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Excitation of an extreme ultraviolet spectrum of hydrogen by means of a vacuum arc

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EXCITATION OF AN EXTREME ULTRAVIOLET SPECTRUM OF HYDROGEN BY MEANS OF A VACUUM ARC

by

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INTRODUCTION

This thesis is a report on a research project carried out at the suggestion of, and under the guidance of Doctor C. Rulon Jeppesen, Professor of Physics. There were three main objectives to this experimental study: (1) To photograph an extreme ultraviolet spectrum of hydrogen excited by means of a vacuum arc under conditions set forth in Part IV--Procedure, (2) To measure the wave lengths in this spectrum and assign intensities to the spectral lines, (3) To make a comparison between the spectral line intensities in this spectrum and the spectral line intensities obtained by means of a discharge tube. Study of the spectrum of hydrogen by means of discharge tube has been carried out previous to this.[1] Also, studies of the arc spectrum of hydrogen under similar conditions but for different wave lengths outside of the vacuum region have been undertaken, one by R. W. Wood and G. H. Dieke[2] in 1937 and one by M. Kiuti[3] in Japan in 1923.

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[1]Jeppesen, C. R., "The Emission Spectrum of Molecular Hydrogen In The Extreme Ultraviolet", Physical Review, vol. 44, page 165, 1933, and Unpublished Data.

[2]Wood, R. W. and Dieke, G. H., "Spectrum Of The Arc In Hydrogen, "Physical Review, vol. 53, page 146, 1938.

[3]Kiuti, M., Proc. Phys. Math. Soc. of Japan, 1923.

No attempt is made in this work to explain the discrepancies or to correlate the agreements found between the arc and discharge spectra either as to intensities or appearance and non-appearance of certain spectral lines. However, with the information obtained from this study, and work previously carried out in the visible part of the spectrum,[1,2] a correlation between the arc spectrum and the discharge tube spectrum may be possible.

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[1]Wood, R. W. and Dieke, G. H. "Spectrum Of The Arc In Hydrogen", Physical Review, vol. 53, page 146, 1938.

[2]Kiuti, M., Proc. Phys. Math. Soc. of Japan, 1923.

APPARATUS AND EQUIPMENT

I Vacuum System

To obtain the required pressures throughout the system it was necessary to employ two mechanical hyvac fore pumps together with a double stage mercury diffusion pump. One hyvac pump was connected to the system at a point between the slit of the spectrograph and the ring seal of the arc chamber. The outlet on the arc chamber used for this connection is illustrated in the photograph of the chamber on page 8. The main purpose of this pump was to maintain the best vacuum possible in the spectrograph while hydrogen was being constantly introduced into the arc chamber. The other hyvac pump was attached at two points, one a direct connection to the arc chamber, the other a connection through the mercury diffusion pump to the gas outlet of the spectrograph. The mercury diffusion pump made it possible to obtain pressures on the order of 10^{-6} millimeters of mercury in the spectrograph. This type of vacuum system is necessary when dealing with the extreme ultraviolet since the light source, the arc chamber, cannot be sealed off from the spectrograph due to light absorption by any solid media in this region of the spectrum. Also it is necessary to maintain the whole spectrograph at as low a pressure as possible to prevent light absorption in the spectrograph. It was with this in mind that the mercury diffusion pump was employed. The vacuum maintained by this mechanical pump and the mercury diffusion pump combination was measured by means of a McLeod gauge attached directly to the diffusion pump. The pressure in the arc chamber, both before and after the arc was made, was measured by means of a mercurial barometer type gauge attached to the arc chamber.

II The Spectrograph

The vacuum spectrograph used in obtaining the spectrograms was designed by Doctor C. R. Jeppesen. It employs a Johns Hopkins grating ruled 11,800 lines per centimeter and has a radius of curvature of 42 centimeters. The spectrograph gives dispersion on the order of 20 angstroms per millimeter with a probable error of .05 angstroms. The mounting is of the modified Paschen-Runge type set at almost normal incidence.

III Hydrogen Purification

The hydrogen used in this study was obtained from commercial tanks. Certain impurities in the hydrogen as it came from the tanks made it necessary to "wash" or purify the hydrogen by bubbling it through a water bath. Failure to "wash" the hydrogen resulted in the plugging of the capillary in front of the arc and plugging of the slit in the spectrograph during the arcing. After purification in the water bath the hydrogen was dried by passing it through a tube of "dry-rite". This was found necessary to suppress the atomic spectrum which appears strongly in the presence of water vapor.

IV Power Supply

The generator used to develop the required voltage and current was run by a 60 cycle, 220 volt, 3 phase, motor turning at the rate of 1750 cycles per second. The generator produced a potential of 1000 volts with a current of one ampere. The current was then controlled by rheostats to get the exact amperage required.

V Film

The film used in the spectrograph to take the hydrogen arc spectrograms was process pan photographic film from which Schumann emulsions were prepared in accordance with the method of Hopfield and Appleyard.[1] Two slight changes were necessary in the procedure to procure best results for the spectrograms taken in this work. The liquid emulsion was put into thermos bottle for maturing at 55°C and the maturing was

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[1]Hopfield, J. J., and E. T. S. Appleyard, "Simplified Method of Preparing Schumann Plates", <u>Journal Of The Optical Society of America</u>, 22, pages 488-495, Sept. 1932.

allowed to continue for a period of forty-five minutes.

VI Arc Chamber

The arc chamber, made of pyrex glass, was blown, in the main, by Dr. Jeppesen. The over-all length from brass taper to the end of the cap was approximately 24 centimeters. Other general dimensions were not of vital importance and may be approximated from figure 1, page 8. Red sealing wax was used for sealing the taper and the cap to the rest of the chamber. The tungsten electrodes had a diameter of 1.75 millimeters and were mounted at right angles to each other. The glass tube inclosing one of the electrodes was made in two parts separated by means of a short piece of heavy rubber tubing. This was to allow for flexability in adjustment of the arc gap. The upper end of the electrode was gripped by a small clamp which could be twisted to vary the distance between the ends of the electrodes. The capillary in the center of the glass tube attached to the ring seal was centered so as to present a direct line from arc to the slit of the spectrograph through the capillary. The electrodes produced light of such high intensity in comparison to the light from the arc that it was imperative that the light from the electrodes be eliminated from the slit of the spectrograph. This, as well as maintaining the large pressure differential between the arc chamber and the spectrograph, was the purpose of the capillary. It was found that a capillary of .68 millimeters produced the best all around results. The metal shield had as it's primary purpose the shielding of the capillary and the slit of the spectrograph from two undesirable effects--the producing of intense light by the ends of the electrodes and the producing of tiny particles from the reaction of certain impurities in the hydrogen with the electrodes. These particles, if left unchecked tended to clog and close the capillary and the slit of the spectrograph. The shield also made it easier to align the slit and the arc by cutting down on glare from the glass capillary. The arc was absolutely invisible in the glare of the incandescent tungsten electrodes even when they were concealed behind the shield.

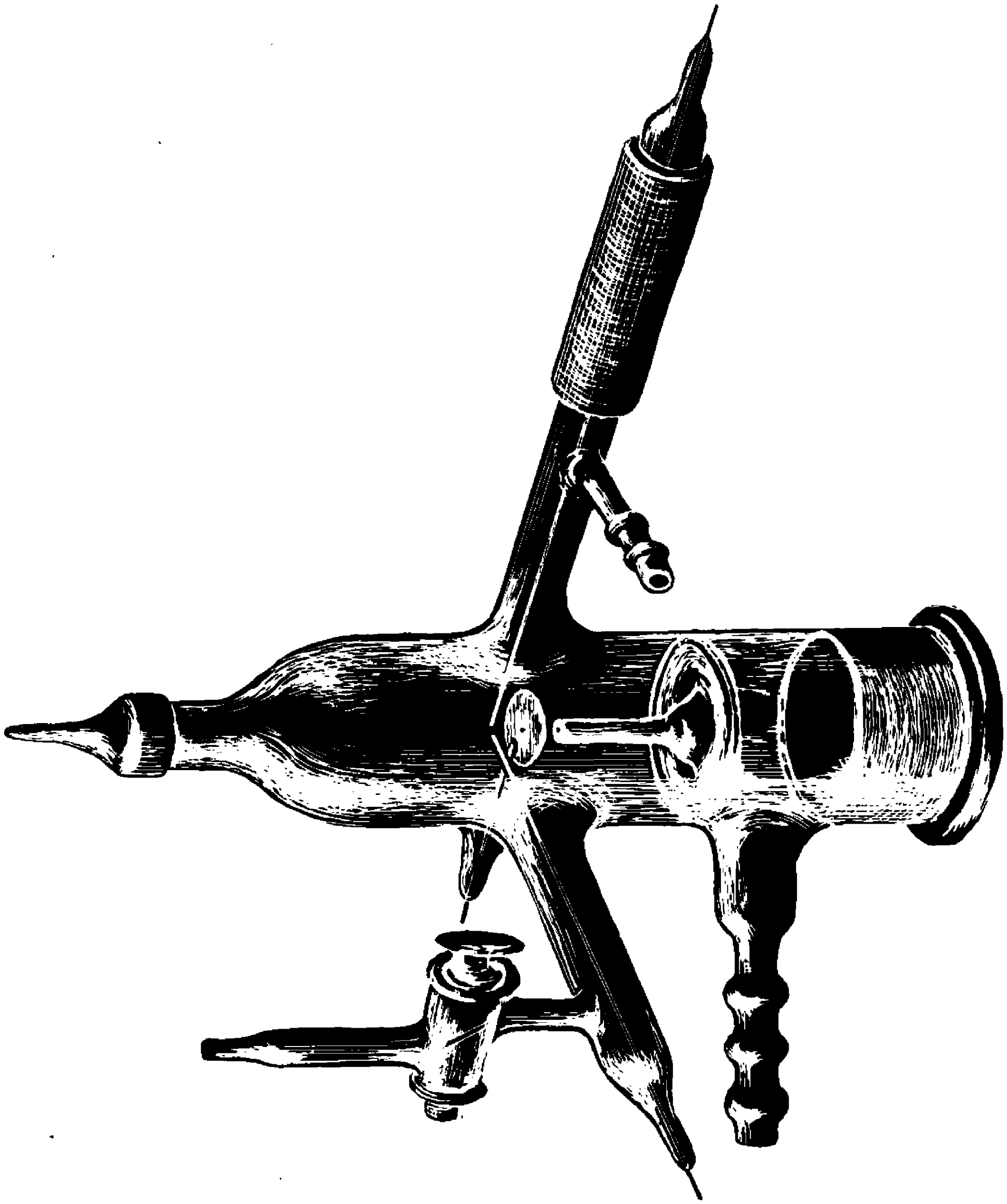


Figure 1--Arc Chamber

A. Parts from left to right

1. Removable cap to allow for adjusting and cleaning
2. Electrodes
3. Metal shield
4. Glass tube with .68 millimeter capillary
5. Ring seal

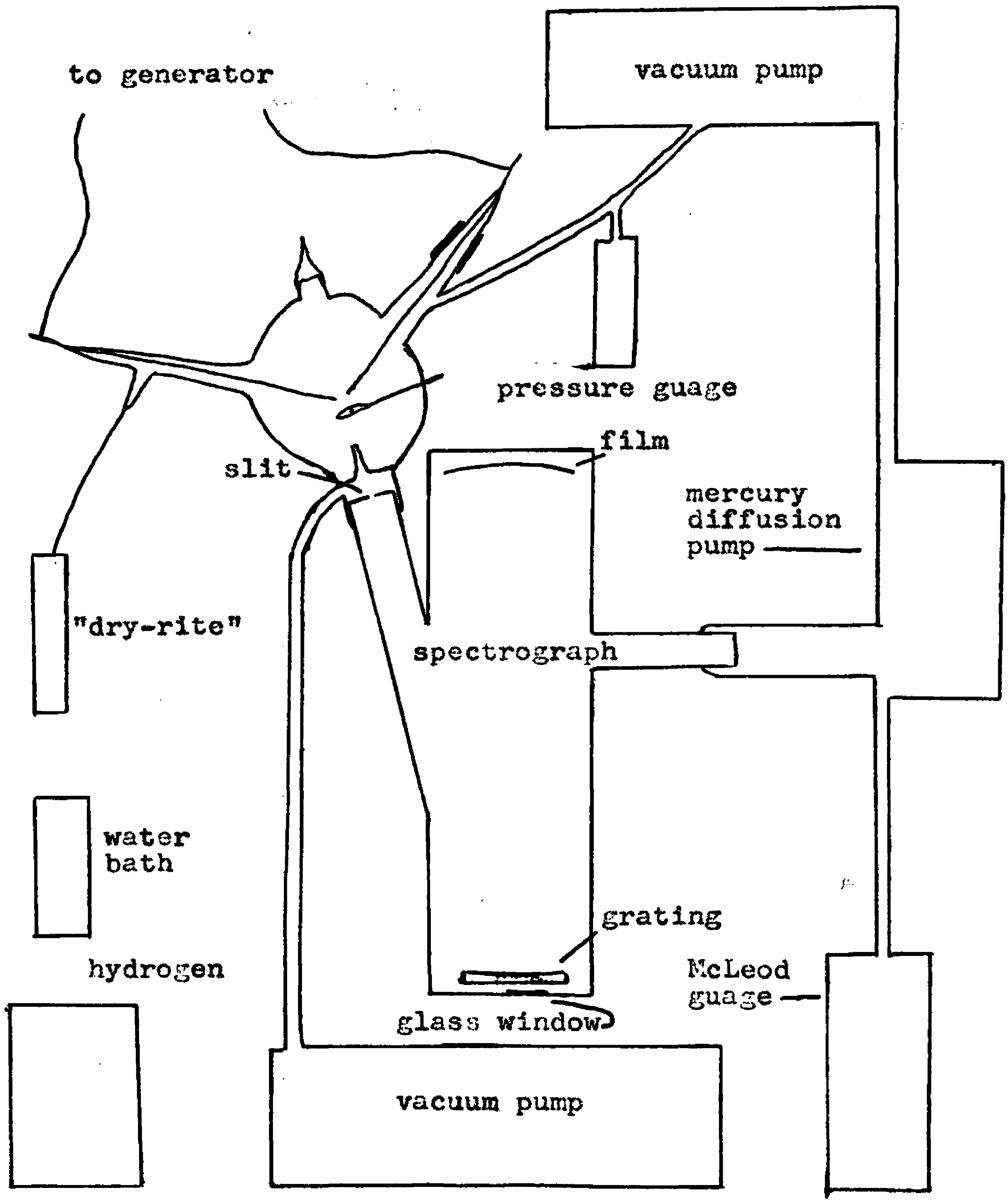
6. Opening leading to vacuum pump
7. Brass taper for sealing to spectrograph

B. Parts on upper "arm"

1. Opening leading to vacuum pump and mercurial barometer type pressure gauge
2. Rubber tube to allow for flexibility in adjustment of arc gap
3. Seal for electrode

C. Parts on lower "arm"

1. Opening leading through stopcock to
2. Seal for electrode



BLOCK DIAGRAM

EXPERIMENTAL PROCEDURE

I Operation

Preliminary work was carried out by use of a quartz spectrograph in an effort to determine fundamental conditions of pressure, current and distance between electrodes. The spectrograms taken by this means did not justify the time spent in producing them so it was therefore decided to shift immediately to the vacuum spectrograph. Shortly after setting up on the vacuum spectrograph a move was necessitated by remodeling in the physics department and transferring of the laboratory equipment. It was then found necessary to adjust the spectrograph to some extent and a cleaning of the grating was undertaken. The latter was probably unnecessary but results had been spotty and no definite cause had been located. It was thought that the particles produced in the arc chamber from the impure hydrogen may have affected the grating. It turned out, however, that this was not the case.

The arc chamber was set in place and then rotated until the slit of the spectrograph was in the exact center of the capillary. This was possible to observe with the cap (see figure 1) removed and a light set behind the window of the spectrograph. (The window is located at one end of the spectrograph behind the grating.) After the exact position of the arc chamber was determined the cap was sealed on with red sealing wax and a capillary from the hydrogen source was sealed on the lower "arm" (see figure 1). The exact diameter of this capillary was determined by the gas pressure it was able to maintain during operation of the hyvac pumps and the mercury diffusion pump. The exact length was not important but the capillary was approximately two feet long. The capillary used to take the spectrograms used in this investigation maintained a pressure of 18.5 centimeter of mercury prior to the "make" of the arc. Due to the increase in temperature from the hot electrodes the pressure rose to 25.5 centimeters of mercury when the maximum temperature was reached in the arc chamber.

The vacuum developed by the diffusion pump before the introduction of the hydrogen was approximately 10^{-5} millimeters of mercury. Under the conditions listed in the above paragraph the pressure rose to approximately 10^{-3} milli meter of mercury. Two conditions determined this final pressure; the size of the capillary between the arc and the slit of the spectrograph (a set condition), and the size of the slit itself (a variable condition). The slit was set at a position such that a spectrogram would be obtained that was as sharp as possible and still contain all the spectral lines with intensities that could be measured. The slit was varied very slightly on the two spectrograms used in this investigation in order to obtain one very sharp spectrum and one with broader but more intense lines to be sure that all possible lines were included.

Before starting the arc, the chamber was thoroughly exhausted by means of the vacuum system and washed out two or three times with hydrogen. The potential of 1000 volts with a current of .2 amperes was applied at the protruding ends of electrodes located in each "arm" of the arc chamber. The current was regulated by means of several rheostats put both in series and in parallel. As soon as the circuit was closed by making contact between the electrodes, the electrodes were separated and positioned approximately 2 millimeters apart. However, a slight variance was tolerable as long as the current was adjusted to .2 ampere.

The first attempts at taking the spectrograms resulted in the filling of the slit of the spectrograph and the capillary opening nearest to the electrodes with fine particles. Because of this and because of the intense light from the electrodes, a shield was introduced between the electrodes and the capillary opening (see figure 1). The shield proved very beneficial in the controlling of both the light and the stray particles but when a finer adjustment was made on the slit it became apparent that the source of these particles must be eliminated as the slit continued to clog up. This was accomplished by "washing" the hydrogen and then drying it as set forth previously in Part III--Hydrogen Purification.

Exposure time was varied from a few minutes to well over an hour but best results were obtained at close to the hour period. The condition of the film varied to some extent due to different methods employed in making and handling it. However, a good usuable film was eventually obtained and used for the final exposures. A large number of spectrograms were actually made but the final choice was made with several things in mind--resolving power, extent of spectra and condition of the film being held uppermost in importance.

II Measurements

The best exposures obtained under optimum conditions were measured on a Gaetner comparator with an accuracy of one micron. Each spectral line on both exposures was measured twice, once beginning at the short wavelength end and once beginning at the long wavelength end. The average of these linear displacements, as taken by the comparator for each line found on the spectrogram, were then interpolated linearly into wavelengths by using known lines as standards. The wavelengths obtained for each spectrogram from this interpolation were then plotted on error curves and corrected values of each wavelength found. The two results, one from each error curve, were then averaged where possible and recorded in the following table.

III Spectrograms

The spectrograms shown are the end results of a number of different exposures taken under varying conditions in an attempt to obtain spectra that are as clear and precise as possible. The conditions used to obtain each spectrogram are given under each photograph. An enlarged section of each spectrogram is included for closer study. An attempt has been made to line up, as near as possible, the arc spectra and the discharge tube spectra so that an intensity comparison can be made. However, a more exact study can be made from the table and therefore no identification of lines has been attempted on the films. The first Lyman line is distinguishable on the discharge tube spectrum, however, by it's' prominence on the left hand side of the film.

Figure 2--Arc Spectrum

Pressure in arc chamber--25.5 cm. of mercury; Time--45 minutes
Pressure in spectrograph--10^{-3} mm. of mercury; Current--.2 amp.
Wavelengths increase from left to right in this spectrogram

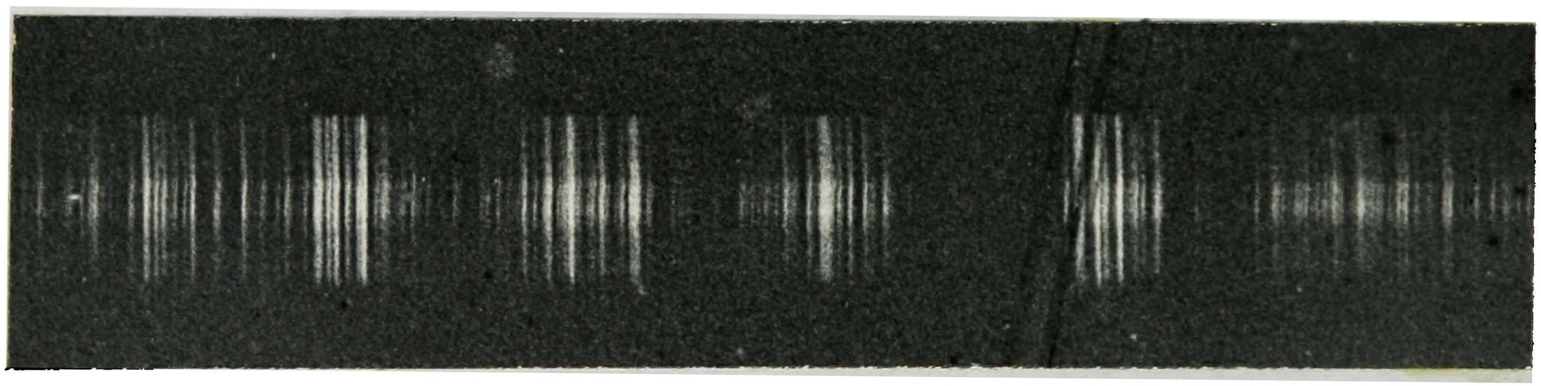


Figure 3--Enlargement of figure 2

Spectral lines from approximately 1134 to 1274 λ are shown

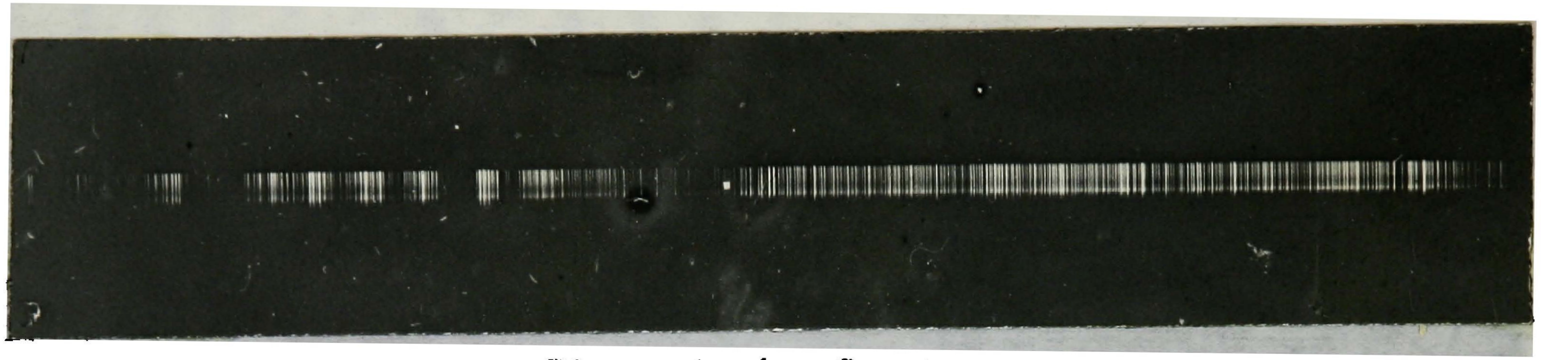


Figure 4--Arc Spectrum.

Pressure in arc chamber--25.5 cm. of mercury; Time--1 hour
Pressure in spectrograph--.5 x 10^{-2} mm. of mercury; Current--.2 amp.
Wavelengths increase from left to right in this spectrogram

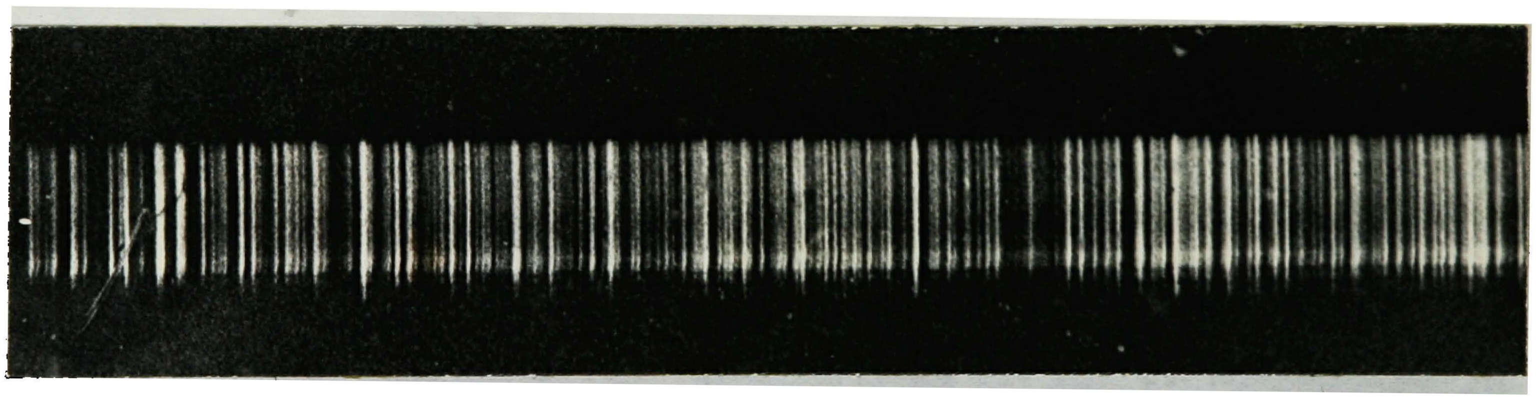


Figure 5--Enlargement of figure 4

Spectral lines from approximately 1320 to 1460 are shown

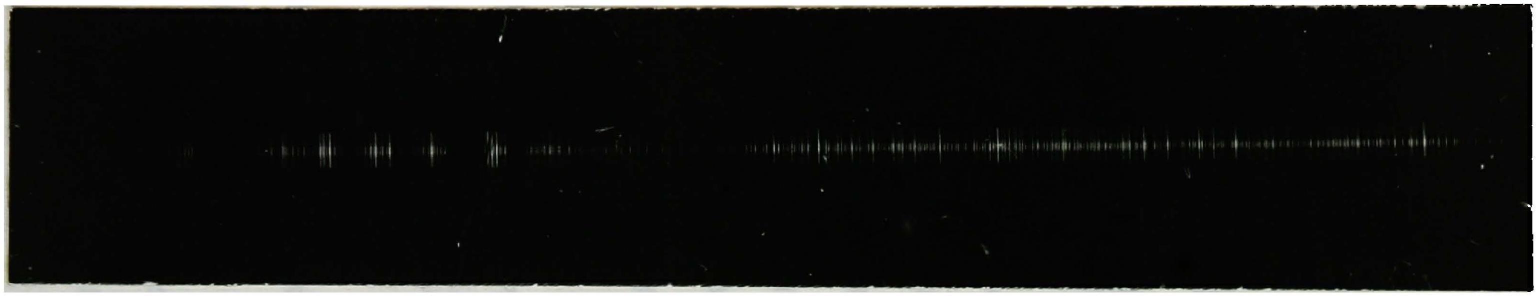


Figure 6--Same as figure 2

This figure is repeated here so a comparison of the two different types of spectrum can be made.

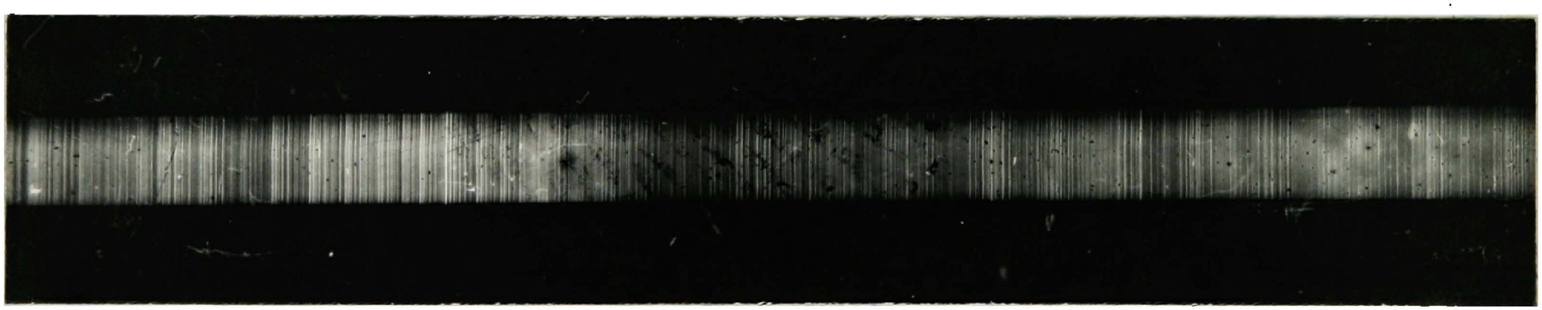


Figure 7--Discharge tube Spectrum

TABLE OF WAVELENGTHS, INTENSITIES AND WAVE NUMBERS

Inasmuch as symbols have been used in the following table, an explanation of these symbols is needed at this time if the reader is to clearly understand the meaning of the four columns in the table.

The first one of the columns is headed I_d and stands for the estimated relative intensity of the spectral lines found from the discharge spectrum. The second column is headed I_a and stands for the estimated relative intensity of spectral lines found from the arc spectrum. In the third column the Greek letter λ (lambda) is used to denote wave length in angstrom units as this is the standard symbol used in such cases. At the top of column four the Greek letter ν (nu) is used to denote the wave number (the reciprocal of the wave length in centimeters) as this is also the standard symbol used for wave number. To the right hand side of column, beside some of the vacuum intensity ratings, there is an occasional asterick. This is to denote that these lines appeared broadened and not too distinct and may be grouped together differently than has been presented. If the I_d column is blank for a particular line in the I_a column, that line does not appear on the discharge spectrum.

The intensities are expressed by numbers varying from 0 through 7 which were estimated as the spectrograms were measured. A line of 0 intensity was just perceivable while a line of 7 intensity appeared very dark. Since two spectrograms were involved in the measurements, these intensity numbers represent the average of the two different exposures.

TABLE OF WAVELENGTHS, INTENSITIES AND WAVE NUMBERS

I_d	I_a	λ	ν
4	0	1045.12	95683
1	0	1045.69	95631
8	3	1046.71	95537
4	0	1047.16	95496
5	3	1047.93	95426
1	4	1066.56	93759
1	2	1069.52	93500
3	1	1071.46	93331
1	0	1072.66	93226
3	0	1077.81	92781
3	0	1082.47	92381
3	0	1086.85	92009
4	1	1093.45	91454
5	2	1094.72	91348
3	3	1097.55	91112
4	2	1098.14	91063
4	1	1099.29	90968
4	2	1100.60	90860
4	1	1101.59	90778
5	3	1102.15	90732
	1	1102.84	90675
5	4	1104.29	90556
3	1	1104.89	90507
2	4	1105.88	90426
8	5	1107.10	90326
2	1	1107.84	90266
4	1	1108.22	90235
4	1	1109.76	90110
3	1	1110.37	90060
5	0	1119.07	89360
1	1	1133.45	88226
1	2	1134.87	88116
1	0	1136.07	88023
5	2	1137.49	87913
1	2	1138.63	87825
0	2	1139.40	87765
0	3	1139.86	87730
	0	1140.50	87681

TABLE

I_d	I_a	λ	ν
0	1	1141.18	87629
3	3	1143.02	87488
3	6	1144.37	87384
3	5	1145.22	87319
5	4	1145.87	87270
0	1	1146.48	87224
5	2	1146.93	87189
0	2	1147.77	87125
4	5	1148.46	87073
2	3	1150.63	86909
1	5	1153.03	86728
3	0	1153.60	86685
3	1	1154.68	86604
0	1	1156.09	86498
3	3	1156.94	86435
3	0	1158.00	86356
3	2	1158.60	86311
6	7	1159.70	86229
4	5	1160.76	86150
5	6	1161.32	86109
5	5	1162.32	86035
1	4	1163.31	85962
7	6	1163.84	85922
0	2	1164.94	85841
4	4	1165.70	85785
	0	1166.70	85712
	0	1167.00	85690
3	2	1167.32	85666
0	3	1168.16	85605
3	1	1168.80	85558
0	0	1169.48	85508
3	2	1171.95	85328
5	1	1174.30	85157
3	1	1174.92	85112
5	2	1175.86	85044
3	0	1176.70	84983
	0	1177.66	84914
5	4	1178.24	84872
1	2	1179.20	84803
4	5	1180.38	84718
4	2	1181.31	84652
	3	1181.82	84615
3	5	1182.46	84569
4	2	1183.14	84521
3	2	1183.96	84462

TABLE

I_d	I_a	λ	ν
4	3	1184.34	84435
2	4	1185.21	84373
2	2	1185.76	84334
3	1	1186.46	84284
3	3	1187.10	84239
6	5	1187.79	84190
4	5	1188.29	84155
4	3	1189.41	84075
4	1	1191.61	83920
3	0	1192.26	83874
	0	1192.99	83823
5	0	1194.56	83713
0	0	1195.52	83646
3	1	1197.80	83486
2	1	1198.81	83416
3	1	1199.41	83374
2	1	1200.03	83331
1	1	1201.02	83263
6	3	1201.82	83207
2	2	1202.57	83155
3	3	1203.92	83062
3	5	1205.06	82983
0	5} *	1205.68	82941
3	4}	1206.11	82911
5	3	1206.64	82875
4	4	1207.60	82809
5	4	1208.92	82718
0	1	1209.64	82669
3	3	1210.76	82593
0	0	1212.98	82442
1^{st} Lyman	0	1215.67	82259
3	0	1224.91	81639
	3	1227.16	81489
5	7	1228.31	81413
2	1	1229.37	81342
6	7	1229.94	81305
2	4	1230.67	81257
5	6	1231.89	81176
0	0	1232.87	81172
2	2	1233.43	81075
5	3	1234.07	81033
1	4	1235.35	80949
3	1	1238.96	80713
1	1	1240.07	80641

TABLE

I_d	I_a	λ	ν
2	2	1244.39	80361
2	2	1245.96	80259
3	0	1246.27	80239
4	1	1246.76	80208
6	1	1247.36	80169
0	1	1247.90	80135
	1	1248.34	80106
5	2	1248.85	80074
	0	1249.25	80048
4	1	1249.83	80011
1	1	1250.53	79966
4	3	1251.34	79914
3	1	1251.73	79889
	1	1252.03	79870
1	3	1253.62	79769
1	2	1254.81	79693
2	0	1255.33	79660
1	0	1255.40	79656
2	1	1255.70	79637
3	1	1256.34	79596
4	3	1257.21	79541
3	3	1257.83	79502
3	2	1258.79	79441
1	1	1260.01	79364
1	3	1261.36	79280
4	3	1261.84	79249
	0	1262.92	79182
4	0	1263.58	79140
4	2	1264.24	79099
5	2	1265.69	79008
1	1	1266.78	78940
4	1	1268.02	78863
3	2	1268.87	78810
5	0	1269.68	78760
2	2	1270.45	78712
4	2	1271.26	78662
4	2	1271.88	78624
4	2	1272.77	78569
	1	1273.90	78499
	1	1274.80	78444
	1	1275.55	78398
1	1	1276.54	78337
2	0	1277.79	78260

TABLE

I_d	I_a	λ	ν
4	1	1278.74	78202
	1	1279.42	78160
1	2	1280.68	78084
5	1	1281.08	78059
	0	1282.31	77984
6	2	1283.08	77937
4	1	1284.32	77862
0	1	1285.72	77777
4	4	1286.50	77730
4	1	1287.82	77651
	0	1289.16	77570
5	1	1290.12	77512
0	0	1291.85	77408
1	0	1292.51	77366
1	2	1293.23	77326
0	2	1299.76	76937
4	0	1302.29	76788
2	2	1307.20	76499
	1	1312.44	76194
0	0	1313.41	76138
2	1	1314.67	76065
2	1	1315.36	76025
	0	1315.93	75992
	0	1316.47	75961
3	1	1319.08	75780
	0	1320.12	75751
0	0	1322.25	75629
4	1	1323.27	75570
2	2	1324.64	75492
3	1	1327.01	75357
3	1	1327.61	75323
	1	1328.50	75273
1	1	1329.13	75237
	0	1330.09	75183
5	2	1331.08	75127
6	3	1333.76	74976
4	2	1334.36	74942
0	1	1335.09	74901
0	1	1335.56	74875
8	3	1335.85	74859
4	4	1337.48	74767
3	2	1337.85	74747
1	2	1338.55	74708

TABLE

I_d	I_a	λ	ν
2	4	1340.88	74578
	2	1341.73	74531
5	5	1342.26	74501
4	1	1343.65	74424
2	7 }*	1345.13	74342
4	7	1345.45	74325
4	6 }*	1346.97	74241
0	5	1347.28	74224
0	4	1349.06	74126
0	2	1349.90	74080
	1	1350.25	74060
	1	1350.57	74043
	2	1351.06	74016
1	5	1352.44	73940
4	5	1353.47	73884
	2	1354.06	73852
	2	1354.64	73820
3	4	1355.50	73774
	4	1356.47	73721
2	3	1357.39	73671
	2	1358.02	73637
0	4	1359.07	73580
3	2	1359.83	73539
0	0	1360.24	73516
	0	1360.67	73493
0	0	1361.04	73473
	1	1361.67	73439
0	2	1362.17	73412
3	7	1363.39	73347
2	2	1364.04	73312
	0	1365.23	73248
	2	1365.65	73225
	5	1366.36	73187
	4	1367.43	73130
4	1	1368.03	73098
	1	1369.06	73043
	2	1369.63	73012
1	2	1370.36	72974
	5	1371.18	72930
0	1	1371.99	72887
4	5	1372.67	72851
4	2	1373.43	72810
	2	1374.00	72780
	2	1374.51	72753

TABLE

I_d	I_a	λ	ν
0	1	1375.22	72716
3	0	1375.92	72679
	5	1376.90	72627
0	0	1377.18	72612
	1	1378.06	72566
	2	1378.64	72535
	1	1379.21	72505
	4	1380.07	72460
	2	1380.71	72427
0	0	1381.33	72394
	1	1381.93	72363
	3	1382.73	72321
	4	1383.81	72264
	2	1384.82	72212
	5	1385.46	72178
2	2	1386.11	72144
2	3	1387.41	72077
1	2	1387.84	72054
	1	1388.79	72005
	1	1389.64	71961
	2	1390.39	71922
	1	1391.03	71889
	4	1391.94	71842
	3	1392.94	71771
	2	1393.40	71767
4	4	1393.92	71740
	2	1395.13	71678
1	2	1395.66	71651
5	3	1396.20	71623
	0	1396.68	71598
4	4	1397.37	71563
0	1	1397.88	71537
4	3	1398.95	71482
0	1	1399.80	71439
	2	1400.53	71402
0	2	1401.06	71375
3	3	1402.10	71322
6	5	1402.66	71293
0	0	1403.36	71258
	2	1404.13	71218
2	3	1404.76	71187
2	2	1405.55	71147
	3	1406.37	71105
3	3	1407.32	71057

TABLE

I_d	I_a	λ	ν
0	2	1407.80	71033
	3	1408.68	70988
	0	1409.22	70961
	2	1409.82	70931
3	3	1410.39	70902
0	2	1411.76	70834
5	6	1412.76	70783
	2	1414.12	70715
	2	1414.71	70686
	0	1415.21	70661
o	3	1415.72	70635
1	2	1416.24	70610
	2	1417.37	70553
	2	1418.42	70501
1	3	1419.20	70462
	3	1420.06	70420
	0	1421.19	70364
	0	1421.94	70326
	1	1422.51	70298
	2	1423.12	70268
0	1	1425.45	70153
2	4	1426.52	70101
	1	1427.04	70075
4	5	1427.69	70043
	1	1428.35	70011
2	3	1428.89	69984
	4}	1430.01	69930
	3} *	1430.63	69899
3	4}	1430.96	69883
1	5	1432.86	69790
	4	1434.01	69735
	2	1434.52	69710
3	3	1435.04	69684
2	7	1436.08	69634
0	1	1436.68	69605
0	1	1437.06	69587
2	3	1437.51	69565
2	3	1438.01	69541
1	0	1438.49	69517
2	4	1439.03	69491
0	2	1440.31	69429
	5	1440.86	69403
0	2	1441.63	69366
0	4	1442.77	69311

TABLE

I_d	I_a	λ	ν
6	5	1443.46	69278
	1	1444.59	69224
2	4	1445.11	69199
4	5	1446.10	69152
	3	1447.35	69092
	2	1448.56	69034
0	2	1449.16	69005
3	5	1450.22	68955
	2	1451.03	68917
2	4	1451.95	68873
0	4 }*	1452.32	68855
	4 }	1452.57	68843
	1	1453.05	68821
	2	1453.85	68783
	1	1454.34	68760
5	4	1454.89	68734
2	4	1456.07	68678
	3	1457.33	68619
4	5	1458.13	68581
0	4	1459.32	68525
1	4	1460.05	68491
	4	1460.87	68452
1	3	1461.93	68403
	5	1462.56	68373
	3	1463.23	68342
4	4	1463.76	68317
1	4	1465.00	68259
	0	1465.65	68848
	1	1466.19	68204
	4	1467.00	68166
	3	1467.77	68131
5	5	1468.41	68101
	2	1469.03	68072
	3	1469.73	68040
1	2	1470.48	68005
1	1	1470.90	67986
	1	1471.47	67959
1	3	1472.39	67921
	1	1473.02	67888
3	5	1473.77	67853
2	4	1474.64	67813
	4	1475.35	67781
2	2	1476.24	67740
	3	1476.53	67726

TABLE

I_d	I_a	λ	ν
2	4	1476.97	67706
	2	1477.55	67680
	0	1478.43	67640
	3	1479.47	67592
0	2	1480.13	67562
	0	1480.89	67527
2	4	1481.54	67497
	2	1482.36	67460
	1	1483.65	67401
	4	1484.69	67354
	1	1485.47	67319
	3	1485.92	67298
5	5	1486.60	67268
0	3	1487.11	67245
2	3	1487.70	67218
0	1	1488.04	67202
0	3	1488.39	67187
5	4	1489.05	67157
4	4	1489.57	67133
4	4	1491.68	67093
0	3	1492.26	67012
	3	1492.51	67001
0	2	1493.85	66941
	0	1494.15	66928
5	6	1495.17	66885
	2	1495.65	66865
	1	1495.94	66848
4	4	1499.58	66685
	3	1500.41	66648
	3	1501.02	66621
0	2	1501.97	66579
	1	1503.49	66512
	1	1503.71	66502
0	0	1504.34	66474
4	6	1504.74	66457
1	4	1505.66	66416
1	1	1506.59	66375
1	1	1507.06	66354
	2	1507.67	66328
	1	1508.23	66303
	0	1509.06	66266
	0	1509.85	66232
0	3	1510.70	66194

TABLE

I_d	I_a	λ	ν
4	4	1511.26	66170
1	2	1511.97	66139
4	0	1512.56	66113
4	5	1513.47	66073
5	5	1514.97	66008
1	3	1515.70	65976
3	3	1516.16	65956
3	5	1517.40	65902
0	1	1517.96	65878
2	5}*	1518.67	65847
1	2}	1518.98	65834
3	3	1519.97	65791
0	2	1521.65	65718
0	2	1522.23	65693
6	6	1523.23	65650
	1	1524.67	65588
2	3	1525.20	65565
0	1	1526.02	65530
2	3	1526.56	65507
3	4	1527.32	65474
0	0	1529.59	65377
3	4	1530.73	65328
1	2	1531.31	65304
4	5	1532.04	65272
2	4	1532.46	65255
3	3	1532.94	65234
	1	1534.15	65183
1	2	1534.78	65156
	3	1536.43	65086
	1	1536.78	65071
5	5	1537.47	65042
3	3	1539.31	64964
2	2	1540.01	64935
1	1	1540.68	64906
1	3	1541.78	64860
	0	1542.08	64847
	1	1543.06	64806
2	4	1543.63	64782
2	3	1544.22	64758
2	3	1544.57	64743
5	4	1544.87	64730
1	3	1545.59	64700
	2	1546.63	64657
2	4	1547.27	64630

TABLE

I_d	I_a	λ	ν
	3	1548.29	64587
0	3	1549.84	64523
2	3	1550.57	64492
1	2	1551.65	64448
	2	1552.62	64407
	2	1552.89	64396
5	4	1553.49	64371
3	4	1554.98	64310
3	3	1555.83	64274
3	1	1556.53	64245
	3	1557.38	64210
	0	1558.16	64178
0	1	1558.83	64151
0	1	1559.85	64109
0	0	1560.33	64089
	1	1561.31	64048
4	4	1562.37	64005
	0	1563.19	63972
0	1	1564.12	63934
3	3	1565.29	63886
1	1	1565.80	63865
	0	1566.42	63840
2	3	1567.40	63800
	0	1567.90	63780
4	3	1569.43	63717
1	1	1570.01	63694
	4	1571.27	63643
4	2	1571.96	63615
1	2	1572.65	63587
0	1	1573.37	63558
	3	1574.06	63530
0	0	1575.01	63492
	2	1575.69	63464
1	2	1576.13	63447
	2	1576.96	63413
	3	1577.33	63398
	1	1578.69	63344
1	1	1579.25	63321
1	2	1579.96	63293
	3	1580.66	63265
3	3	1581.18	63244
3	2	1581.46	63233
4	4	1581.82	63218
	1	1583.24	63162

TABLE

I_d	I_d	λ	ν
4	3	1583.90	63135
4	4	1585.43	63074
4	3	1587.41	62996
5	3	1588.73	62943
3	5	1589.16	62926
4	4	1590.14	62888
1	2	1590.78	62862
6	2	1591.35	62840
0	1	1591.74	62824
	0	1592.17	62807
0	2	1592.89	62779
5	3	1593.37	62760
2	4	1593.76	62745
2	2	1595.64	62671
5	5	1596.07	62654
	3	1599.12	62534
2	1	1601.40	62445
5	4	1601.97	62423
	4	1602.73	62394
2	3	1603.66	62357
3	3	1604.47	62326
1	2	1604.82	62312
3	3	1605.16	62299
3	2	1606.25	62257
0	0	1606.99	62228
4	6	1607.55	62206
3	6	1607.93	62192
4	6	1608.36	62175
4	3	1609.07	62148
1	3	1609.89	62116
6	2	1610.35	62098
3	2	1610.96	62075
1	2	1611.32	62061
	2	1611.57	62051
5	5	1613.18	61989
5	5	1613.73	61968
4	3	1614.86	61925
5	5	1616.57	61859
1	1	1617.56	61841
1	1	1618.21	61797
3	4	1619.75	61738
4	2	1620.73	61701
3	2	1621.91	61656
	1	1622.92	61617

TABLE

I_d	I_a	λ	ν
	1	1623.44	61598
0	1	1625.30	61527
	1	1625.78	61509
3	2	1628.37	61411
	2	1633.65	61213
2	2	1634.06	61197
2	0	1635.19	61155
0	0	1635.98	61125
2	2	1638.38	61036
3	1	1638.90	61017
4	2	1640.30	60964
2	0	1642.83	60871
3	1	1644.40	60812
2	0	1645.58	60769

EXPERIMENTAL RESULTS

The extreme ultraviolet spectrum of the H_2 molecule as excited by an arc rather than in a low pressure discharge tube has been photographed for the first time.

A tabulation of the intensities and wave lengths for all the lines appearing on two spectrograms, resulting in 588 spectral lines is given. A comparison of these lines with those on discharge tube spectrograms, shows obvious very large differences in relative intensities of lines in the two types of sources. In fact, many lines that are relatively strong in the one source do not appear at all in the other and those lines in the table for which no intensity estimate is given in the discharge tube column are newly observed lines and have been observed and measured for the first time in the present work. As was stated previously, it was not the purpose of this investigation to delve further into these differences in the arc and discharge spectra. However, a further study of these two spectra may develop a correlation between them.

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