The deuterons were found by setting the shunt at the position which gave the greatest neutron yield per microampere of ions.

With a slit at the target 16 mm wide and 20 mm high and an angle of deflection of 8°, a target current of 200 microamperes is obtained. The neutron yield under these conditions at 100 kv is 22 mC per microampere and at 124 kv is 37 mC per microampere. It is estimated that these values are correct to within 10 or 15 percent exclusive of the unknown error due to making the comparison with the detector foil in only one position. The greater part of this error arises from the uncertainty in the strength of the Rn-Be sources which were used as standards for comparison. Amaldi, Hafstad and Tuve[6] have measured the yield, in mC equivalent, from the $D+D_2O$ reaction for voltages from 1000 kv to 300 kv, and Roberts[8] shows curves of relative yields from 300 kv to 40 kv. From these it is estimated that the use of deuterons accelerated by 100 kv impinging on an ice target should give a yield of 21 mC per microampere. The value given here is in satisfactory agreement with this figure, and is evidence of the fact that nearly all the ions arriving at the target are deuterons. Our value is also in reasonable agreement with the yield of slow neutrons as measured by Roberts.[8]

Constant neutron intensities equivalent to 4 curies at 100 kv and 6.5 curies at 124 kv have been obtained. For these yields the power input at the target is about 20 watts and does not cause any serious decay of the target. For instance, a 12-minute bombardment does not change the neutron intensity a measurable amount, and in view of the ease with which the target can be renewed, the source of neutrons is, for most purposes, sufficiently constant. Due to the fact that the voltmeter used in these measurements is limited to voltages below 125 kv and that some additional corona shielding is required, all measurements were made at potentials below 125 kv. However, constant neutron intensities of 10 curies should be possible for voltages somewhat less than 200 kv.

The rate of consumption of liquid nitrogen is approximately 400 grams per hour when the power input is 20 watts. The amount of D_2O required is very small, as the targets must be quite thin. In fact, an ice layer which is thick enough to be just visible is too thick and is very quickly reduced to a thin target.

In conclusion, we wish to express our indebtedness to Professor Harold C. Urey for the gift of the pure heavy water used in these experiments, to Dr. Francis Carter Wood of the Crocker Research Laboratory for the gift of some of the high voltage equipment, and especially to Professor Bergen Davis for his interest and helpful counsel throughout the course of this work.

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[8] Roberts, Phys. Rev. 51, 810 (1937).

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Absorption Spectra of Manganese and Silver in the Schumann Region*

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A method has been developed for observing absorption spectra of high melting point materials in the Schumann region. The absorption spectra of manganese and silver have been investigated in the region between λ800A and λ1930A. Many new lines in MnI have been observed and it has been possible to link some of these with known levels in the Mn atom. A new sequence of terms, the $d^9snp\ ^6P^0$, has been found in AgI.

INTRODUCTION

H. BEUTLER, in 1933, published the first of a series of papers[1] describing the investigation of the absorption spectra of certain metallic vapors in the Schumann region. His experiments proved very fruitful in establishing new series of lines which arise from transitions involving the outermost closed shells of the atoms investigated. Beutler's work was limited,

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* Condensed from a Dissertation presented to the Faculty of the Massachusetts Institute of Technology.

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[1] H. Beutler, Zeits. f. Physik 86, 495 (1933).

however, to the metals of lower melting point because the material was vaporized in a glass tube in vacuum. The spectral range was restricted because Beutler employed a helium continuum against which he observed the absorption lines, and this extended only from 600A to 1100A.

Professor G. R. Harrison suggested to the author that the development of a method for observing this sort of spectrum over a wider spectral range and for materials of higher melting point would be a profitable field for investigation. In the present paper is described the method developed for the observation of the absorption spectra of high melting point materials in the Schumann region, and the results obtained for manganese and silver.

Apparatus

The source of continuous radiation employed was a Lyman discharge tube similar to the one described by Duncan.[2] The female part of a Pyrex grind was supported by a 26 mm tube which was sealed with red sealing wax into a water-cooled socket soldered to the absorption furnace. A 1 mm Pyrex capillary 20 to 30 mm long was sealed directly to a tube extending from the inside end of the male part of the grind. A tube extending out from the other end of the grind supported a copper cup, affixed with sealing wax, which carried a tube for introducing gas into the discharge tube and a copper wire holding an aluminum rod which formed an electrode of the discharge tube.

A 12μf condenser charged to 6000 v was discharged twice per second through the Pyrex capillary from the aluminum electrode to the furnace, which was maintained at ground potential, though the frequency with which discharges occurred could be adjusted. It was found that two discharges per second were all that the tube could stand.

A tungsten cylinder $5\frac{1}{4}$ inches long and of $\frac{9}{16}$ inches outside diameter rolled from 15 mil tungsten sheet was used as a furnace tube to vaporize metals. One inch of each end of the cylinder was held in massive, water-cooled copper blocks, which served as supports for the tube and as electrical connections to transmit the large currents which were used to heat the furnace tube to the desired temperatures. This furnace tube was enclosed in a cast bronze box, which was water-cooled and protected from the direct radiation from the furnace tube by water-cooled shields everywhere except at the ends of the tube.

The current used to heat the furnace was supplied by a 220–22 v step-down transformer capable of supplying 1500 amperes. The secondary was so arranged that from one to five turns could be used to supply current to the furnace. A further control on the current through the furnace was a length of water-cooled lead tubing, any fraction of which could be shorted out, in series with the furnace tube. This arrangement permitted almost continuous variation of the heating current up to 1500 amperes. The temperatures produced ranged up to 2300°C.

This furnace was connected directly to the spectrograph in such a way that the end of the furnace tube was about four inches from the spectrograph slit. Between the tube and the spectrograph slit was placed a set of baffles and the outlet to a fast pumping system, so arranged as to decrease the amount of gas and particles tending to reach the slit from the furnace.

The end of the furnace housing away from the spectrograph had a 3 mm aperture through which light from the discharge tube could enter to traverse the furnace tube and strike the slit of the spectrograph. The side of the housing was equipped with a one-inch glass window through which the temperature of the furnace tube could be measured with an optical pyrometer.

The spectrograph employed was a conventional grazing incidence vacuum spectrograph employing a 2-meter, 30,000 line per inch glass grating ruled by R. W. Wood. The grating was illuminated at 79.5° angle of incidence and the plate holder was set to cover the region from 200A to 1930A. The dispersion varied from 1.08A/mm at 200A to 2.87A/mm at 1930A.

Experimental Procedure

The operation of the Lyman discharge offered the greatest experimental difficulties. The diameter and length of the capillary were not very critical, but if the length was more than 40 mm or the diameter less than 0.8 mm the tube

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[2] A. B. F. Duncan, Phys. Rev. **47**, 822 (1935).

shattered very readily. If the capillary was shorter than 15 mm or the diameter of the capillary greater than 2 mm the spectrum produced was rich in emission lines, and the intensity of the background was much decreased.

It was necessary always to warm the capillary before starting the discharge by running a high voltage, uncondensed, oscillating discharge through it by means of a leak tester or a small high voltage transformer. It was also necessary to start the discharge at low voltage and gradually increase the voltage to the desired value. It was found that the discharge would not operate at pressures less than 10^{-2} mm of Hg. It was, of course, necessary to maintain the furnace and spectrograph at pressures between 10^{-3} and 10^{-4} mm of Hg or to fill them with a transparent gas such as hydrogen, in order to obtain spectra in the desired spectral region. However, even hydrogen and helium are practically opaque below λ800A and each of them introduces strong absorption bands which might obscure the atomic lines for which search was being made, if any considerable pressure is used.

The first attempt was to run the discharge tube at a pressure of 10^{-3} mm of Hg. It was found that although the furnace itself was maintained at a pressure of 10^{-3} mm by the previously described pumping system, once the discharge was started, the heat produced in the capillary drove out so much gas that the discharge would continue to operate. At a pressure of 10^{-4} mm Hg in the furnace, however, the discharge would fail after the first few flashes unless an auxiliary kick from a leak tester was used. Since the Cenco leak testers available were not built for continuous operation and soon fail if operated in that manner, a special contact maker was added to the one used for the discharge tube, which turned on the leak tester an instant before the contact for the main discharge was made and kept it going until the discharge occurred. Thus, the leak tester was on approximately 10 percent of the time. This scheme proved very satisfactory and runs an hour long could be made, maintaining the furnace and spectrograph at pressures of 5×10^{-4} mm of Hg or less without failure of the leak tester or the discharge tube.

Another method of maintaining the discharge which proved very satisfactory was controlling the pressure in the discharge tube by admitting hydrogen to it through a palladium tube sealed in lead glass, the temperature of which could be accurately controlled by means of a potential divider and an electrical heating coil. With this scheme the pressure in the spectrograph rose from 5×10^{-5} mm to 10^{-3} mm of Hg during an hour-long run. Under these conditions the atomic lines of hydrogen appeared strongly in absorption, but only the strongest members of the band systems showed up.

In using the furnace to produce vapor for absorption studies, ordinarily from 1 to 5 grams of the material was placed in a small boat in the center of the furnace tube. The furnace was then sealed and evacuated and the tube heated to a temperature a little above the melting point of the material to be studied, for about 10 minutes. This procedure served to remove practically all the grease and other volatile impurities from the furnace. The pressure in the furnace and spectrograph ordinarily rose from 10^{-4} to 10^{-2} mm of Hg during this process. Upon shutting the furnace off, or upon continued heating, the pressure slowly fell again to the original value. When the furnace was turned on again and heated to temperatures as much as 800°C to 1000°C above the melting point of the material being studied there was seldom an appreciable change in the pressure in the spectrograph or the furnace during runs up to an hour long.

Since the range of the spectrograph is rather wide and the emission of the source extends over the entire region and overlapping orders are not desirable in absorption studies, it was necessary to break the spectrum up into sections and study one portion at a time. A very convenient method of isolating the region between 1200A and 1900A was available by use of excellent LiF windows obtained from Professor D. C. Stockbarger as filters to eliminate wave-lengths shorter than 1200A. A clean freshly cleaved piece of this material, 0.5 mm thick, was found to transmit approximately 50 percent of the incident light above 1300A. At wave-lengths shorter than 1300 the transmission appeared to drop off rather sharply to complete opacity somewhere near 1050A. By introducing hydrogen, helium or nitrogen, with the oxygen removed by passing over hot copper filings and the water vapor

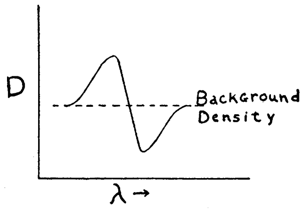

FIG. 1. Overlapping absorption and emission lines of Si II.

removed by liquid-air traps, into the body of the spectrograph at pressures of from 0.5 to 1.0 mm of Hg, it was found possible to isolate the region between 800 and 1600A. At wave-lengths shorter than 1300A exposure times were from 3 minutes to 15 minutes. In the region between 1300A and 1900A exposure times ranged from 30 minutes to an hour. At wave-lengths shorter than 800A there was no method available for eliminating overlapping orders. This may account for my failure to observe any absorption lines below this point.

The silver used in this study was obtained in small granules and in the form of 2 mm wires. The purity was fairly high; the emission spectrum showed traces of Na, K, Ca, and Fe to be present. The metal was placed in the furnace and baked out, as has been described, then the absorption spectrum was photographed with furnace temperatures varying from 1000°C to 1600°C by steps of 100°. One picture was taken with the furnace at 1900°C in an attempt to bring out more series members, but the silver disappeared so rapidly that even after five minutes exposure the absorption lines were pretty well filled up. At 1500°C the silver evaporated so fast that it was necessary to remove the window and clean it three times to obtain a 30 minute exposure in the region 1300A–1900A. With a boat $2\frac{3}{4}$ inches long and $\frac{3}{16}$ inches deep it was easy to put enough material in the furnace to last 30 minutes at 1400°C. At 1500°C and 1600°C it was necessary to fill the boat twice during a 30 minute exposure.

The manganese used was obtained from Mackay Chemical Company and was of such purity that the emission spectrum showed only slight traces of impurities. The absorption spectrum of the element was photographed with the furnace at temperatures from 1200°C to 1800°C with the temperature varied in steps of 200°C. Manganese seemed to evaporate from the furnace tube much more rapidly than silver, once the melting point had been passed. It was necessary to charge the furnace tube every fifteen minutes at temperatures up to 1400°C and every ten minutes at higher temperatures. At 2000°C five grams of manganese completely disappeared from the furnace tube during a five minute exposure.

In addition to the data obtained from absorption studies new information was obtained on the emission spectra of manganese and silver. Hollow cathode and arc pictures of silver were taken on a 1-meter normal incidence vacuum spectrograph and on a 21 foot grating, and on a 2-meter broad range vacuum spectrograph. Arc emission plates of manganese obtained on the M.I.T.-W.P.A. wave-length program were also used. Measurements made on these plates gave excellent wave number agreement.

RESULTS

The characteristics of the emission spectrum from the Lyman discharge tube were of considerable interest. The origin of the continuous radiation is not definitely known, but it is thought to be emitted by hot particles torn out of the walls of the capillary by the disruptive discharge. The equivalent temperature of the discharge varies considerably with applied voltage, with the condenser capacitance discharged through the capillary, and with the pressure of gas within the capillary. These changes of temperature are evident from the appearance of atomic lines in the spectrum produced. By far the strongest emission lines on the plates were those of Si IV, N IV and O IV and O V. The lines of Si III and C III and C IV were always present in emission. The lines of B I, Si I, C I, and N I always appeared in absorption. The lines of B II and Si II appeared in emission when the discharge was comparatively cool, but when the discharge was hot these two ionized spectra appeared in absorption. At an intermediate temperature a peculiar condition existed in which certain lines of Si II appeared both in absorption and emission. A microphotometer trace of one of these lines has the appearance of the curve in Fig. 1 where the density of the blackening is plotted as ordinate and wave-length as abscissa. The total spread of the lines is in general about 0.4A.

The explanation of the phenomenon seems to be that at the start of the discharge some of the Si atoms emit the lines of the Si II spectrum. The emission wave-length is shifted slightly by the fact that there exists a strong electric field in the capillary. As the contact breaks and the field is removed the temperature of the discharge continues to rise and sufficient singly ionized silicon atoms are produced to give the absorption spectrum of Si II in the continuous radiation from the hot gas of the discharge. This occurs in a field-free space so the position of the absorption line is the true position of the Si II spectrum line. Attempts to measure the positions of these two lines with any accuracy have failed because of the difficulty of determining the centers of gravity of an absorption and an emission line when the two are partially superposed. However, the measurements seem to bear out the above theory. It was further observed that at the highest temperatures most of the lines of Si IV appeared heavily self-reversed, some symmetrically and some asymmetrically.

TABLE I. *Absorption lines of manganese in Schumann region.*

WAVE-LENGTH (A)	INTENSITY	WAVE NUMBER (cm⁻¹)	WAVE-LENGTH (A)	INTENSITY	WAVE NUMBER (cm⁻¹)
1923.05	0?	52000.73	64.27	2	293.4
22.53	1	014.79	63.95	1?	308.3
18.34	1	128.40	63.62	2	323.7
14.03	0?	245.78	63.10	1	348.0
13.70	2	254.79	62.40	1?	380.7
1877.55	2	53260.90	59.36	2	522.2
76.48	4	291.27	54.40	3	756.9
75.81	5	310.31	52.48	3	847.8
58.59	1	804.23	50.95	2	920.4
58.18	1	819.00	50.05	0?	963.1
01.98	2	55494.5	49.68	2	980.7
1785.53	2?	56005.8	48.61	1	69031.7
85.39	5*db*	010.2	48.09	0	056.5
56.72	2	924.3	47.74	2*d*	073.2
56.60	3	928.2	23.49	1	70249.9
56.51	2	931.1	23.20	0	264.2
32.62	5	57716.1	21.35	1	355.6
17.11	4	58237.4	19.22	1	461.2
06.69	2	592.9	04.70	1	71189.6
1670.81	3	59851.2	04.50	2	199.7
43.06	5*d*	64806.3	00.72	1	71391.8
1490.50	5	67091.6	1398.47	0	506.7
85.36	0	323.7	47.15	2	74230.8
85.10	0	335.5	14.01	3*d*	76102.9
78.54	2*d*?	634.3	1267.44	2*D*	78899.2
78.32	1	644.4	1100.64	1	90856.2
65.27	1?	68246.8	1100.24	1*db*	889.3
65.07	0?	256.1	1099.87	1	919.8
			1085.01	1	92165.0

The appearance of these lines of silicon, boron, carbon, nitrogen, oxygen and hydrogen made it possible to measure the plates without the use of any special source for producing standard lines.

Because of the fact that there were many absorption lines on the plates from the source itself, and the fact that the number and intensity of these lines varied somewhat with different discharge conditions, it was not an easy task to decide that any given absorption line arose from the vapor in the furnace and not from the discharge tube. However, by taking several pictures of the absorption spectrum at each furnace temperature and comparing these with several pictures of the source taken with the furnace cold, and by observing the increase in the intensity of the lines with furnace temperature it was possible to decide very definitely, in most cases, whether a given line did or did not arise from the vapor produced in the hot furnace.

MANGANESE ($Z=25$)

The absorption spectrum of manganese was photographed from 500A to 1930A. The absorp-

TABLE II. *Identification of new lines in manganese.*

WAVE-LENGTH	INTENSITY	CM⁻¹	OBS.-CALC. CM⁻¹	TRANSITION	OBSERVER
6440.95	5	15521.38	*C*	$2^0-b\,^6S_{2\frac{1}{2}}$	*K*
39.143	1	525.73	*C*	$3^0-b\,^6S_{2\frac{1}{2}}$	*K*
38.124	1	528.19	*C*	$4^0-b\,^6S_{2\frac{1}{2}}$	*K*
6223.78	1	16062.97	*C*	$1^0-a\,^8S_{3\frac{1}{2}}$	*K*
5543.44	1	18034.34	−0.05	$5^0-b\,^8S_{3\frac{1}{2}}$	*K*
4621.0	1*u*	21634.3	−0.1	$a\,P_{3\frac{1}{2}}{}^0-b\,^6D_{2\frac{1}{2}}$	*K*
20.2	1*u*	21638.0	−0.2	$a\,P_{3\frac{1}{2}}{}^0-b\,^6D_{3\frac{1}{2}}$	*K*
19.24	1	21642.54	*C*	$a\,P_{3\frac{1}{2}}{}^0-b\,^6D_{4\frac{1}{2}}$	*K*
4583.048	2	21813.45	−0.05	$6^0-a\,^8D_{3\frac{1}{2}}$	*K*
82.804	2	21814.61	−0.05	$6^0-a\,^8D_{2\frac{1}{2}}$	*K*
3731.935	3	26788.16	−0.06	$5^0-b\,^6S_{2\frac{1}{2}}$	*K*
2796.937	1	35742.88	0.05	$v\,^6P_{1\frac{1}{2}}{}^0-a\,^6D_{2\frac{1}{2}}$	*K*
91.273	1	35809.63	−0.28	$v\,^6P_{3\frac{1}{2}}{}^0-a\,^6D_{2\frac{1}{2}}$	*K*
89.36	2	35839.97	−0.04	$v\,^6P_{2\frac{1}{2}}{}^0-a\,^6D_{2\frac{1}{2}}$	*K*
78.554	2	35979.35	−0.10	$v\,^6P_{3\frac{1}{2}}{}^0-a\,^6D_{3\frac{1}{2}}$	*K*
76.223	2	36009.55	00	$v\,^6P_{2\frac{1}{2}}{}^0-a\,^6D_{3\frac{1}{2}}$	*K*
60.924	1	36209.08	−0.04	$v\,^6P_{3\frac{1}{2}}{}^0-a\,^6D_{4\frac{1}{2}}$	*K*
2221.827	50*R*	44993.96	0.08	$x\,^6P_{3\frac{1}{2}}{}^0-a\,^6S_{2\frac{1}{2}}$	*P*
13.847	40*R*	45156.13	0.05	$x\,^6P_{2\frac{1}{2}}{}^0-a\,^6S_{2\frac{1}{2}}$	*P*
08.807	25*R*	45259.15	−0.03	$x\,^6P_{1\frac{1}{2}}{}^0-a\,^6S_{2\frac{1}{2}}$	*P*
1877.55	2	53260.90	0.52	$v\,^6P_{3\frac{1}{2}}{}^0-a\,^6S_{2\frac{1}{2}}$	*P*
76.48	4	53291.27	0.21	$v\,^6P_{2\frac{1}{2}}{}^0-a\,^6S_{2\frac{1}{2}}$	*P*
75.81	5	53310.31	1.01	$v\,^6P_{1\frac{1}{2}}{}^0-a\,^6S_{2\frac{1}{2}}$	*P*
1801.98	2	55494.5	−0.2	$1^0-a\,^6S_{2\frac{1}{2}}$	*P*
1756.72	2	56924.3	1.1	$2^0-a\,^6S_{2\frac{1}{2}}$	*P*
56.60	3	928.2	1.5	$3^0-a\,^6S_{2\frac{1}{2}}$	*P*
56.51	2	931.1	1.0	$4^0-a\,^6S_{2\frac{1}{2}}$	*P*
1464.27	2	68293.4	−1.4	$5^0-a\,^6S_{2\frac{1}{2}}$	*P*
59.36	2	522.2	−0.4	$6^0-a\,^6S_{2\frac{1}{2}}$	*P*
52.48	3	847.8	2.0	$\alpha\,P_{3\frac{1}{2}}{}^0-a\,^6S_{2\frac{1}{2}}$	*P*

tion lines observed are listed in Table I. In the first column are the wave-lengths in International angstrom units. In column two are the intensities and notes as to the characteristics of the line. The intensities are visual estimates. The notations are as follows: *d*, diffuse, *db*, double, ? indicates that there remains some doubt as to whether the line is really manganese, *D*, very diffuse. In the third column are given the wave numbers of the lines.

Each of the wave-lengths given in this table is the average of measurements on at least two plates, and all but the lines of lowest intensity were measured at at least two temperatures. Intensity estimates were made from plates taken at the highest temperature used.

Manganese has twenty-five extranuclear electrons, with the $3d^5 4s^2\ {}^6S_{2\frac{1}{2}}$ term as a ground state. The next level is 17000 cm^{-1} above this and arises from the configuration $3d^6 4s$. The first members of the $d^5s(^7S)nP$, $d^5s(^5S)np$ and $d^6(^5D)np$ series have been established by the work of McLellan and McLay and by Catalan as given by Bacher and Goudsmit.[3] In addition to the $^6P^0$ terms from these configurations there is a $^6P^0$ at 10,050 cm^{-1} (Bacher and Goudsmit) and another at 6675 cm^{-1} recently correctly placed by Meggers,[4] the configurations of which have not been established.

TABLE III. *Absorption lines of silver in the Schumann region.*

WAVE-LENGTH	INTENSITY	CM^{-1}
1893.12	1	52822.8
17.54	1	55019.4
1776.80	0	56281.0
1651.55	3	60549.2
49.95	2	60607.9
1578.47	1	63352.5
1549.14	100*D*	64551.9
15.60	100*D*	65980.5
07.50	50*d*	66335.0
1472.35	1	67918.6
55.02	1	68727.6
33.93	2	69738.4
31.68	2	69848.0
1310.95	1	76280.6
10.50	1	76306.8
1283.12	2*d*	77869.5
06.51	4	82883.7
1148.87	15*d*	87042.1
32.30	2	88315.8
1072.80	5	93214.2
32.33	2	96869.3

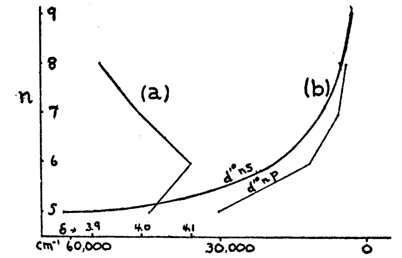

FIG. 2. Variation of (*a*) quantum defect and (*b*) relative position of $d^{10}ns$ and $d^{10}np$ with total quantum number.

It has been possible to identify a few new lines with the data compiled in this study. These are listed in Table II. Column 1 gives the wave-length, column 2 the intensity, column 3 the wave number, column 4 the difference between the observed and calculated value of the wave number, column 5 the transition and column 6 the author who observed the lines. *K* indicates that the wave-length is from Kayser's *Handbuch; P* that the measurement was made by the author. Measurements at wave-lengths longer 1930A were made on emission spectrograms. Shorter wave-lengths are from absorption plates. Those transitions for which an estimated error is replaced by a *C* were used to determine the position of the energy level directly.

SILVER ($Z=47$)

In Table III is the list of absorption lines found in the silver spectrum. The conventions observed in Table I have been followed in compiling Table III.

Silver has 47 extranuclear electrons and a configuration ending with $4d^{10}5s$, giving a $^2S_{\frac{1}{2}}$ term as ground state. The known spectrum of AgI arises from excitation of the *s* electron. The terms arising from the configurations d^9s^2, d^9sp, d^9sd etc. are as yet unknown. Almost all the strong lines in the emission spectrum of AgI have been assigned to transitions, so the emission from the d^9s^2, d^9sp, etc. levels must be very weak. The knowledge of this spectrum is also very limited with respect to the principal series, of which only the first two members are known.

In Table III there are three lines of low intensity, with wave-lengths greater than 1636A where the principal series in silver should converge. Of these 1817 and 1776 have approximately

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[3] Bacher and Goudsmit, *Atomic Energy States.*

[4] W. F. Meggers, Nat. Bur. Stand. J. Res. **10**, 757 (1933).

the proper intensity and position to be the third and fourth members of the principal series. If these two lines are identified as members of the principal series the variation in the quantum defect which results is shown in Fig. 2(*a*) and the relative positions of the $d^{10}ns$ and $d^{10}np$ levels is shown in Fig. 2b. Although the relative positions of $d^{10}ns$ and $d^{10}np$ are approximately what is to be expected and the variation in the quantum defect is no more than would be expected from perturbations of the levels, it is hardly justifiable to include these lines in the principal series until combinations between the ${}^2P^0{}_{1\frac{1}{2},\,\frac{1}{2}}$ levels involved and even terms above the ground state have been identified. These combinations, which lie at longer wave-lengths than 7000A, have not been observed in previous work nor in my observations of the emission spectrum.

The outstanding characteristic of the absorption spectrum of silver in the Schumann region is the presence of three extraordinarily intense lines at 1507, 1515 and 1550. Professor Shenstone has suggested that these three lines may occupy the same position in the silver spectrum that 2181, 2178 and 2165 do in the spectrum of CuI. The line at 1549 is nearly coincident with a strong emission line and was at first not recognized as an absorption line.

TABLE IV. *Series in silver arising from the* ${}^2S-{}^2P^0$ *transition.*

WAVE-LENGTH	INTENSITY	CM^{-1}	n	$n-n^*$
1515.60	100*D*	65980.5	5	3.61
1507.50	50*d*	66335.0		
1148.87	15*d*	87042.1	6	3.58
1072.80	5	93214.2	7	3.71
1032.33	2	96869.3	8	3.59

The doublet at 1507–1515 is the first member of a series arising from the ${}^2S-{}^2P^0$ transition. The series is listed in Table IV.

This series arises from the transitions between the $d^{10}s\ {}^2S_{\frac{1}{2}}$ level and a sequence of inverted ${}^2P$ terms arising from the configurations d^9snp; n : 5, 6, 7, 8. The quantum defect is very nearly constant except for the term of total quantum number 7. The variation in this term may be due to a perturbation, but it corresponds to a displacement of 530 cm^{-1}. A more likely possibility appears to be that the true line is obscured in the wings of 1066.3 of Si IV which is very strong on the plates. The calculated wave-length of the lines using a quantum defect of 3.59 is 1066.55A.

An attempt was made to observe the emission lines arising from transitions between the $d^9s5p\ {}^2P^0{}_{1\frac{1}{2},\,\frac{1}{2}}$ levels and levels above the ground state in AgI. A pair of lines 4267.75 and 4203.95 of intensities 2 and 1 respectively was observed, which has been identified as arising from the transition $d^9s5p\ {}^2P^0{}_{1\frac{1}{2},\,\frac{1}{2}}-d^{10}6s\ {}^2S_{\frac{1}{2}}$. The line at 4203.95 was partially covered by a Rowland ghost of the strong line 4212.68, but it is believed that a fairly accurate measurement of the wave-length was obtained. Lines corresponding to no other transitions were identified.

The absorption lines which have not been arranged in series probably arise from some of the remaining terms given by the d^9snp configuration.

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