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The Extreme Ultraviolet Spectra of Ne IV, V and VI

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An electrical discharge suitable for the excitation of high stages of ionization in gases has been developed. This discharge has been used to excite neon gas and the resulting emission has been recorded with a 3-meter grazing incidence vacuum spectrograph. One hundred and seventeen lines have been identified in the spectrum of Ne IV; fifty-six lines in Ne V, and twenty-five in Ne VI. It has been possible to make fairly accurate calculations of the ionization potentials of Ne IV and Ne V as 96.43 volts and 125.8 volts, respectively. The ionization potential of Ne VI is estimated to be 157 volts.

THIS investigation is the outgrowth of an attempt to develop a light source which would yield the spectra of highly ionized atoms of gaseous elements. Although the past few years have brought extensive advances in the knowledge of the spectra of highly ionized atoms of elements that can be fixed in a solid electrode, there have been no corresponding additions to the knowledge of the spectra of ions that can be handled only as gases.[1] Boyce in his investigations of neon[2] and argon[3] found the greatest excitation provided by the electrodeless discharge to correspond to the lowest excited levels of Ne IV and A V. Neon was selected as the most suitable subject for investigation because the spectra of the ions of neon can be predicted very accurately by interpolation among the data of Edlén for boron, carbon, nitrogen and oxygen,[4] of Bowen[5] and Edlén[6] for fluorine and those of Soderquist for sodium, magnesium and aluminum[7] and because the excitation required to produce a given stage of ionization for neon is greater than that for any other rare gas except helium. That this is the case is readily seen from a diagram such as Fig. 1 in which the position of the lowest level of each ion relative to the ground state of the normal atom is plotted as ordinate and various rare gas ions are located in separate columns.

EXPERIMENTAL

Two general types of discharge tubes were used as sources. The first was very similar in design and performance to the capillary tubes used to produce short wave-length continuous radiation. A tungsten wire inserted part way into a Pyrex or quartz capillary of about 2-mm bore served as one electrode for a highly condensed electrical discharge which took place inside the bore of the capillary. This discharge could be viewed by looking end-on at the capillary, or by drilling a hole in the side of the capillary and viewing transversely. Neon was admitted to the region of the discharge by letting it flow in along the tungsten wire. This type of tube proved quite successful in producing highly ionized atoms, and some results from this tube were given in a preliminary report.[8] However, the spectra from the capillary tubes showed very broad, diffuse lines.

The second type of discharge tube employed was very similar in design to the usual Geissler tube for observing the spectra of gases. A ring electrode of heavy tungsten wire was placed at each end of a central Pyrex tube of about 10-mm bore and 150-mm length, which was surrounded by a water-cooling jacket. The central tube was then fitted with replaceable quartz inner tubes with bores ranging from 3 mm to 7 mm. Neon was introduced to the tube at the end remote from the spectrograph and allowed to flow through the tube and through the slit of the spectrograph. The electrical discharge took place periodically between the tungsten electrodes. The larger bore tubes proved to be successful in

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[1] In a note published while this investigation was in progress Parker and Phillips (Phys. Rev. **58**, 93(L) (1940) have described the excitation of A VI, VII and VIII.

[2] J. C. Boyce, Phys. Rev. **46**, 378 (1934).

[3] J. C. Boyce, Phys. Rev. **48**, 396 (1935).

[4] B. Edlén, Nova Acta Regiae Soc. Scient. Upsaliensis, [IV] 9, No. 6, 3 (1934).

[5] I. S. Bowen, Phys. Rev. **45**, 82 (1934).

[6] B. Edlén, Zeits. f. Physik **94**, 47 (1935).

[7] J. Soderquist, Nova Acta Regiae Soc. Scient. Upsaliensis, [IV] 9, No. 7, 3 (1934).

[8] F. W. Paul, Phys. Rev. **56**, 1067(L) (1939).

eliminating most of the fuzziness of the lines, while by suitable adjustments of the electrical circuit greater excitation could be obtained with these tubes than with the capillary tubes. The reason for this last observation was that the capillary tubes more frequently failed at the higher voltages and capacitances.

The rate of flow of gas through the discharge tubes was made steady by a reservoir system and adjusted by means of a series of external capillaries of various bores and lengths.

The electrical circuit consisted of a transformer, a rectifier tube, and a bank of condensers. The voltage applied to the tubes was varied from 5 kv to 105 kv and the capacitance connected in parallel with the discharge tubes was varied from 0.1 μf to 1.8 μf. The rate at which discharges occurred and the voltage across the tube was adjusted by means of a spark gap in series with the tube, as well as by varying the output and voltage of the transformer.

The spectrograms were obtained in the recently constructed 3-meter grazing incidence vacuum spectrograph at the Ohio State University. The angle of incidence was set at about 84°. The dispersion at 500A was approximately 1 A/mm. Ilford type Q-2 and Eastman special ultraviolet sensitive plates were used. Exposure times of five minutes to two hours with about two discharges per second gave a good range of blackening of the plates.

Although the gas system was reasonably free of leaks and efforts were made to obtain pure gas (purified neon in Pyrex flasks was used and was passed through liquid-air cooled, activated charcoal before it entered the discharge tube), the spectra were always contaminated with many strong lines of carbon, nitrogen and oxygen. In the discharge tubes of smaller bore the lines of silicon were also observed. Although these impurities were bothersome in that they obscured parts of some multiplets, they served as very convenient wave-length standards.

Many spectrograms of the discharge were taken in the region from 96 to 1010A with various discharge conditions. From these, six were selected which showed the sharpest lines and the best variation in the spectrum with changing discharge conditions. Each of these has been measured twice on various comparators including the one at the Ohio State University, the large measuring engine at Massachusetts Institute of Technology and a smaller comparator at the University of Rochester.

RESULTS

All of the spectrograms show quite strongly the lines of Ne III, IV and V. The spectrum of Ne II shows up only very faintly, except at the lower voltages and capacitances, and the spectrum of Ne VI appears faintly on the spectrograms obtained with the highest excitation conditions. Under no conditions were even the strongest lines of Ne I observed. Changing the discharge conditions changes the distribution of intensity among these spectra. As was expected, the use of greater voltages or greater capacitances, or both, resulted in the production of higher excitation spectra. The use of smaller bores in the discharge tubes also produced higher excitations. The effect of varying the pressure in the discharge could not be well established, as the discharge was somewhat critical to pressure variations, and failed to

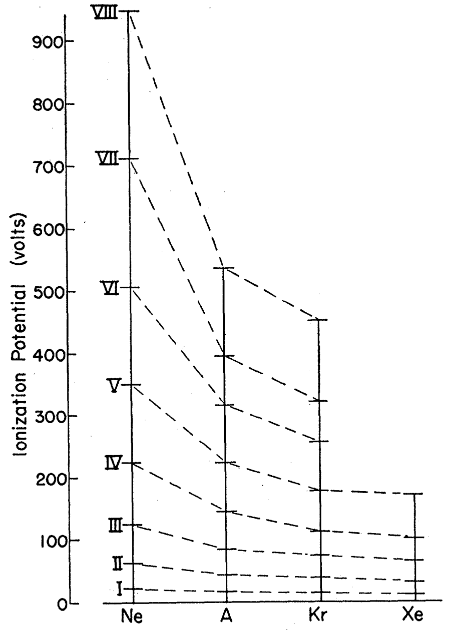

FIG. 1. The positions of various rare gas ions relative to the lowest level of the normal atom. All intervals above Ne V, A IV, Kr III and Xe III are estimated from isoelectronic sequence data. The broken lines connect the same stage of ionization in different gases. From this diagram one can predict that if a source produces the spectrum of Ne VI it will almost certainly produce that of A VII and probably some of A VIII.

TABLE I. *Lines identified as belonging to the spectrum of* Ne IV.

INT.	λ A.U.	ν CM⁻¹	TRANSITION
1	786.141	127,204	$2p^5\,{}^2P^0_{1/2}-2s^22p^2(^1D)3d{}^2P_{3/2}$
3*h*	780.250	128,164	$2p^5\,{}^2P^0_{3/2}-2s^22p^2(^1D)3d{}^2P_{3/2}$
	763.959	calc.	$2p^5\,{}^2P^0_{1/2}-2s^22p^2(^1D)3d{}^2S_{1/2}$
3*h*	758.317	131,871	$2p^5\,{}^2P^0_{3/2}-2s^22p^2(^1D)3d{}^2S_{1/2}$
1	609.168	164,158	$2s2p^4\,{}^2P_{1/2}-2p^5\,{}^2P^0_{3/2}$
5	606.527	164,873	$2s2p^4\,{}^2P_{3/2}-2p^5\,{}^2P^0_{3/2}$
2	605.595	165,127	$2s2p^4\,{}^2P_{1/2}-2p^5\,{}^2P^0_{1/2}$
2	602.999	165,838	$2s2p^4\,{}^2P_{3/2}-2p^5\,{}^2P^0_{1/2}$
150	543.891	183,860	$2s^22p^3\,{}^4S^0_{3/2}-2s2p^4\,{}^4P_{5/2}$*
100	542.073	184,477	$2s^22p^3\,{}^4S^0_{3/2}-2s2p^4\,{}^4P_{3/2}$*
80	541.127	184,799	$2s^22p^3\,{}^4S^0_{3/2}-2s2p^4\,{}^4P_{1/2}$*
3	539.731	185,277	$2s2p^4\,{}^2S_{1/2}-2p^5\,{}^2P^0_{3/2}$
1	536.965	186,232	$2s2p^4\,{}^2S_{1/2}-2p^5\,{}^2P^0_{1/2}$
25	521.813	191,640	$2s^22p^3\,{}^2P^0_{3/2}-2s2p^4\,{}^2D_{5/2}$*
25	521.742	191,666	$2s^22p^3\,{}^2P^0_{1/2}-2s2p^4\,{}^2D_{3/2}$*
200	469.865	212,827	$2s^22p^3\,{}^2D^0_{3/2}-2s2p^4\,{}^2D_{5/2}$*
200	469.817	212,849	$\left\{\begin{matrix}2s^22p^3\,{}^2D^0_{3/2}-2s2p^{42}\,D_{3/2}\\2s^22p^3\,{}^2D^0_{5/2}-2s2p^{42}\,D_{5/2}\end{matrix}\right\}$*
50	433.237	230,821	$2s2p^4\,{}^2D-2p^5\,{}^2P^0_{3/2}$
25	431.472	231,765	$2s2p^4\,{}^2D_{3/2}-2p^5\,{}^2P^0_{1/2}$
150	421.609	237,187	$2s^22p^3\,{}^2P^0-2s2p^4\,{}^2S_{1/2}$*
100	388.218	257,587	$2s^22p^3\,{}^2P^0-2s2p^4\,{}^2P_{3/2}$*
125	387.141	258,304	$2s^22p^3\,{}^2P^0-2s2p^4\,{}^2P_{1/2}$*
200*w*	358.721	278,768	$2s^22p^3\,{}^2D^0-2s2p^4\,{}^2P_{3/2}$* Blend C III
50	357.831	279,461	$2s^22p^3\,{}^2D^0_{3/2}-2s2p^4\,{}^2P_{1/2}$
3	294.390	339,686	$2s2p^4\,{}^4P_{1/2}-2s^22p^2(^3P)3p{}^4P^0_{1/2}$
3	294.100	340,020	$2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)3p{}^4P^0_{1/2}$
1	293.947	340,197	$2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)3p{}^4P^0_{3/2}$
5	293.649	340,543	$2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)3p{}^4P^0_{5/2}$
10	293.429	340,798	$2s2p^4\,{}^4P_{5/2}-2s^22p^2(^3P)3p{}^4P^0_{3/2}$
15	293.123	341,154	$2s2p^4\,{}^4P_{5/2}-2s^22p^2(^3P)3p{}^4P^0_{5/2}$
10	287.206	348,182	$2s2p^4\,{}^4P_{1/2}-2s^22p^2(^3P)3p{}^4S^0_{3/2}$
15	286.934	348,512	$2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)3p{}^4S^0_{3/2}$
15	286.688	349,104	$2s2p^4\,{}^4P_{5/2}-2s^22p^2(^3P)3p{}^4S^0_{3/2}$
8	248.004	403,219	$2s2p^4\,{}^4P_{1/2}-2s2p^3(^5S)3s{}^4S^0_{3/2}$
8	247.807	403,540	$2s2p^4\,{}^4P_{3/2}-2s2p^3(^5S)3s{}^4S^0_{3/2}$
10	247.422	404,168	$2s2p^4\,{}^4P_{5/2}-2s2p^3(^5S)3s{}^4S^0_{3/2}$
25	234.701	426,074	$2s^22p^3\,{}^2P^0-2s^22p^2(^3P)3s{}^2P_{1/2}$
25	234.316	426,774	$2s^22p^3\,{}^2P^0-2s^22p^2(^3P)3s{}^2P_{3/2}$
25	223.605	447,217	$2s^22p^3\,{}^2D^0_{3/2}-2s^22p^2(^3P)3s{}^2P_{1/2}$
25	223.241	447,946	$2s^22p^3\,{}^2D^0_{5/2}-2s^22p^2(^3P)3s{}^2P_{3/2}$
40	222.600	449,236	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)3s{}^2D_{5/2,\,3/2}$
5	218.766	457,109	$2s2p^4\,{}^4P_{1/2}-2s^22p^2(^3P)4p{}^4D^0_{1/2}$
25	218.643	457,367	$\left\{\begin{matrix}2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)4p{}^4D^0_{1/2}\\2s2p^4\,{}^4P_{1/2}-2s^22p^2(^3P)4p{}^4D^0_{3/2}\end{matrix}\right\}$
20*db*	218.483	457,702	$2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)4p{}^4D^0_{3/2}$
15	218.343	457,995	$2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)4p{}^4D^0_{5/2}$
(10)	218.184	458,329	$2s2p^4\,{}^4P_{5/2}-2s^22p^2(^3P)4p{}^4D^0_{3/2}$
(20)	218.131	458,440	$2s2p^4\,{}^4P_{1/2}-2s^22p^2(^3P)4p{}^4P^0_{1/2}$
(25)	217.830	459,074	$2s2p^4\,{}^4P_{5/2}-2s^22p^2(^3P)4p{}^4D^0_{7/2}$
(15)	217.777	459,185	$2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)4p{}^4P^0_{3/2}$
15	217.640	459,474	$\left\{\begin{matrix}2s2p^4\,{}^4P_{5/2}-2s^22p^2(^3P)4p{}^4P^0_{3/2}\\2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)4p{}^4P^0_{5/2}\end{matrix}\right\}$
15	217.337	460,115	$2s2p^4\,{}^4P_{5/2}-2s^22p^2(^3P)4p{}^4P^0_{5/2}$
15	215.843	463,300	$2s2p^4\,{}^4P_{1/2}-2s^22p^2(^3P)4p{}^4S^0_{3/2}$
3	215.711	463,583	$2s2p^4\,{}^4P_{3/2}-2s^22p^2(^3P)4p{}^4S^0_{3/2}$
(5)	215.396	464,261	$2s2p^4\,{}^4P_{5/2}-2s^22p^2(^3P)4p{}^4S^0_{3/2}$
150	212.556	470,464	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)3s{}^2D$
80	208.899	478,701	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)3s{}^4P_{1/2}$
100	208.734	479,079	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)3s{}^4P_{3/2}$
100	208.485	479,651	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)3s{}^4P_{5/2}$
5	204.908	488,024	$2s2p^4\,{}^4P_{1/2}-2s2p^3(^5S)3d{}^4D^0$
15	204.786	488,315	$2s2p^4\,{}^4P_{3/2}-2s2p^3(^5S)3d{}^4D^0$
25	204.531	488,923	$2s2p^4\,{}^4P_{5/2}-2s2p^3(^5S)3d{}^4D^0$
15	204.270	489,548	$2s^22p^3\,{}^2P^0-2s^22p^2(^1S)3s{}^2S_{1/2}$
50	194.623	513,814	$2s^22p^3\,{}^2P^0-2s^22p^2(^3P)3d{}^2P_{3/2}$
40	194.477	514,200	$2s^22p^3\,{}^2P^0-2s^22p^2(^3P)3d{}^2P_{1/2}$
100	194.276	514,732	$2s^22p^3\,{}^2P^0-2s^22p^2(^1S)3d{}^2D$
15	190.645	524,535	$2s^22p^3\,{}^2P^0-2s^22p^2(^3P)3d{}^2D_{3/2}$
25	190.565	524,755	$2s^22p^3\,{}^2D^0_{3/2}-2s^22p^2(^3P)3d{}^2D_{5/2}$
15	186.915	535,003	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)3d{}^2P_{3/2}$
5	186.787	535,369	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)3d{}^2P_{1/2}$
150	186.575	535,977	$2s^22p^3\,{}^2D^0-2s^22p^2(^1S)3d{}^2D$
( )	185.370	538,416	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)3d{}^2F_{5/2}$ (O V)
20	185.479	539,145	$2s^22p^3\,{}^2D^0_{5/2}-2s^22p^2(^3P)3d{}^2F_{7/2}$
12	183.247	545,712	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)3d{}^2D_{3/2}$
15	183.165	545,956	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)3d{}^2D_{5/2}$
( )	182.829	calc.	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)3d{}^2D$ (O IV)
20	181.691	550,506	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)3d{}^2P_{1/2}$
20	181.614	550,618	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)3d{}^2P_{3/2}$
15	180.402	554,318	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)3d{}^2S_{1/2}$
80	177.161	564,458	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)3d{}^2F$
50	176.007	568,159	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)3d{}^2D$
8	174.920	571,690	$2s^22p^3\,{}^2D^0_{3/2}-2s^22p^2(^1D)3d{}^2P_{1/2}$
10	174.880	571,821	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)3d{}^2P_{3/2}$
3	174.303	573,714	$2s^22p^3\,{}^2P^0-2s^22p^2(^3P)4s{}^2P_{1/2}$
( )	174.120	calc.	$2s^22p^3\,{}^2P^0-2s^22p^2(^3P)4s{}^2P_{3/2}$ (O IV)
80	172.620	579,307	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)3d{}^4P_{5/2}$
50	172.525	579,626	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)3d{}^4P_{3/2}$} Resolved
40	172.492	579,737	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)3d{}^4P_{1/2}$} in third
2	168.101	594,880	$2s^22p^3\,{}^2D^0_{3/2}-2s^22p^2(^3P)4s{}^2P_{1/2}$ order
5	167.921	595,518	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)4s{}^2P_{3/2}$
( )	166.113	calc.	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)4s{}^2D$ (O V)
(2)	163.602	611,239	$2s^22p^3\,{}^2P^0-2s^22p^2(^3P)4d{}^2D_{3/2}$
12	163.562	611,389	$2s^22p^3\,{}^2P^0_{3/2}-2s^22p^2(^3P)4d{}^2D_{5/2}$
10	160.471	623,165	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)4s{}^2D$
15	158.822	629,636	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)4d{}^2F_{5/2}$
15	158.646	630,302	$2s^22p^3\,{}^2D^0_{5/2}-2s^22p^2(^3P)4d{}^2F_{7/2}$
(2)	158.105	632,491	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)4d{}^2D_{3/2}$
5	158,063	632,659	$2s^22p^3\,{}^2D^0-2s^22p^2(^3P)4d{}^2D_{5/2}$
2	157.862	633,465	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)4s{}^4P_{1/2}$
3	157.781	633,790	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)4s{}^4P_{3/2}$
5	157.626	634,413	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)4s{}^4P_{5/2}$
3	156.873	637,458	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)4d{}^2D$
5*h*	156.480	639,059	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)4d{}^2P$
5	154.488	647,299	$2s^22p^3\,{}^2P^0-2s^22p^2(^1S)4d{}^2D$
15	152.231	656,896	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)4d{}^2F$
15	151.817	658,662	$2s^22p^3\,{}^2D^0-2s^22p^2(^1S)4d{}^2D$
( )	151.456	calc.	$2s^22p^3\,{}^2D^0-2s^22p^2(^1S)4d{}^2P$ (O V)
1	150.931	662,554	$2s^22p^3\,{}^2P^0-2s^22p^2(^1D)5s{}^2D$
2	149.589	668,498	$2s^22p^3\,{}^2D^0-2s^22p^2(^1S)4d{}^2D$
4	148.942	671,402	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)4d{}^4P_{5/2}$
3	148.787	672,102	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)4d{}^4P_{3/2}$
1	148.660	672,676	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)4d{}^4P_{1/2}$
2*db*	146.262	683,704	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)5s{}^2D$
1	144.288	693,106	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)5s{}^4P_{1/2}$
2	144.151	693,717	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)5s{}^4P_{3/2}$
2	144.019	694,353	$2s^22p^3\,{}^4S^0_{3/2}-2s^22p^2(^3P)5s{}^4P_{5/2}$
3	142.929	699,648	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)5d{}^2F$
3	140.127	713,638	$2s^22p^3\,{}^2D^0-2s^22p^2(^1D)6s{}^2D$

* Identified by Boyce.

operate at higher pressures. However, quadrupling the pressure appeared to make the discharge brighter so that shorter exposures were needed, without changing the degree of excitation appreciably.

Ne IV

The spectrum of Ne IV was very well developed, the strongest lines on the plates being due usually to Ne IV. The identifications by Boyce were corroborated and the analysis extended to include 117 lines which arise from transitions among 70 levels. The lines identified as Ne IV are given in Table I. The intensities and characteristics of the lines are given in the first column; in the second the wave-lengths in angstroms; in the third the wave numbers in reciprocal centimeters, and in the fourth the assignment. An *h* after the intensity indicates that the line was not sharp. Parentheses, ( ), around the intensity or in place of an intensity estimate indicated that the line was partially or completely obscured by neighboring lines. The symbol *db* after an intensity indicates that the line appeared double but unresolved. A *w* indicates that the line was very wide. The abbreviation calc. in place of a wave number in the second column indicates that the wave-length was calculated from the position of the levels concerned as determined by experimental evidence and that the emission line was not observed.

Most of the assignments seem to be quite certain from their agreement with the predicted positions of the levels, and with the predicted multiplet separations, the intensities of the lines relative to neighboring lines, and the consistency of the assignments with each other.

The lowest configurations of Ne IV are the $2s^22p^3$, giving rise to the lowest terms of both the doublet and the quartet systems; the $2s2p^4$ and the $2p^5$. The higher even terms are due to the configurations $2s^22p^2ns$ and $2s^22p^2nd$. These have been fairly well established for $n=3$, 4. A few levels for which $n=5$ have been found and in the doublet spectrum one identification for $n=6$ is made. The line identified as arising from a transition between the $2p^2(^1D)6s\,^2D$ levels and the low $^2D^0$ level fits well in a Ritz series formula for the $2s^22p^3\,^2D^0-2s^22p^2(^1D)ns\,^2D$ series and is probably correctly assigned.

It is surprising that so little evidence as to the positions of the higher odd levels in the doublet system can be found. Although several transitions between high odd levels and lower even levels should give lines of considerable strength in the region investigated, none of these has been certainly identified in the doublet spectrum.

Although special efforts were made to resolve the groups of lines at λλ469.8 and 521.8, no resolution beyond that obtained by Boyce resulted. The assignments of values in these groups are accordingly those given by Boyce as are the wave-lengths of the λ469 group which appeared as a single very broad band on our plates. The intensities and the wave-lengths of the 521 group are those determined in this investigation. The average value obtained from eleven pairs of lines for the separation of the $2s^22p^3\,^2D^0$ levels from the $2s^22p^3\,^2P^0$ levels is 21,205 cm^{-1}. This is taken as the separation of the centers of gravity and the positions of the levels are given accordingly, with separations according to Boyce's estimates. The term table for the doublet system is given in Table II. The position of the $2s^22p^3\,^2D^0$ levels relative to the ground state of Ne V is determined from the limit of the $2s^22p^3\,^2D^0-2s^22p^2(^1D_2)ns\,^2D$ series as determined with a Ritz formula, and the observed $^1D_2-{}^3P_0$ separation in Ne V. The limit of the series is 773,459 cm^{-1}. The $^1D_2$ level is found to be 30,294 cm^{-1} above the $^3P_0$ level. The value 743,165 cm^{-1} thus arrived at is taken to be the position of the center of gravity of the $2s^22p^3\,^2D^0{}_{5/2,\,3/2}$ pair. No combinations between the doublet and quartet systems have been observed.

In the quartet system the transitions from high levels of even parity to the low $^4S^0$ are well established. The positions of the $2p^2(^3P)nd\,^4D$ and ^4F levels are still undetermined. Here the positions of the high odd levels seem quite

TABLE II. *Term table for the doublet system of* Ne IV.

Config.	Term	cm^{-1}	Config.	Term	cm^{-1}	Config.	Term	cm^{-1}	Config.	Term	cm^{-1}
$2s^22p^3$	$^2D^0_{5/2}$	38,540	$2p^5$	$^2P^0_{1/2}$	483,275	$2s^22p^2(^3P)3d$	$^2D_{5/2}$	584,508	$2s^22p^2(^3P)4d$	$^2F_{7/2}$	668,842
	$^2D^0_{3/2}$	38,565	$2s^22p^2(^3P)3s$	$^2P_{1/2}$	485,805	$2s^22p^2(^1D)3d$	^2F	603,007		$^2D_{3/2}$	671,017
	$^2P^0_{1/2}$	59,747		$^2P_{3/2}$	486,507		^2D	606,708		$^2D_{5/2}$	671,177
	$^2P^0_{3/2}$	59,757	$2s^22p^2(^1D)3s$	$^2D_{5/2,3/2}$	509,001		$^2P_{1/2}$	610,258	$2s^22p^2(^1D)4d$	^2F	695,445
$2s2p^4$	$^2D_{5/2}$	251,397	$2s^22p^2(^1S)3s$	$^2S_{1/2}$	549,302		$^2P_{3/2}$	610,371		^2D	697,212
	$^2D_{3/2}$	251,413	$2s^22p^2(^3P)3d$	$^2P_{3/2}$	573,558		$^2S_{1/2}$	614,072		^2P	698,813
	$^2S_{1/2}$	296,941		$^2P_{1/2}$	573,943	$2s^22p^2(^3P)4s$	$^2P_{1/2}$	633,456	$2s^22p^2(^1S)4d$	^2D	707,050
	$^2P_{3/2}$	317,341	$2s^22p^2(^1s)3d$	^2D	574,505		$^2P_{3/2}$	634,065	$2s^22p^2(^1D)5s$	^2D	722,280
	$^2P_{1/2}$	318,042		$^2F_{5/2}$	576,965	$2s^22p^2(^1D)4s$	^2D	661,714	$2s^22p^2(^1D)5d$	^2F	738,197
$2p^5$	$^2P^0_{3/2}$	482,213		$^2F_{7/2}$	577,685	$2s^22p^2(^3P)4d$	$^2F_{5/2}$	668,185	$2s^22p^2(^1D)6s$	^2D	752,187
				$^2D_{3/2}$	584,275						

TABLE III. *Term table for the quartet system of* Ne IV.

Config.	Term	cm^{-1}	Config.	Term	cm^{-1}	Config.	Term	cm^{-1}	Config.	Term	cm^{-1}
$2s^22p^3$	$^4S^0_{3/2}$	0	$2s^22p^2(^3P)3p$	$^4P^0_{3/2}$	524,676	$2s^22p^2(^3P)4s$	$^4P_{3/2}$	633,790	$2s^22p^2(^3P)4p$	$^4P^0_{5/2}$	643,975
$2s2p^4$	$^4P_{5/2}$	183,860		$^4P^0_{5/2}$	525,017		$^4P_{5/2}$	634,413		$^4S^0_{3/2}$	648,060
	$^4P_{3/2}$	184,477		$^4S^0_{3/2}$	532,978	$2s^22p^2(^3P)4p$	$^4D^0_{1/2}$	641,908	$2s^22p^2(^3P)4d$	$^4P_{5/2}$	671,402
	$^4P_{1/2}$	184,799	$2s^22p^2(^3P)3d$	$^4P_{5/2}$	579,307		$^4D^0_{3/2}$	642,184		$^4P_{3/2}$	672,102
$2s^22p^2(^3P)3s$	$^4P_{1/2}$	478,701		$^4P_{3/2}$	579,626		$^4D^0_{5/2}$	642,472		$^4P_{1/2}$	672,676
	$^4P_{3/2}$	479,079		$^4P_{1/2}$	579,737		$^4D^0_{7/2}$	642,934	$2s2p^3(^5S)3d$	$^4D^0$	672,799
	$^4P_{5/2}$	479,651	$2s2p^3(^5S)3s$	$^4S^0_{3/2}$	588,021	$2s^22p^2(^3P)4p$	$^4P^0_{1/2}$	643,239	$2s^22p^2(^3P)5s$	$^4P_{1/2}$	693,106
$2s^22p^2(^3P)3p$	$^4P^0_{1/2}$	524,391	$2s^22p^2(^3P)4s$	$^4P_{1/2}$	633,465		$^4P^0_{3/2}$	643,672		$^4P_{3/2}$	693,717
										$^4P_{5/2}$	694,353

TABLE IV. *Lines identified as belonging to the spectrum of* Ne V.

INT.	λ A.U.	ν CM⁻¹	TRANSITION
80	572.336	174,722	$2s^22p^2\,{}^3P_2-2s2p^3\,{}^3D^0_3$
25	572.106	174,793	$2s^22p^2\,{}^3P_2-2s2p^3\,{}^3D^0_2$
50	569.830	175,491	$2s^22p^2\,{}^3P_1-2s2p^3\,{}^3D^0_2$
25	569.759	175,513	$2s^22p^2\,{}^3P_1-2s2p^3\,{}^3D^0_1$
40	568.418	175,927	$2s^22p^2\,{}^3P_0-2s2p^3\,{}^3D^0_1$
( )	488.940	calc.	$2s^22p^3\,{}^3P^0_{2,1,0}-2p^4\,{}^3P_2$ (Ne III)
3*w*	487.070	205,309	$2s2p^3\,{}^3P^0_{2,1}-2p^4\,{}^3P_1$
50	482.987	207,045	$2s^22p^2\,{}^3P_2-2s2p^3\,{}^3P^0_{2,1}$
25	481.361	207,744	$2s^22p^2\,{}^3P_1-2s2p^3\,{}^3P^0_{2,1}$
15	481.281	207,779	$2s^22p^2\,{}^3P_1-2s2p^3\,{}^3P^0_0$
25	480.406	208,157	$2s^22p^2\,{}^3P_0-2s2p^3\,{}^3P^0_1$
5	422.347	236,772	$2s2p^3\,{}^3D^0_{2,1}-2p^4\,{}^3P_2$
15	422.214	236,847	$2s2p^3\,{}^3D^0_3-2p^4\,{}^3P_2$
15	420.951	237,557	$2s2p^3\,{}^3D^0_{2,1}-2p^4\,{}^3P_1$
10	420.386	237,876	$2s2p^3\,{}^3D^0_1-2p^4\,{}^3P_0$
25	416.834	239,904	$2s^22p^2\,{}^1S_0-2s2p^3\,{}^1P^0_1$
80	416.198	240,270	$2s^22p^2\,{}^1D_2-2s2p^3\,{}^1D^0_2$
100	365.594	273,526	$2s^22p^2\,{}^1D_2-2s2p^3\,{}^1P^0_1$
50	359.385	278,253	$2s^22p^2\,{}^3P_2-2s2p^3\,{}^3S^0_1$ Blend O III
50	358.472	278,962	$2s^22p^2\,{}^3P_1-2s2p^3\,{}^3S^0_1$ Blend N III
40	357.955	279,365	$2s^22p^2\,{}^3P_0-2s2p^3\,{}^3S^0_1$
2	195.621	511,193	$2s2p^3\,{}^3P^0_1-2s2p^2({}^4P)3s\,{}^3P_0$
3	195.553	511,370	$2s2p^3\,{}^3P^0_{2,1}-2s2p^2({}^4P)3s\,{}^3P_1$
5	195.368	511,854	$2s2p^3\,{}^3P^0_{2,1}-2s2p^2({}^4P)3s\,{}^3P_2$
10	184.730	541,331	$2s^22p^2\,{}^1S_0-2s^22p({}^2P)3s\,{}^1P^0_1$
50	173.932	574,937	$2s^22p^2\,{}^1D_2-2s^22p({}^2P)3s\,{}^1P^0_1$
5	167.921	595,518	$2s^22p^2\,{}^3P_2-2s^22p({}^2P)3s\,{}^3P^0_1$
5	167.837	595,816	$2s^22p^2\,{}^3P_1-2s^22p({}^2P)3s\,{}^3P^0_0$
25	167.670	596,410	$2s^22p^2\,{}^3P_2-2s^22p({}^2P)3s\,{}^3P^0_2$ $2s^22p^2\,{}^3P_1-2s^22p({}^2P)3s\,{}^3P^0_1$
3	167.610	596,623	$2s^22p^2\,{}^3P_0-2s^22p({}^2P)3s\,{}^3P^0_1$
15	167.483	597,076	$2s^22p^2\,{}^3P_1-2s^22p({}^2P)3s\,{}^3P^0_2$
8	164.294	608,665	$2s^22p^2\,{}^5S^0_2-2s^22p({}^4P)3s\,{}^5P_1$
10	164.145	609,217	$2s^22p^2\,{}^5S^0_2-2s^22p({}^4P)3s\,{}^5P_2$ (O V)
10	164.023	609,670	$2s^22p^2\,{}^5S^0_2-2s^22p({}^4P)3s\,{}^5P_3$
2	156.610	638,529	$2s^22p^2\,{}^1S_0-2s^22p({}^2P)3d\,{}^1P^0_1$
12	151.424	660,397	$2s^22p^2\,{}^1D_2-2s^22p({}^2P)3d\,{}^1D^0_2$(O V, Ne IV)
3	148.787	672,102	$2s^22p^2\,{}^1D_2-2s^22p({}^2P)3d\,{}^1P^0_1$
15	147.132	679,662	$2s^22p^2\,{}^1D_2-2s^22p({}^2P)3d\,{}^1F^0_3$
15	143.344	697,623	$2s^22p^2\,{}^3P_2-2s^22p({}^2P)3d\,{}^3D^0_3$
10	143.273	697,968	$2s^22p^2\,{}^3P_1-2s^22p({}^2P)3d\,{}^3D^0_2$
5	143.219	698,231	$2s^22p^2\,{}^3P_0-2s^22p({}^2P)3d\,{}^3D^0_1$
15	142.724	700,653	$2s^22p^2\,{}^3P_2-2s^22p({}^2P)3d\,{}^3P^0_2$
4	142.661	700,962	$2s^22p^2\,{}^3P_2-2s^22p({}^2P)3d\,{}^3P^0_1$
10	142.503	701,746	$2s^22p^2\,{}^3P_{1,0}-2s^22p({}^2P)3d\,{}^3P^0_{2,1,0}$
10	142.441	702,045	$2s^22p^2\,{}^3P_1-2s^22p({}^2P)3d\,{}^3P^0_0$
15	140.791	710,273	$2s2p^3\,{}^5S^0_2-2s2p^2({}^4P)3d\,{}^5P_3$
15	140.757	710,444	$2s2p^3\,{}^5S^0_2-2s2p^2({}^4P)3d\,{}^5P_2$
5	140.716	710,651	$2s2p^3\,{}^5S^0_2-2s2p^2({}^4P)3d\,{}^5P_1$
2	136.215	734,134	$2s^22p^3\,{}^5S^0_2-2s2p^2({}^4P)4s\,{}^5P$
5	129.034	774,990	$2s^22p^2\,{}^1D_2-2s^22p({}^2P)4s\,{}^1P^0_1$
1	128.793	776,440	$2s2p^3\,{}^5S^0_2-2s2p^2({}^4P)4d\,{}^5P$?
2	125.830	794,723	$2s^22p^2\,{}^3P-2s^22p({}^2P)4s\,{}^3P^0$
3	123.712	808,329	$2s^22p^2\,{}^1D_2-2s^22p({}^2P)4d\,{}^1D^0_2$
20*db*	122.520	816,913	$2s^22p^2\,{}^1D_2-2s^22p({}^2P)4d\,{}^1F^0_3$ Also Ne VI
1	118.841	841,460	$2s^22p^2\,{}^3P-2s^22p({}^2P)4d\,{}^3D^0$
5	118.715	842,354	$2s^22p^2\,{}^3P-2s^22p({}^2P)4d\,{}^3P^0$

certainly determined by the transitions into the $2s2p^4\;{}^4P$ levels. However, the transitions from the $3p\;{}^4D^0$ levels seem to be covered by impurity lines, and the exact positions of the $4p\;{}^4D^0_{5/2}$ and ${}^4P^0_{1/2}$ are somewhat doubtful due to overlapping by neighboring lines. Table III gives the term table for the quartet system. A Ritz formula fitted to the $2s^22p^3\;{}^4S^0_{3/2}-2s^22p^2({}^3P_2)ns\;{}^4P_{5/2}$ series gives the limit 782,826 cm^{-1}. This locates the ${}^4S^0_{3/2}$ level 781,714 cm^{-1} below the $2s^22p^2\;{}^3P_0$ level of Ne V, giving an ionization potential of 96.43 volts for Ne IV.

Ne V

The spectrum of Ne V was much weaker than that of Ne IV. Table IV includes 56 lines which have been assigned to transitions among 47 levels. The arrangement and notation of the table are the same as for Table I. The notations after the assignments indicate that the line is classified in two spectra and that the lines of another spectrum partially obscure the present line. Although many of the levels are determined from only one line the assignments appear fairly safe, with a few exceptions. The $2s^22p^2\;{}^1D_2-2s^22p({}^2P)4d\;{}^1F^0_3$ assignment is that line of a pair which gives best agreement with the predicted value. The relative intensities of the two groups of lines identified as $2s^22p^2\;{}^3P-2s^22p({}^2P)4d\;{}^3D^0$ and ${}^3P^0$ appear out of proportion. It may be that the shorter wave-length group is in coincidence with some other lines.

Certain lines which should be included in this spectrum are missing because overlapping lines make their accurate identification impossible. In this group are the transitions from the $2p^4\;{}^1D_2$ and ${}^1S_0$ levels to the $2s2p^3\;{}^1D^0_2$ and ${}^1P^0_1$ levels, which are covered by second-order O III lines, and the $2s2p^3\;{}^3P^0-2s2p^2({}^4P)3d\;{}^3P$ lines which are obscured by the strong O V lines at λ166A.

The term scheme of the singlet system is given in Table V; that of the triplet system in Table VI, and that of the quintet system in Table VII. The absolute value of the $2s^22p^2\;{}^3P_0$ level relative to the $2s^22p\;{}^2P^0_{1/2}$ level of Ne VI is estimated from the $2s^22p^2\;{}^3P_2-2s^22p({}^2P_{3/2})nd\;{}^3P^0$ and ${}^3D^0$ series, for each of which two members are observed, to be 1,019,950 cm^{-1}. This corresponds to an ionization potential of 125.8 volts. From the intersystem combinations ${}^3P_1-{}^1D_2$, ${}^3P_2-{}^1D_2$ ob-

TABLE V. *Term table for the singlet system of* Ne V.

CONFIG.	TERM	CM⁻¹	CONFIG.	TERM	CM⁻¹
$2s^22p^2$	${}^1D_2$	30,294	$2s^22p({}^2P)3d$	${}^1D^0_2$	690,691
	${}^1S_0$	63,900		${}^1P^0_1$	702,412
$2s2p^3$	${}^1D^0_2$	270,564		${}^1F^0_3$	709,956
	${}^1P^0_1$	303,812	$2s^22p({}^2P)4s$	${}^1P^0_1$	805,284
$2s^22p({}^2P)3s$	${}^1P^0_1$	605,231	$2s^22p({}^2P)4d$	${}^1D^0_2$	838,623
				${}^1F^0_3$	847,207?

TABLE VI. *Term table for the triplet system of* Ne V.

CONFIG.	TERM	CM^{-1}	CONFIG.	TERM	CM^{-1}	CONFIG.	TERM	CM^{-1}	CONFIG.	TERM	CM^{-1}
$2s^22p^2$	$^3P_0$	0	$2s2p^3$	$^3P^0_0$	208,193	$2s^22p(^2P)3s$	$^3P^0_2$	597,492	$2s2p^2(^4P)3s$	$^3P_0$	719,350
	$^3P_1$	414		$^3S^0_1$	279,365	$2s^22p(^2P)3d$	$^3D^0_1$	698,231		$^3P_1$	719,527
	$^3P_2$	1112	$2p^4$	$^3P_2$	412,681		$^3D^0_2$	698,382		$^3P_2$	720,011
$2s2p^3$	$^3D^0_3$	175,834		$^3P_1$	413,466		$^3D^0_3$	698,735	$2s^22p(^2P)4s$	$^3P^0$	795,279
	$^3D^0_2$	175,905		$^3P_0$	413,803		$^3P^0_2$	701,765	$2s^22p(^2P)4d$	$^3D^0$	842,020
	$^3D^0_1$	175,927	$2s^22p(^2P)3s$	$^3P^0_0$	596,230		$^3P^0_1$	702,074		$^3P^0$	842,914
	$\left.\begin{matrix}^3P^0_2\\ ^3P^0_1\end{matrix}\right\}$	208,157		$^3P^0_1$	596,626		$^3P^0_0$	702,459			

TABLE VII. *Term table for the quintet system of* Ne V.

CONFIG.	TERM	CM^{-1}	CONFIG.	TERM	CM^{-1}
$2s2p^3$	$^5S^0_2$	86,700	$2s2p^2(^4P)3d$	$^5P_2$	797,144
$2s2p^2(^4P)3s$	$^5P_1$	695,365		$^5P_1$	797,351
	$^5P_2$	695,917	$2s2p^2(^4P)4s$	^5P	820,834
	$^5P_3$	696,370	$2s2p^2(^4P)4d$	^5P	863,140
$2s2p^2(^4P)3d$	$^5P_3$	796,973			

served in the spectra of gaseous nebulae as given by Bowen,[9] the $2s^22p^2\ ^1D_2$ level is located 30,294 cm^{-1} above the $2s^22p^2\ ^3P_0$ level, giving the value 989,656 cm^{-1} for its position relative to the $2s^22p^2P^0_{1/2}$ level of Ne VI. From isoelectronic sequence data the $2s2p^3\ ^5S^0_2$ level is estimated to be 86,700±300 cm^{-1} above the $2s^22p^2\ ^3P_0$ level. No intersystem combinations have been identified in the extreme ultraviolet.

Ne VI

A few of the stronger lines of Ne VI have been identified and are recorded in Table VIII. These make possible the location of the levels of lower excitation relative to the ground state $^2P^0$. The positions of the levels and the fine structure separations are in good agreement with the predicted values. Two unresolved groups of lines have been identified as belonging to the quartet system. It is unfortunate that the $2p^3\ ^4S^0_{3/2}$ level was not located. Transitions between this level and the low $2s2p^2\ ^4P$ should produce lines at about 220,000 cm^{-1} and from this group the splitting of the ^4P could be evaluated.

The resulting term table for the doublet system is given in Table IX and for the quartet system in Table X. The value of the $2s^22p^2P^0_{1/2}$ is estimated from isoelectronic sequence data to be 1,274,000±1000 cm^{-1}. This gives an ionization potential of 157 volts for Ne VI. The $2s2p^2\ ^4P_{1/2}$

TABLE IX. *Term table for the doublet system of* Ne VI.

CONFIG.	TERM	CM^{-1}	CONFIG.	TERM	CM^{-1}
$2s^22p$	$^2P^0_{1/2}$	0	$2s^2(^1S_0)3s$	$^2S_{1/2}$	722,610
	$^2P^0_{3/2}$	1316	$2s^2(^1S_0)3p$	$^2P^0_{1/2}$	763,096
$2s2p^2$	$^2D_{5/2}$	178,998		$^2P^0_{3/2}$	763,385
	$^2D_{3/2}$	179,020	$2s^2(^1S_0)3d$	^2D	816,405
	$^2S_{1/2}$	232,587	$2s2p(^3P)3p$	^2P	878,852
	$^2P_{1/2}$	249,292		^2S	900,408
	$^2P_{3/2}$	250,112		^2D	906,373

TABLE X. *Term table for the quartet system of* Ne VI.

CONFIG.	TERM	CM^{-1}
$2s2p^2$	^4P	99,300
$2s2p(^3P)3s$	$^4P^0$	834,113
$2s2p(^3P)3d$	$^4D^0$	924,791

TABLE VIII. *Lines identified as belonging to the spectrum of* Ne VI.

INT.	λ A.U.	ν CM^{-1}	TRANSITION	INT.	λ A.U.	ν CM^{-1}	TRANSITION
15	562.805	177,682	$2s^22p^2P^0_{3/2}-2s2p^2\ ^2D_{5/2}$	2	171.212	584,071	$2s2p^2\ ^2D_{3/2}-2s^2(^1S_0)3p^2P^0_{1/2}$
1	562.735	177,704	$2s^22p^2P^0_{3/2}-2s2p^2\ ^2D_{3/2}$	5*w*	171.114	584,405	$2s2p^2\ ^2D_{5/2,3/2}-2s^2(^1S_0)3p^2P^0_{3/2}$
5	558.595	179,021	$2s^22p^2P^0_{1/2}-2s2p^2\ ^2D_{3/2}$	3	138.630	721,344	$2s^22p^2P^0_{3/2}-2s^2(^1S_0)3s^2S_{1/2}$
5	432.393	231,271	$2s^22p^2P^0_{3/2}-2s2p^2\ ^2S_{1/2}$	3	138.397	722,559	$2s^22p^2P^0_{1/2}-2s^2(^1S_0)3s^2S_{1/2}$
( )	429.947	calc.	$2s^22p^2P^0_{1/2}-2s2p^2\ ^2S_{1/2}$ (O II)	4	136.089	734,813	$2s2p^2\ ^4P-2s2p(^3P)3s^4P^0$
10	403.262	247,978	$2s^22p^2P^0_{3/2}-2s2p^2\ ^2P_{1/2}$	10*w*	122.686	815,089	$2s^22p^2P^0_{3/2}-2s^2(^1S_0)3d^2D$
25	401.939	248,794	$2s^22p^2P^0_{3/2}-2s2p^2\ ^2P_{3/2}$	20*db*	122.520	816,913	$2s^22p^2P^0_{1/2}-2s^2(^1S_0)3d^2D$ (also Ne V)
15	401.138	249,291	$2s^22p^2P^0_{1/2}-2s2p^2\ ^2P_{1/2}$	5*h*	121.140	825,491	$2s2p^2\ ^4P-2s2p(^3P)3d^4D^0$
5	399.820	250,113	$2s^22p^2P^0_{1/2}-2s2p^2\ ^2P_{3/2}$	1	113.870	878,194	$2s2p^2\ ^2P^0-2s2p(^3P)3p^2P$
2	194.936	512,989	$2s2p^2\ ^2P_{3/2}-2s^2(^1S_0)3p^2P^0_{1/2}$	1	111.142	899,750	$2s2p^2\ ^2P^0-2s2p(^3P)3p^2S$
2	194.839	513,244	$2s2p^2\ ^2P_{3/2}-2s^2(^1S_0)3p^2P^0_{3/2}$	2	110.410	905,715	$2s2p^2\ ^2P^0-2s2p(^3P)3p^2D$
25*db*	194.625	513,808	$2s2p^2\ ^2P_{1/2}-2s^2(^1S_0)3p^2P^0_{1/2}$ (O V)				
3	188.424	530,718	$2s2p^2\ ^2S_{1/2}-2s^2(^1S_0)3p^2P^0_{3/2}$ (O ?)				
	188.498	calc.	$2s2p^2\ ^2S_{1/2}-2s^2(^1S_0)3p^2P^0_{1/2}$				

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[9] I. S. Bowen, Rev. Mod. Phys. **8**, 55 (1936.)

level is estimated to be 99,300±500 cm^{-1} above the $2s^22p\ ^2P^0{}_{1/2}$ level.

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A New Mass Spectrograph and the Isotopic Constitution of Nickel

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A new double focusing mass spectrograph which has a 90° electric field and a 60° magnetic field has been constructed and used to determine the isotopic constitution of nickel. The instrument and the null method of measurement are described. The isotopic constitution of nickel is found to be $\text{Ni}^{58}-62.8$ percent $\text{Ni}^{60}-29.5$ percent, $\text{Ni}^{61}-1.7$ percent, $\text{Ni}^{62}-4.7$ percent, $\text{Ni}^{64}-1.3$ percent.

INTRODUCTION

THE published values of the abundance ratios among the isotopes of nickel have for some time shown considerable discrepancies. Aston[1] found Ni^{61} to be 1.7 percent of the total and failed to find Ni^{64}. De Gier and Zeeman,[2] who used the parabola method of positive ion analysis, failed to find Ni^{61}, probably because of the low resolving power of their instrument, but found Ni^{64} to constitute 0.9 percent of the total. Lub,[3] using a similar apparatus, also found Ni^{64} to be 0.9 percent of the total, but found Ni^{61}, which he estimated to be 0.1 percent of the total. Dempster[4] published a photograph of the mass spectrum of nickel in which it appeared that the abundance of Ni^{61} was approximately equal to the abundance of Ni^{64}.

These results were all obtained from photographic observations. Dempster used an oscillating spark between nickel electrodes as an ion source. The others all used a discharge tube containing nickel carbonyl. The organic compounds of the C_5 group, present in the latter case, may lead to erroneous estimates of the relative intensities of the nickel lines by their superposition on the nickel lines.

APPARATUS

A new double focusing mass spectrograph has been constructed. The design of this instrument is based on the theory published by R. Herzog.[5] A radial electric field is used as an energy analyzer in this instrument. The mean orbit radius in this field is ten cm and the deflection of the beam is 90°. Guard plates, which are applied at the ends of the field to reduce the stray field, are cut so that they do not interfere with the passage of the beam. A magnetic field serves as a momentum analyzer and gives the mass dispersion. The mean radius of the orbits in this field is 16.6 cm and the beam is deflected 60°.

In Herzog's paper the fundamental focusing condition is given by

$$(l'-g')(l''-g'')=f^2. \tag{1}$$

Here l' is the distance from the source slit to the edge of the field, measured along the orbit, and g'' is the distance beyond the field at which an originally parallel bundle of rays meet; l'' is the distance beyond the field at which the orbits intersect or focus. g' is the distance from the field to the point from which diverge orbits that are parallel after passing through the field. f is the focal length. Continuing in Herzog's notation, we

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[1] F. W. Aston, Proc. Roy. Soc. **149**, 396 (1935).

[2] J. de Gier and P. Zeeman, Proc. K. Akad. Amst. **38.8**, 810 (1935).

[3] W. A. Lub, Proc. K. Akad. Amst. **42.3**, 253 (1939).

[4] A. J. Dempster, Phys. Rev. **50**, 98 (1936).

[5] R. Herzog, Zeits. f. Physik **89**, 447 (1934).