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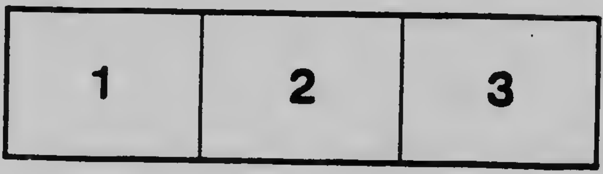
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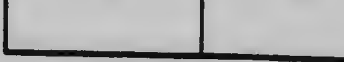
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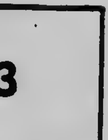

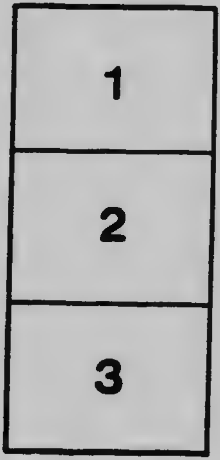

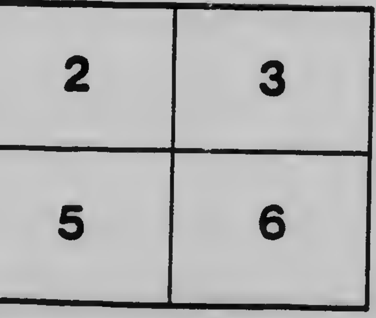

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PAPERS FROM THE
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No. 61: NEW LINES IN THE EXTREME ULTRA-VIOLET OF CERTAIN METALS, BY D. S. AINSLIE and D. S. FULLER

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New Lines in the Extreme Ultra-Violet of Certain Metals.

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University of Toronto.

Presented by PROFESSOR E. F. BURTON, Ph.D., F.R.S.C.

(Read May Meeting, 1918.)

The experiments described below form an extension of the recent work of Lyman,[1] Handke,[2] Wolff,[3] and Saunders[4], on the extreme ultra-violet region.

By using a fluorite vacuum spectroscope and a vacuum arc lamp, photographs of spectral lines were obtained free from the disturbance due to the absorption of the light by glass, quartz or air. The arc could be manipulated from the outside of the case of the spectrograph; the current ranged from four to fifteen amperes, according to the metal used.

For the hard metals with high melting points the terminals of the arc were made of the metal; when a soft metal was used, the terminals were made of iron and were hollowed out in a cup-shaped cavity in which the metal sample was placed.

The whole apparatus was connected up by a lead pipe to a set of trimount oil pumps in series, so that it could be quickly evacuated. The vacuum was tested by having a discharge tube sealed in by a side connection. The vacuum used when photographs were being taken was that which gives a dark, green discharge.

A hydrogen discharge tube fitted with a fluorite window was arranged in the apparatus, so that on one and the same plate there could be obtained both the hydrogen spectrum and the spectrum of any given metal in the same region. By adjusting the cover slit, a photograph of the gas spectrum could be obtained on the bottom of the plate, and then, without moving the plate, the cover slit could be adjusted, the discharge tube could be replaced by the vacuum arc lamp, and thus the spectrum of the metal could be thrown on the same plate just above the hydrogen spectrum. This afforded a means of comparing each metal spectrum with that of the gas.

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[1] Lyman: Spectroscopy of the Extreme Ultraviolet (Longmans).
[2] Handke: Inaug. Diss. Berlin., Aug. 1909.
[3] Wolff: Ann. de. Phys. 42 p. 825, 1913.
[4] Saunders: Astro phys. Jour. 43, p. 234, 1916.

It is important to notice that in obtaining the spectra of metals, the secondary gas spectrum is always present. Thus, by having the gas spectrum immediately above, and on the same plate, the lines due to the gas that might otherwise be attributed to the metal, could be easily picked out. When an intermittent arc, obtained by using a small current, was used, the time of exposure was longer and the secondary spectrum always came up strong, while when a high current was used, the arc remained much more steady and the secondary spectrum was much weaker relatively to that of the metal.

The length of the exposure ranged from 5 to 10 minutes for the metals. The steadier the arc remained, the shorter the time required. When being used, the arc could always be observed through a glass window sealed in the end of the casing of the arc.

The apparatus was connected up to a hydrogen [illegible] that when not in use it could be filled with hydrogen gas. [illegible] hydrogen gas, together with phosphorous pentexide kept the interior free from moisture.

Results.

With the apparatus described above, the vacuum arc spectra of lead, tin, iron, nickel, cobalt, and thallium were investigated; also the spectra of copper, aluminium, zinc, and carbon, which were studied by Ainslie last year, were repeated, and the wave lengths of lines carefully measured again.

In calculating the wave lengths of the lines of these different spectra, certain lines previously determined were used as standards. From these lines, by means of graphical interpolation, the various lines were carefully measured. In working with a prism spectroscope it is necessary to use quite a large number of lines as standards, in order to get accurate result by graphical means. It is impossible to get results with this instrument by referring to a few standard lines, such as Saunders did using a grating spectroscope. For the region from 1850 down, hydrogen and aluminium lines measured by Lyman, and for the region above 1850, carbon monoxide by Lyman, and copper and thallium lines by Eder and Valenta, were used.

Copper.

The copper vacuum arc spectrum was obtained by using a current of about 9 amperes. With this current the arc was almost continuous. The results obtained agree fairly well with those of Eder and Valenta for the region covered by their work and from λ 1750 down they agree with the values of Handke[1] obtained by using a copper spark.

[1] Lyman, Spectroscopy of the Extreme Ultra-Viotet, p. 122.

Intensity	Wave Length	$^1/_\lambda$	E. & V. λ	Handke
4	2370·0	42194	2369·91	
4	2297·0	43529		
4	2267·0	44111		
10	2247·0	44504	2247·08	
4	2231·5	44813		
6	2221·0	45025		
6	2213·0	45209		
8	2195·8	45541	2195·87	
8	2182·2	45825	2181·80	
4	2151·1	46488	{2151·95 2149·05	
6	2137·5	46784	2136·05	
4	2125·8	47041	2125·26	
4	2112·5	47337	2112·19	
4	2104·8	47510	2104·88	
4	2055·4	48652	2055·05	
6	2044·0	48924	2043·84	
6	2037·3	49084	2037·24	
4	2026·2	49353	2025·53	
4	2001·0	49975	....	
4	1979·6	50515	1979·26	{1749·9 1747·1
4	1748·6	57189	....	
4	1739·7	57481	....	{1739·0 1741·0
6	1721·8	58080	....	1721·9
4	1708·5	58531	....	1708·5
2	1704·9	58654	....	1705·0
4	1693·4	59053	....	
1	1692·5	59084	....	1692·3
4	1686·7	59301	....	1686·6
2	1684·6	59361	....	1684·3
1	1681·7	59428	....	{1681·2 1681·9
2	1679 1	59556	....	1679·0
2	1674·6	59680	....	1674·5
2	1671·5	59826	....	1671·6
2	1670·1	59877	....	1669·8
2	1651·9	60536	....	1651·9
8	1642·1	60898	....	1641·8
8	1594·2	62727	....	1594·2
Intensity	..	..	E. & V.	Handke

Aluminium.

The vacuum arc spectrum for aluminium was obtained by using aluminium alone as terminals in the arc lamp. The arc remained steady for short periods but was mostly intermittent. For the intermittent arc the current was about eight amperes when the terminals touched together, but when separated the current quickly dropped to zero, and therefore it was necessary to separate and touch the terminals continually in order to obtain a photograph.

Intensity	λ	1/λ	λ
10	2367·5	42239	2367·2 E & V.
10	2139·5	46740	
7	2061·5	48508	
6	2026·0	49358	
14	1990·0	50251	1989·9 "
4	1935·1	51677	1935·3 "
10	1930·4	51803	1930·4 "
32	1862·7	53685	1862·8 L
32	1854·8	53914	1854·7 "
4	1766·6	56606	{1766·9 H {1766·0 "
10	1762·0	56754	1761·9 L
10	1724·3	57995	1725·0 L
8	1720·7	58116	1721·2 "
4	1718·5	58190	1719·3 "
4	1670·6	59859	1670·6 "
14	1611·7	62046	1611·8 "
12	1605·6	62282	1605·6 "

ZINC.

The vacuum arc spectrum of zinc was obtained by putting zinc in iron terminals in the arc lamp. The current used was 6 amperes which gave a fairly continuous and intense arc. The lines obtained do not agree with the values given by Handke[1] for a zinc spark.

Int.	λ	1/λ	λ
2	2372·5	42149	
2	2336·0	42808	
10	2287·5*	43715	
6	2265·0*	44150	2265·08 E. & V.
2	2205·5	45341	
1	2171·5	46051	
16	2139·5	46739	2139·27 S
2	2104·8	47510	2104·98 "
4	2100·5	47608	2100·53 "
2	2096·5	47698	2097·44 "
6	2087·3	47908	2087·66 "
1	2079·8	48082	2079·57 "
2	2065·0	48426	2064·93 "
6	2062·5	48485	2062·57 "
16	2025·5	49370	2026·19 "
3	1821·8	54890	
10	1589·6	62909	1589·76 W
1	1510·4	66207	
1	1491·5	67047	
6	1486·2	67286	1486·20 W
2	1478·5	67636	
4	1477·6	67923	
4	1457·9	68592	1457·9 W
4	1457·5	68658	1457·56 "
4	1451·1	69913	1450·82 "
3	1445·0	69204	
Int.	..	..	..

S. Saunders, Astrophysical Journal Vol. 43, p. 239, 1916. W. Wolff-Lyman, Spectroscopy of the Extreme Ultra-Violet, p. 123.

[1] These two lines may be due to cadmium but they appear to be zinc.

Carbon.

The carbon vacuum arc spectrum was obtained by using carbon alone as terminals in the vacuum arc lamp. A continuous arc was obtained by using a current of about 10 amperes. In addition to the lines given below a large number of broad and poorly defined bands occur which seem to correspond to those of the carbon monoxide spectrum. Upon measuring some of the more prominent ones, it was found that their wave lengths were different from those of the carbon monoxide spectrum obtained from the discharge tube. This may be due to the fact that the carbon arc is at a very high temperature compared to that of the discharge tube.

The lines of the spectra of copper, aluminium, zinc and carbon were measured last year by Ainslie, using the same apparatus but without the hydrogen comparison spectrum. The measurements were not very accurate and were repeated this year, using standard gas lines for comparison.

The carbon line spectrum is very strong in this region and the lines 1548·5, 1550·7 (1560·5, 1561·2, 1562·0) and 1656·9 correspond apparently to 1548·2, 1550·8, 1561·2 and 1656·8, given by Lyman as lines of certain origin. The line at 1561 appeared as a poorly defined triplet and was found in the spectra of all the metals worked with except zinc.

Line Spectrum of Carbon

Int.	λ	$1/\lambda$	λ
2	2307·5	43337	
9	2298·0	43516	2296·94 E. & V.
2	2219·0	45065	
5	2088·5	47876	
15	1930·5	51827	1930·12 "
9	1758·1	56879	
5	1749·7	57152	
10	1656·9	60354	
9	1562·0	64020	
9	1561·2	64053	
9	1560·5	64082	
2	1550·7	64487	
3	1548·5	64591	
5	1482·8	67439	
6	1464·5	68282	

BAND SPECTRUM OF CARBON

Intensity	λ	Int.	λ
3	2194·5	4	1811·7
4	2142·3	2	1806·8
4	2115·3	4	1793·6
4	2088·0	2	1774·6
3	2067·0	1	1748·0
2	2047·5	5	1729·9
2	2037·0	2	1725·0
1	2030·7	2	1721·3
4	1993·2	4	1712·7
3	1973·3	4	1706·5
2	1953·5	2	1670·6
2	1900·2	3	1653·4
1	1843·1	3	1649·1
1	1827·0	4	1630·7
2	1825·1	4	1597·9
1	1819·8	3	1576·6

IRON

The vacuum arc spectrum of iron was obtained by using iron terminals in the vacuum arc lamp. A current of 15 amperes was used, but even with this high current the arc was intermittent and not very bright, which made it difficult to get a good photograph of the spectrum.

Int.	λ	1/λ	λ
5	2394·5	41762	2394·68 E. & V.
5	2380·2	42013	
4	2360·0	42373	
4	2346·0	42626	2345·48 "
2	2097·5	47666	2097·20 "
4	2078·8	48105	
3	2061·5	48508	
2	1926·0	51921	1925·60 B.
4	1913·8	52252	1913·40 "
3	1894·3	52790	1894·90 "

B. Bloch, Journal de Physique, 5 Série, p. 628, 1914.

TIN.

To obtain the vacuum arc spectrum of tin, some pure tin metal was put in iron terminals in the vacuum arc lamp, the current was 5 amperes, which gave an intense intermittent arc. Lines were found in this spectrum to extend far down in the ultra-violet region.

Int.	λ	1/λ	E. & V. λ	Saunders λ
6	2334·0	42845	2334·87	2335·53
6	2317·8	43144	2217·38	2317·93
3	2287·0	43725	2286·8	2287·28
8	2268·8	44075	2269·02	2269·65
6	2247·0	44504	2246·11	2246·73
6	2211·0	45228	....	2210·38
5	2199·5	45465	{2199·68 {2199·4	2199·93
12	2152·5	46457	2151·62	2152·08
2	2041·2	48990		
1	1941·0	51520		
20	1899·8	52637	1899·8	
6	1831·4	54603		
20	1811·2	55212		1811·29
16	1756·6	56928		
1	1741·3	57428		
20	1699·5	58841		
6	1489·2	67150		
9	1475·2	67787		
4	1438·3	69526		
4	1437·3	69574		
4	1402·4	71303		
4	1400·5	71402		

THALLIUM.

The thallium vacuum arc spectrum was obtained by putting thallium in iron terminals. The current used was about 6 amperes which gave a continuous and intense arc. There is considerable variation in these results from those of Saunders. This may be due to the fact that Saunders used standard aluminium and zinc lines, while in this work the gas lines measured by Lyman were used as standards.

Int.	λ	$^1/_\lambda$	λ Saunders	λ E. & V.
4	2394·7	41759	....	2394·72
4	2379·5	42043	2380·34	2379·68
2	2316·0	43178	....	2316·14
8	2298·5	43506	2298·05	2298·25
2	2238·0	44683	2238·59	
2	2210·7	45235	2210·46	
2	2168·5	46115		
2	2139·5	46740	2139·98	2139·44
14	1907·8	52416	1908·68	
6	1891·8	52860	1892·72	
2	1827·3	54725	1828·00	
6	1814·2	55121	1814·72	
8	1792·2	55797		
6	1660·0	60241		
6	1653·8	60467		
8	1561·8	64029		
16	1559·0	64144		
5	1538·5	64998		
4	1508·2	66304		
6	1499·8	66676		
2	1491·0	67069		
4	1478·0	67659		

Lead.

The lead vacuum arc spectrum was obtained by putting lead in iron terminals in the vacuum arc lamp. The arc was almost continuous and very intense, being sustained by a current of 4 amperes. As it was not possible to obtain chemically pure lead, a sample of ordinary lead was used. Hence some of the lines recorded here may be due to impurities.

Int.	λ	$^1/_\lambda$	λ Saunders
4	2430·5	41144	
5	2403·0	41515	2402·62
7	2394·0	41771	2394·52
5	2246·2	44520	2247·53
12	2204·4	45360	2204·18
8	2170·5	46072	2170·60
8	2060·5	48532	
2	1925·8	51926	
4	1913·7	52255	
2	1904·2	52527	1904·88
2	1898·7	52668	
2	1895·5	52756	
14	1821·7	54894	1822·06
10	1796·5	55664	1796·53
1	1744·2	57333	
2	1741·1	57435	
10	1726·2	57930	
12	1682·5	59435	1682·54
12	1671·6	59823	
3	1597·6	62594	
12	1555·8	64276	
4	1511·7	66150	
1	1494·7	66903	
1	1492·7	66993	
5	1434·0	69735	
5	1431·9	69837	

Nickel.

The vacuum arc spectrum of nickel was obtained in a similar manner to that of iron. Nickel alone was put in the terminals of the vacuum arc lamp. The current used was 7 amperes, when the curcuit was closed. This gave a strong intermittent arc. A large number of sharp and well-defined lines appear in the nickel spectrum in this region.

Int.	λ	1/λ	λ E.&V.
4	2394·0	41771	2394·68
4	2375·0	42105	2375 51
2	2366·5	42257	2366·62
2	2356·5	42436	2356·49
6	2345·5	42636	2345·48
6	2335·0	42827	2334·68
12	2315·5	43187	2316·12
12	2303·5	43412	2303·10
12	2297·5	43526	2297·60
7	2288·0	43706	2287·74
8	2278·8	43884	2278·65
6	2271·0	44033	2270·33
6	2264·5	44160	2264·57
8	2255·0	44346	2253·94
8	2226·4	44916	2226·41
8	2218·3	45080	2206·81 }
4	2208·2	45286	2206·72 }
4	2203·3	45386	2201·51
3	2195·2	45554	
6	2187·5	45714	.....
8	2177·7	45920	.....
9	2168·5	46115	2169·19
2	2161·0	46275	2161·31
5	2129·3	46964	2128·67
6	2114·3	47297	2113·61
6	2108·3	47432	2108·04
1	2097·7	47671	2097·2
2	2030·0	49261	
4	2021·0	49480	
1	2005·0	49875	
6	1991·0	50226	
2	1982·0	50454	
4	1964·8	50895	
2	1902·3	52568	
4	1859·2	53786	
6	1854·5	53923	
5	1849·7	54063	
6	1846·7	54151	

Int.	λ	1/λ	λ E.&.V.
6	1829·4	54663	
4	1822·5	54870	
4	1818·7	54984	
1	1806·7	55350	
4	1794·3	55732	
4	1790·5	55850	
4	1787·5	55944	
2	1781·2	56126	
9	1767·8	56568	
6	1763·2	56715	
1	1758·7	56860	
6	1750·8	57117	
6	1746·0	57274	
5	1740·2	57465	
5	1737·3	57561	
2	1732·3	57727	
3	1729·4	57824	
3	1722·2	58065	
5	1720·0	58140	
6	1714·8	58282	
6	1709·5	58497	
3	1707·3	58572	
2	1701·3	58779	
2	1698·3	58882	
8	1692·5	59084	
4	1687·9	59245	
2	1661·8	60176	
2	1656·5	60368	
6	1653·2	60489	
2	1650·1	60569	

Bloch has also measured the spectrum of Nickel down to λ1851[1]. He has measured a great number of lines not obtained in this work. The strong lines of his spectrum correspond fairly well with the strong lines measured above.

Cobalt.

The vacuum arc spectrum of Cobalt was obtained by putting cobalt in iron terminals. The current used was about 12 amperes when the circuit was closed. This gave an intense intermittent arc. The spectrum obtained was similar to that of iron and showed up lines that belonged to Carbon. Eder and Valenta's work covers the lines measured in this work down to λ2173·44. Bloch has also made

[1]Journal de Physique, 5 Série, p. 631, 1914.

measurements down to λ1872·94, but his results do not correspond closely with those given below. This may be due to the fact that he used a spark in air, rather than the vacuum arc as used in this work.

Intensity	λ	1/λ	
3	2387·5	41885	
3	2354·0	42481	
5	2347·0	42607	
4	2344·5	42653	
4	2325·5	43001	
7	2313·2	43230	
7	2308·0	43327	
2	2293·0	43611	
8	2286·5	43735	
4	2246·5	44534	
4	2138·7	46757	
2	2099·3	47635	
5	2061·5	48503	
7	2026·2	49354	
2	1939·5	51560	
9	1929·5	51827	
3	1912·2	52296	
4	1893·8	52804	
10	1861·4	53721	
10	1853·0	53966	
2	1819·8	54951	
1	1740·3	57461	
2	1710·9	58449	
7	1669·9	59884	

From λ2400 to λ2000 the experimental error is probably as much as one angstrom unit. This is due to the fact that the dispersion in this region is small, being about ·05mm. per angstrom unit; also the lines obtained on the photographic plate are not as well defined. These measurements are given for a guide for future research work with vacuum arc sources.

From λ2000 down, the probable error is on the average, well within half an angstrom unit. The dispersion varies from ·067mm. at λ2000 to ·20mm. at λ1400 per angstrom unit.

Summary of Results.

The vacuum arc spectra of copper, zinc, aluminium, carbon, iron, tin, lead, thallium, nickel and cobalt have been studied from λ2400 to λ1400. The vacuum arc spectra obtained for copper, zinc and aluminium were found to correspond with the results obtained for the spark spectra of these metals by previous observers. For tin, lead and thallium, Saunders has given measurements between about λ2400 and λ1800, which correspond fairly well with these results. Several new lines have been observed and measured between λ1800 and λ1400. For the arc spectra of iron, cobalt, nickel and carbon, several lines were obtained, and measured, some of which corresponded with results given in previous work.

This work was begun by Mr. Ainslie under the direction of Professor J. C. McLennan and continued by the joint authors under the direction of Professor E. F. Burton.

UNIVERSITY OF TORONTO STUDIES

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