1			
23·15	1					
24·36	3–4	24·30	2			
25·41	1–2	25·40	1	25·37	1	
		26·78	2	..	..	Probably masked by Ca line at λ 4226·91.
				26·87	4	Ca.
27·92	3–4	27·90	2			
29·92	3–4	29·87	2			
32·68	5–6	32·62	3	32·60	7	
33·09	5–6	33·09	3	33·11	7	
34·18	5–6	34·12	3	34·15	7	
34·71	4	34·70	2–3	34·67	7	
35·92	4–5	35·90	2–3	35·91	4	
36·78	<1					
39·15	2	39·12	1–2			
39·80	<1					
40·29	2–3	40·25	2			
40·54	3	40·53	2			
41·52	3	41·48	2			
46·91	1					
47·43	1	47·46	1			
51·42	<1	51·45	1			
53·00	1–2	53·02	1·2			
55·59	<1	55·60	1·2			
57·50	4	57·53	2	57·52	4	
59·47	4	59·46	2	59·45	4	
60·00	1					
60·28	1					
60·46	1					
61·32	2–3	61·37	2			
62·30	4	62·32	2	62·31	4	
65·25	3	65·28	2			
66·07	2					

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4267·48	2	4267·50	1–2			
68·78	6	68·78	3	4268·79	0*	* ? (10)
69·89	3–4	69·92	2			
70·51	3–4	70·49	2			
71·75	6	71·71	3	71·71	17*	* ? (7)
72·93	<1					
73·50	<1					
76·50	<1					
77·10	5–6	77·12	3	77·10	7	
78·53	<1					
79·12	2	79·12	1–2			
83·08	3–4	83·06	2			
84·19	6	84·19	3	84·21	5	
86·57	3–4	86·57	2			
87·93	3–4	87·97	2			
89·00	1					
91·45	3	91·46	2			
91·96	5–6	91·97	3	91·98	1	
96·30	5	96·28	2–3	96·27	7	
97·29	1					
97·85	4–5	97·86	2–3	97·84	7	
98·17	4–5	98·17	2–3			
98·79	<1					
99·27	1–2			99·24	1	
4302·32	1–2					
03·70	2–3	4303·70	2	4303·70	2	
05·64						
06·40	5	06·35	2–3			
06·76	<1					
07·32	5	07·33	2–3			
08·61	<1					
09·75	2	09·69	1–2			
09·95	5	09·95	3	09·95	7	
11·66	1					
11·83	1					
12·58	1	12·56	1			
14·11	2–3	14·06	1–2			
15·02	2					
15·95	<1	16·02	1			
18·04	<1					
				18·80	2	Ca.
20·15	<1					
20·49	1–2	20·46	1			
22·53	1–2	22·51	1			
29·90	<1					
30·18	6	30·18	3	30·18	0*	* ? (10).
31·28	1					
32·60	2	32·56	1–2			
32·96	6	32·98	3	32·98	10	
34·25	3	34·23	1–2			
35·06	<1					
35·69	<1					

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4336·33	2–3	4336·29	1–2			
39·31	<1					
41·19	7	41·15	3	4341·16	10	
42·39	2–3	42·36	1–2			
43·02	3–4	43·00	2			
45·39	<1					
47·02	<1					
47·64	1					
50·86	1					
50·97	2–3					
52·68	2					
53·02	7	53·02	4	53·04	18*	* ? (8).
53·54	2					
55·14	3–4	55·09	2	55·14	4	
56·14	4–5	56·10	2–3	56·10	4	
56·98	2					
57·64	2	57·60	1–2			
57·86	1	57·82	1			
60·77	2–3	60·75	1–2			
61·24	1–2	61·18	1			
61·58	2–3	61·57	1–2			
63·54	<1	63·48	1			
63·75	3–4	63·69	2	63·69	4	
64·40	3–4	64·37	2	64·38	4	
65·94	2–3	65·92	1–2			
66·76	<1					
67·26	1	67·24	1			
68·23	5	68·25	2			
68·78	3–4	68·76	1–2	68·76	4	
69·24	2	69·25	1			
71·98	<1					
73·40	4	73·40	2	73·38	6	
74·01	3–4	73·99	2	73·98	3	
74·38	<1					
75·28	1–2					
75·51	3–4	75·47	2			
76·25	1–2	76·25	1			
77·05	<1					
77·33	<1					
78·13	2–3	78·06	2			
79·44	10	79·38	4–5	79·39	1*	* ? (10). Strongest line in the whole spectrum.
80·75	4	80·69	2	80·72	4	
81·21	2			81·19	1	
81·43	1					
81·93	1					
83·39	<1					
84·13	1	84·07	1			
84·42	2	84·37	1			
84·92	9	84·87	4–5	84·87	1*	* ? (10). Very strong line.
85·53	2					
87·42	2–3	87·40	1–2			
88·32	1					

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5	λ.	Int. Max. =15.	
4390·13	9	4390·13	4–5	4390·14	7	
90·80	2	90·79	1			
91·88	2	91·84	1–2			
92·28	4	92·24	2	92·23	4	
93·28	3	93·26	2	93·26	3	
94·03	3	94·01	2	94·00	4	
95·05	2–3	94·98	1–2			
95·42	8	95·40	4–5	95·38	10	
95·77	1–2					
96·61	<1					
96·93	<1					
				97·39	1	
97·56	<1					
98·09	<1					
99 63	2					
4400·74	8	4400·74	4	4400·74	10	
01·34	1					
01·91	1					
02·79	1					
03·87	3–4	03·86	1–2	03·83	4	
05·20	3–4	05·20	2–3			
06·33	3–4			06·28	8	
06·80	7	06·80	4–5	06·80	8	
07·83	7	07·85	4–5	07·80	8	
08·35	5	08·36	4	08·37	5	
08·67	6	08·67	4–5	08·66	5	
12·33	4–5	12·30	2	12·30	4	
13·60	<1					
13·90	2					
14·74	2	..	..	..	..	Not due to Fe.
15·25	3					
16·71	6	16·63	3	16·63	5	
17·83	<1					
18·88	<1					
20·14	4–5	20·08	2–3			
21·77	6	21·73	3	21·74	10	
22·42	2	22·40	1·2			
22·71	1–2					
23·40	4	23·32	1–2	23·37	8	
		23·41	1–2			
24·11	2	24 10	1–2	24·08	2	
24·77	3	24·74	1–2	24·74	4	
				25·59	1	Ca.
25·95	3	25·86	2			
26·22	5	26·17	3			
27·49	4					
28·72	5-6	28·68	3	28·68	5	
30·02	5	29·95	3			
30·71	2-3	30·68	2			
31·36	<1					
31·91	<1					
32·28	<1					

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4433·09	2					
34·80	4	4434·80	2			
35·60	1					
36·33	6	36·31	3–4	4436·31	7	
38·02	7	38·02	3–4	38·00	7	
39·19	2					
41·90	7	41·88	3–4	41·85	2	
43·56	4	43·52	2	43·51	4	
44·39	6–7	44·40	3–4	44·38	3	
46·04	1					
49·78	3–4	49·77	2–3	49·74	4	
51·13	3–4	51·09	2	51·07	4	
52·19	7	52·19	4	52·18	8	
52·91	2–3	52·91	2			
53·30	1–2					
54·34	1					
				54·94	1	Ca.
				56·07	1	Ca.
56·68	2–3	56·68	2	56·67	3	
57·67	5	57·65	3–4	57·63	3	
58·00	4	57·97	2–3			
58·57	2					
				58·91	1	
59·96	6–7	59·93	4	59·92	8	
60·52	7	60·46	4–5	60·46	10	
				60·85	4	
61·18	3–4					
62·52	6	62·56	3–4	62·53	10	
64·46	2 3					
64·95	2–3					
65·69	2–3			65·67	3	
67·09	2–3	67·04	2			
67·87	<1					
68·23	4–5	68·19	2–3	68·17	3	
68·95	3–4	68·94	2	68·93	3	
69·87	6	69·88	3–4	69·87	7	
				70·87	1	
71·51	<1					
71·96	<1					
73·45	<1					
74·22	5	74·21	3	74·21	7	
74·91	5–6	74·89	3–4	74·90	7	
		76·06	2			Probably masked by strong Ag line at λ 4476·29.
77·48	<1					
80·21	4	80·20	2-3	80·21	3	
84·24	1					
86·39	<1	86·44	1			
89·08	7	89·06	3–4	89·10	7	
90·99	4–5	90·95	2–3	90·98	4	
91·36	2	91·35	1–2	91·34	2	
91·65	1	91·66	1	91·65	1	

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4495·17	1	4495·16	1–2			
96·24	5	96·26	3	4496·23	5	
97·00	4	97·03	2			
97·55	3	97·57	2	97·57	5	
4501·00	1–2	4501·01	2	4501·00	2	
01·45	1			01·41	1	
02·12	5–6	02·12	3	02·12	4	
06·30	2–3	06·30	2			
06·40	1	06·41	1–2			
06·73	1–2	06·77	2	06·74	1	
08·10	<1	08·11	1			
09·46	2–3	09·49	2	09·46	2	
11·63	2–3	11·64	2	11·60	2	
13·83	2–3	13·79	2	13·79	2	
14·36	4	14·36	2-3	14·36	4	
15·73	2	15·74	1–2	15·73	1	
17·75	3	17·77	2	17·74	3	
20·35	2–3	20·31	2	20·33	2	
20·71	2	20·67	1–2	20·69	2	
24·39	5–6	24·38	3	24·38	5	
25·33	3–4	25·31	2	25·34	2	
28·19	3–4	28·16	2–3	28·17	3	
28·64	2	28·66	2			
29·50	2–3	29·47	2	29·48	2	
29·78	5	29·76	2–3			
30·98	3	30·97	2	30·97	3	
34·08	3			34·11	3	
37·83	3–4	37·84	2	37·83	4	
40·18	3–4	40·18	2	40·18	4	
41·60	1	41·57	1			
45·56	7	45·57	3–4	45·57	10	
49·79	6	49·81	3	49·82	8	
52·03	3	52·05	2	52·02	2	
				*52·73	5	* ? 53·27.
53·25	5–6	53·25	2–3			
55·59	<1					
60·89	7	60·90	3	60·89	7	
64·79	1	64·76	1	64·76	1	
70·62	3–4	70·60	2			
71·97	6	71·96	3	71·96	5	
77·33	8	77·36	4	77·35	7	
78·89	5–6	78·92	3	78·91	5	
79·38	3–4	79·38	2–3	79·37	2	
80·57	8	80·57	4	80·56	8	
81·40	1			81·41	1	
83·96	3	83·96	2	83·97	2	
86·20	1	86·15	1–2			
86·51	9	86·54	4–5	86·55	8	
88·97	1	88·94	1			
91·41	5–6	91·39	2–3	91·41	5	
94·27	10	94·27	4–5	94·22	10	
4600·41	1	4600·34	1–2			

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ	Int. Max. =15.	
4603·15	1					
06·33	5	4606·33	2–3	4606·32	4	
07·42	1	07·40	1–2	07·39	1	
				08·63	1	
09·84	2–3	09·84	2	09·82	4	
11·11	1–2	11·10	1–2	11·10	1	
11·95	2	11·92	2			
				13·98	1	
14·10	<1	14·08	1	14·09	1	
16·20	<1	16·18	1	16·19	11*	*? (1).
17·00	<1	17·03	1			
18·00	<1	18·00	1			
19·00	1					
19·92	7–8	19·85	2	19·90	0*	*? (10).
		19·97	2–3			
21·42	1	21·43	1	21·43	1	
24·61	5	24·62	2	24·58	4	
26·66	4–5	26·67	2	26·67	4	
30·25	<1	30·24	1	30·24	1	
35·38	6	35·35	2–3	35·35	7	
36·36	1	36·34	1–2	36·34	1	
40·27	4	40·25	2	40·23	5	
40·92	4	40·92	2	40·92	5	
44·24	<1			44·24	1	
44·66	2	44·64	2	44·62	2	
46·20	<1	46·17	1	46·16	1	
46·52	6	46·59	2–3	46·57	8	
48·08	1	48·08	1	48·05	1	
49·07	2	49·08	1–2	49·07	2	
53·13	1	53·15	1	53·11	1	
54·80	1	54·84	1–2			
55·50	<1	55·47	1	55·41	1	
57·17	1	57·17	1	57·14	1	
61·00	<1	61·01	1			
62·00	<1	62·02	1			
62·60	1			62·61	1	
				63·31	3	
66·34	2–3	66·33	2			
69·50	<1	69·50	1	69·49	1	
70·66	6–7	70·66	4	70·67	8	
72·48	1	72·48	1			
73·83	1	73·83	1	73·84	1	
79·68	1	79·65	1			
80·03	1–2	79·95	1–2	79·96	1	
81·12	1–2	81·07	1–2	81·07	1	
		82·09	1			
82·93	1					
84·57	2	84·64	2	84·63	3	
87·11	3–4	87·10	2–3	87·10	5	
88·24	<1	88·24	1			
90·45	1–2	90·45	1	90·44	1	
		99·52	2	99·50	2	

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4702·70	1			4702·69	1	
05·23	2–3	4705·26	2	05·28	3	
06·38	4	06·34	2–3	06·36	5	
06·76	5	06·75	2–3	06·76	5	
07·64	2–3	07·62	2	07·63	3	
				08·40	1	
				09·13	1	
09·93	2–3					
10·75	5	10·74	2–3	10·75	5	
13·65	1	13·61	1–2	13·64	1	
14·29	4–5	14·28	2–3			
15·50	<1			15·49	1	
15·62	2	15·61	1–2	15·65	1	
16·11	3	16·08	2	16·08	4	
16·39	1–2	16·36	1–2	16·38	1	
17·89	4–5	17·85	2–3	17·87	5	
21·40	<1	21·42	1–2	21·44	1	
21·71	3–4	21·70	2–3	21·70	4	
23·06	4	23·06	2–3	23·06	4	
23·65	<1	23·65	1	23·63	1	
24·07	<1			24·07	1	
28·85	<1	28·85	1	28·84	1	
29·77	3–4	29·73	2	29·72	5	
30·58	2–3	30·57	2	30·57	2	
31·40	1	31·42	1–2	31·44	1	
31·80	1	31·74	1–2	31·74	1	
32·17	1	32·12	1–2	32·11	1	
37·90	1–2	37·91	1	37·92	1	
38·60	<1	38·51	1–2	38·50	1	
39·80	1	39·79	1	39·85	1	
42·86	3	42·79	2	42·82	5	
46·87	3	46·81	2	46·83	5	
47·30	<1	47·30	1–2	47·31	1	
48·70	3–4	48·70	2	48·72	5	
51·18	3–4	51·16	2	51·21	5	
51·45	1	51·45	1	51·46	1	
51·79	3	51·75	2	51·76	5	
52·05	1			52·04	1	
54·13	3–4	54·13	2–3			
57·62	5–6	57·55 57·68	2 2–3	57·69	4	
58·95	<1	58·92	1–2	58·94	1	
59·20	<1			59·21	1	
64·22	1			64·22	1	
65·91	<1	65·84	1–2	65·86	1	
66·82	5	66·80	2–3	66·84	7	
				69·21	1	
72·76	1	72·74	1	72·78	1	
73·29	1	73·25	1–2	73·26	1	
76·63	6	76·54 76·70	2 3	76·64	5	
				81·51	1	

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4-5.	λ.	Int. Max. =15.	
4784·72	2–3	4784·65	2	4784·66	5	
86·71	5–6	86·70	3	86·71	7	
				89·10	1	
93·15	1–2	93·10	2	93·13	2	
				94·73	1	
95·35	1	95·27	2	95·29	2	
97·08	5–6	97·07	3	97·12	8	
98·19	<1	98·12	1–2	98·15	1	
99·20	1	99·20	1	99·21	1	
99·98	2–3	99·94	2	99·97	4	
				4802·37	1	
4803·24	<1			03·24	1	
07·73	5–6	4807·70	3-4	07·74	10	
08·84	1			08·84	1	
19·23	1	19·22	1–2	19·22	2	
				23·03	1	
27·63	6	27·62	3-4	27·64	10	
29·00	1	29·00	1–2	29·01	1	
				29·43	1	
30·90	1	30·86	1–2	30·88	1	
31·85	6	31·80	3–4	31·84	8	
32·61	6	32·59	3	32·62	8	
33·24	1-2	33·17	2	33·21	3	
34·00	1			34·01	1	
				34·26	1	
				35·04	1	
43·20	<1	43·16	1–2	43 19	2	
46·80	<1			46·80	1	
49·05	1	48·98	1–2	49·00	1	
				49·26	1	
				49·46	1	
51·69	7	51·65	4	51·69	10	
				52·15	1	
				54·11	1	
				55·55	1	
57·20	<1			57·24	1	
58·80	<1			58·81	2	
59·38	<1	59·34	2			
62·83	2	62·83	2	62·80	4	
64·92	7	64·93	4	64·94	10	
				70·33	1	
71·50	2	71·46	2	71·45	3	
				73·17	1	
75·71	7	75·66	4	75·67	10	
80·82	3	80·77	2-3	80·75	6	
81·75	7-8	81·75	4	81·75	10	
82 36	<1			82 36	2	
85·89	1	85·86	2	85·83	2	
87·03	1	87·02	2	86·99	2	
90·30	1–2	90·32	1–2	90·26	1	
91·40	1	91·43	1–2	91·41	2	
91·74	1	91·81	2	91·77	3	

Vanadium Arc Lines—continued.

Kensington.		Hasselberg.		Rowland.		Remarks.
λ.	Int. Max. =10.	λ.	Int. Max. =4–5.	λ.	Int. Max. =15.	
4894·42	1	4894·43	2	4894·40	3	
4900·82	2–3	4900·84	2–3	4900·82	3	
04·60	3–4	04·59	3	04·57	5	
05·05	1	05·10	1–2	05·05	3	
06·05	<1	06·06	1			
				07·05	1	
08·90	1	08·92	1	08·88	1	
				13·28	1	
16·46	1	16·48	1–2	16·44	1	
				19·17	1	
22·60	1	22·60	1–2	22·54	1	
25·87	3–4	25·83	2–3	25·84	7	
32·23	2	32·24	2	32·21	3	

Reference to the foregoing table will show that the Kensington list and Hasselberg's contain many lines in common which are missing from Rowland's. This is probably due to the fact that the latter used carbon poles, which furnish so many lines themselves that it is extremely difficult to pick up all the lines really due to the substance volatilised on them. As an instance of this, in the region between λ 4130 and λ 4216, throughout which the structure lines in the carbon fluting which commences at the latter wave-length are most crowded, Rowland records only eleven lines, whereas in the corresponding region Hasselberg gives forty-nine, and the Kensington photograph shows seventy-five.

Taking Hasselberg's list as a basis we find that the few lines given below occur only in his list.

Lines given by Hasselberg only.

Hasselberg.		Remarks.
λ.	Int. Max. 4–5.	
3902·71	1	
4116·85	1–2	
4210·55	1	Probably masked in the Kensington photograph by a broad line of Ag at λ 4212·1.
4211·02	1	
4226·78	2	Probably masked by line of Ca at λ 4226·91.
4476·06	2	,, ,, ,, Ag at λ 4476·29.
4682·09	1	

Four of these may be present in the Kensington photograph, being probably hidden by lines of Ag and Ca. With regard to the others, reference to unpublished lists of lines in the arc spectra of many other elements suggests no origin which can be assigned to them.

In addition to these lines, Hasselberg has apparently observed as double the following lines recorded as single in the other two lists.

Lines recorded as Double by Hasselberg.

Hasselberg.		Kensington.		Rowland.		Remarks.
λ.	Int. Max. 4–5	λ.	Int. Max. 10.	λ.	Int. Max. 15.	
3931·40	1	3931·46	5			
3931·50	2					
4423·32	1–2	4423·40	4	4423·37	8	
4423·41	1–2					
4619·85	2	4619·92	7–8	4619·90	0*	* ? (10).
4619·97	2–3					
4757·55	2	4757·62	5–6	4757·69	4	
4757·68	2–3					
4776·54	2	4776·63	6	4776·64	5	
4776·70	3					

In considering Rowland's list in relation to the two others, it is found that the following lines are recorded by him only. Some of

Lines given by Rowland only.

Rowland.		Remarks.	Rowland.		Remarks.	Rowland.		Remarks.
λ.	Int. Max. 15.		λ.	Int. Max. 15.		λ.	Int. Max. 15.	
3919·60	1		4456·07	1	Ca.	4823·03	1	
3933·77	3	Ca(K).	4458·91	1		4829·43	1	
3944·13	3	Al.	4460·85	4		4834·26	1	
3961·65	5	Al.	4470·87	1		4835·04	1	
3968·59	1	Ca(H).	4552·73*	5		4849·26	1	
4033·19	3	Mn.	4608·63	1		4849·46	1	
4034·62	2	Mn.	4613·98	1		4852·15	1	
4057·96	1	Pb.	4663·31	3		4854·11	1	
4077·85	1	Sr.	4708·40	1		4855·55	1	
4183·07	4		4709·13	1		4870·33	1	
4226·87	4	Ca.	4769·21	1		4873·17	1	
4318·80	2	Ca.	4781·51	1		4907·05	1	
4397·39	1		4789·10	1		4913·28	1	
4425·59	1	Ca.	4794·73	1		4919·17	1	
4454·94	1	Ca.	4802·37	1				

* Possibly misprint for 4553·27. If so, should not appear in this list.

them are obviously due to other metals existing as impurities either in the poles or in the compound of vanadium which was used, and although several of these lines occur in the Kensington photograph, they have been discarded. Attempts to trace the remaining lines to other origins have been unsuccessful.

With reference to the lines which are absent from Rowland's list, but which appear in the other two, it seems certain that many genuine and strong lines of vanadium have either not been identified by him, or have for some reason been discarded from his list. In this connection, it may be stated that many of the lines recorded by Rowland in his "Table of Solar Wave-lengths" as being due to vanadium, do not appear in his list of vanadium arc lines, though nearly all of them occur as strong lines in both Hasselberg's and the Kensington records. A list of these is given on the next page. Those marked with a † are taken from a list of corrections which he has given* to his "Tables of Solar Wave-lengths." The remainder are taken from his original tables.

Included in this list are seven lines possibly identical with lines in Rowland's arc spectrum, though the difference in his two recorded wave-lengths of the possibly corresponding arc and solar lines varies from ten to nineteen hundredths of a tenth-metre, a difference which is greatly in excess of what he claims to be his limiting error in the estimation of wave-lengths.

In the Kensington list there are 194 lines which do not appear in either Hasselberg's or Rowland's. It will serve no useful purpose to enumerate these in a special table, as they can be easily referred to in the general comparison table given in an earlier part of the paper. An analysis of their intensities shows that seventy-seven are very weak lines, of intensity designated < 1, fifty-three of intensity 1, thirty-nine of intensity 2, twenty of intensity 3, three of intensity 4, and two of intensity 5, the maximum intensity adopted being 10.

No other probable origin has been found for any of them, although the vanadium spectrum has been compared directly with the arc spectra of the following elements:—Ag, Au, Ba, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Di, Fe, Hg, In, Ir, K, La, Li, Mg, Mn, Mo, Na, Ni, Os, Pb, Pd, Rb, Rh, Ru, Sc, Sn, Sr, Ta, Te, Th, Ti, Tl, U, W, Yt, Zn, Zr.

As these lines appear in the spectrum when either the oxide or chloride of vanadium is used, there seems to be no reason to doubt that they are really due to vanadium.

Several of them are evidently present in Hasselberg's photograph, as in his comparison of certain vanadium lines with lines of equal or nearly equal wave-length belonging to other metals he records the following, but has left them out of his comprehensive list of vanadium lines, presumably as being due to other metals which exist as impurities in his vanadium.

* 'Ast.-Phys. Jour.,' vol. 6, p. 384, 1897.

Lines previously recorded as V by Rowland in his "Table of Solar Wave-lengths," which are not included in his Vanadium Arc Lines.

Solar—V lines (Rowland) λ.	Vanadium arc lines.				Remarks.
	Hasselberg.		Kensington.		
	λ.	Int. Max. 4–5.	λ.	Int. Max. 10.	
3893·03	3893·03	3	3892·95	6–7	
94·17†	94·19	2	94·16	4–5	
3903·40†	3903·42	1–2	3903·32	3–4	
04·31†					
10·98	10·95	2	10·92	4	
12·34	12·36	2–3	12·35	5	
34·11†	34·16	3–4	34·18	5–6	
41·32†	41·40	1–2	41·40	3	
42·16†	42·16	2	42·18	4	
43·72†	43·77	2–3	43·81	5	
48·82†			48·79	3	
73·80†	73·79	2	73·79	3–4	
75·51†			75·48	1–2	
4036·92†	4036·93	1	4036·93	2	
51·20	51·11	2–3	51·10	5	
69·76†					
72·30†	72·30	2	72·28	2–3	
83·09†			83·07	3–4	
92·82	92·83	3	92·81	8	
4104·62	4104·55	2	4104·52	4	Possibly Rowland's V arc line at λ 4104·52
04·91	04·92	2	04·93	3–4	
05·32	05·32	3	05·33	7	
23·66	23·65	3	23·59	7	
28·25	28·25	3–4	28·20	9	Ditto at λ 4128·15.
79·54	79·53	2–3	79·54	6	
4232·76	4232·62	3	4232·68	5–6	Ditto at λ 4232·60.
33·09	33·09	3	33·09	5–6	Ditto at λ 4233·01.
92·14	91·97	3	91·96	5–6	Ditto at λ 4291·98.
4375·10					
4420·10	4420·08	2–3	4420·14	4–5	
29·96	29·95	3	30·02	5	
44·57	44·40	3–4	44·39	6–7	Ditto at λ 4444·38.
57·94	57·97	2–3	58·00	4	
88·93	89·06	3–4	89·08	7	Ditto at λ 4489·10.

Hasselberg.		Kensington.		Hasselberg's imputed origin.	Remarks.
λ.	Int.	λ.	Int.		
3975·51	1	3975·48	1-2	Ba, Co	There is no evidence that the lines in the Kensington photograph are due to any of these metals.
4013·67	1	4013·69	<1	Ti	
4020·69	1	4020·73	1	Fe	
4123·35	2	4123·30	3	Ti, Mn	
4315·00	1-2	4315·02	2	Ti	
4618·96	1	4619·10	1	Fe	

The following lines occur in the photograph, but have been left out of the Kensington record as they are considered to be undoubtedly due to other metals.

Lines of other Metals which occur in the Kensington Vanadium Spectrum.

λ.	Int. in V.	Origin.	λ.	Int. in V.	Origin.
3933·83	5	Ca	4215·66	<1	Sr
44·16	1-2	Al	26·91	6	Ca
61·68	2	Al	50·93	<1	Fe
68·63	5	Ca	54·49	2	Cr
81·87	4-5	Ag	74·91	2	Cr
95·46	2-3	Co	89·87	1	Cr
4030·92	3-4	Mn	4302·68	<1	Ca
33·22	3	Mn	07·96	1	Fe
34·64	2-3	Mn	11·21	1-2	Ag
45·90	2	Fe	25·92	1-2	Fe
55·44	10	Ag	83·70	2	Fe
57·97	3	Pb	4404·70	<1	Fe
63·63	1-2	Fe	76·29	6	Ag
4121·48	2-3	Co	4668·70	7	Ag
4212·10	10	Ag			

All these lines are the very strongest in the spectra to which they respectively belong, and although in the vanadium spectrum there are other lines apparently identical in position with some of the weaker lines of Fe, Mn, Co, and Cr, a comparison of their relative intensities in the two spectra shows that they cannot reasonably be ascribed to the presence of such metals as impurities in the vanadium, but must be accepted as genuine lines of both metals, so far as the dispersion employed enables us to form an opinion. These are given in order of wave-length in the following table:—

Coincidences of Vanadium Lines with Lines of other Metals.

λ (Kensington).	Origin of coincident line.	Int. in V.	Int. of coincident line.	λ (Kensington).	Origin of coincident line.	Int. in V.	Int. of coincident line.
3894·16	Cr	4–5	4	4427·49	Fe	4	7
3913·71	Fe	1	2–3	67·09	Co	2–3	4
77·88	Fe	2	4–5	97·00	Cr	4	5–6
4052·60	Mn	1	4	4514·36	Fe	4	<1
68·16	Fe | Mn	2–3	3 | 5	17·75	Fe	3	1
70·94	Fe	2–3	2–3	25·33	Fe	3–4	4
83·07	Mn	3–4	7	34·08	Co	3	4
90·05	Mn	1	4	49·79	Co	6	5
90·74	Mn	8	1–2	4603·15	Fe	1	5
4224·36	Fe	3–4	3	26·66	Mn	4–5	5
34·18	Co	5–6	1–2	54·80	Fe	1	4
4408·35	Mn	5	4	4709·93	Mn	2–3	7
15·25	Fe	3	10	4871·50	Fe	2	6

"A Preliminary Account of the Development of the Free-swimming Nauplius of *Leptodora hyalina* (Lillj.)." By Ernest Warren, D.Sc., Assistant Professor of Zoology, University College, London. Communicated by Professor Weldon, F.R.S. Received February 4,—Read February 28, 1901.

Leptodora appears to be a primitive daphnid in retaining a long, markedly segmented abdomen, and for this reason it seemed likely that an investigation on the development of the winter-generation might throw some light on the vexed questions in Crustacean development. It was more particularly desired to ascertain whether any vestige of a cœlom occurred, and that if so, whether any remnant of it persists in the adult. With this object in view, it was necessary to inquire into the origin of the genital cells and of the antennary and maxillary glands.

In April, 1898, Professor Hickson obtained a few nauplii from Lake Bassenthwaite, Cumberland, and later in the year a large number of adults. This material was most generously placed at my disposal by Professor Weldon, and I wish to express to him my sincere thanks.

The material was insufficient for my purpose; and in the following spring I visited Lake Bassenthwaite to try to obtain fresh material, but I met with very little success. Last spring, however, sufficient material was obtained to continue the investigation.* The preserving reagent employed was Flemming's solution (strong formula).

* I am indebted to the Royal Society for a Government Grant in connection with obtaining this material.