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The Stark Effect in Argon and Krypton

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[Plates 5 and 6]

Introduction

An investigation of the Stark effect in argon and krypton by the Lo Surdo method has been carried out by Ryde and published in final form in 1934. With moderate dispersion he observed displacements and splitting of 45 normal levels for argon and 60 for krypton at maximum fields which varied from 55 to 125 kV/cm. in different exposures. Electric combination lines were reported to be scarce in argon and numerous in krypton. Digests of the work are presented by Ryde in the form of tables intended to give the displacements at 100 kV/cm. These have been compiled by graphical interpolation or from single observations on the assumption that the displacement is proportional to the square of the field.

We have examined with great care the entire evidence as published and conclude that the displacements and the number of sub-levels for certain terms at 100 kV/cm. need correction while others should be omitted from the list. These will be given in detail in our discussion.

In the present investigation Stark effects have been observed for 86 normal levels in argon and 75 in krypton at exactly 100 kV/cm. Seven levels in argon and six in krypton have been found to reverse the directions of their displacements with increasing field. Energy level diagrams are provided which show the normal and displaced positions of the levels, and lend some assistance to an understanding of many effects. While electric combination lines are less numerous in argon than in krypton, the positions of the initial levels concerned are such that they play a more interesting role in the above-mentioned reversals. A number of lines for which Meggers, de Bruin, and Humphreys offered a choice in regard to classifications have been identified from their behaviour in the field.

The Normal Spectrum in the Rare Gases

Following the publication of the analysis of the neon arc spectrum, Ne I, by Paschen in 1919, other workers have classified many of the terms of the remaining rare gases. Since the spectral terms of all the inert gases arise from similar electron configurations and the notation introduced by Paschen is applied to all, the spectra of argon and krypton will be discussed together.

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The first spectrum of argon, A I, has been analysed by Meissner (1926, 1927) and by Saunders (1926); the second spectrum, A II, by Rosenthal (1930). In 1929 Gremmer published a short account of the krypton arc spectrum, which has since been analysed very completely by Meggers, de Bruin, and Humphreys (1931). The analysis of both of these arc spectra has been extended by Rasmussen (1932), who identified a number of new terms in the diffuse and Bergman series and changed the values of a few others. The ionized spectrum of krypton, Kr II, has been analysed by de Bruin, Meggers, and Humphreys (1933).

When a rare gas atom is excited or ionized, it is commonly one of the more loosely-bound p electrons that is excited or removed, leaving the core of the atom with the configuration s^2p^5. Since for a p electron, $l = 1$, $s = \frac{1}{2}$, this core gives rise to an inverted doublet $^2P_{\frac{3}{2},\frac{1}{2}}$. The terms representing the excited states of the neutral atom may thus be derived by adding s, p, d, etc., electrons to the terms $^2P_{\frac{3}{2},\frac{1}{2}}$. As a result of j, j-coupling the J values and the spectral terms resulting from the addition of an electron of type s, p, d, and f, respectively, are shown in Table I.

Due to the large interval $^2P_{\frac{3}{2},\frac{1}{2}}$, these levels fall into two groups, the larger group approaching the lower limit $^2P_{\frac{3}{2}}$. Before these two limits were identified, the difference between them appeared as a displacement constant which had to be added to certain terms before they would fit a Ritz formula. This was the origin of Paschen's "reduced terms" (Paschen, 1920). The interval between the limits increases with the atomic number. In neon it amounts to 782 cm.$^{-1}$, while in argon, krypton, and xenon it is 1431, 5371, and 9621 cm.$^{-1}$ respectively.

Table I—Terms of Argon and Krypton

	With higher limit					With lower limit					
j	0	1	2	3	4	0	1	2	3	4	5
Argon	s_3	s_2					s_4	s_5			
	p_1	p_2	p_3			p_5	p_7	p_6	p_9		
		p_4					p_{10}	p_8			
		s'_1	s''_1	s'''_1		d_6	d_2	d''_1	d'_1	d'_4	
			s''''_1				d_5	d_3	d_4		
			f'_1	f'_2	f'_4		f_1, (X)	f_2	f_3	f_4, (U)	f_8
				f'_3				f_5, (Y)	f_6, (W)	f_7	
Krypton	s_3	s_2					s_4	s_5			
	p_1	p_2	p_3			p_5	p_7	p_6	p_9		
		p_4					p_{10}	p_8			
		s'_1	s''_1	s'''_1		d_6	d_2	d''_1	d'_1	d'_4	
			s''''_1				d_5	d_3	d_4		
			f'_1	f'_2	f'_4		f_1, (X)	f_2, (Z)	f_3	f_4, (U)	f_8
				f'_3				f_5, (Y)	f_6, (W)	f_7	

Experimental

The Vacuum System

The vacuum system is shown diagrammatically in fig. 1. The reservoirs H and He contained hydrogen and helium respectively, while argon or krypton containers were sealed on at A. Small quantities of any of these gases could be admitted to the system through the arrangements of taps shown. A ballast volume of 5 litres to reduce the effect of pressure changes during a run was connected at D, and the pressure was measured by a McLeod gauge attached at C. The system was pumped out through F by a Hyvac pump. The charcoal bulb E, immersed in liquid air, served to clean up any residual air and gases driven out of the walls of the discharge tube during the preliminary run with hydrogen. The discharge tube B was connected to the system by a ground glass joint and could be rotated about a vertical axis to the position which allowed the maximum amount of light to reach the slit.

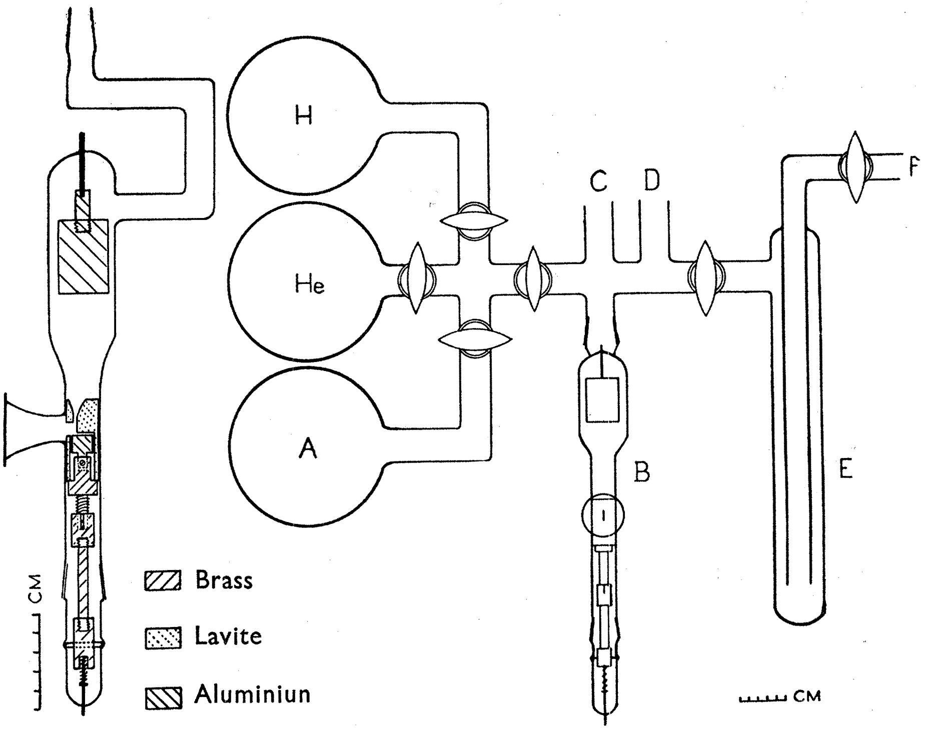

Fig. 1

The Discharge Tube

The Lo Surdo type of discharge tube as modified by Foster (1927) was used in this work in preference to a canal-ray tube. Although the field strength cannot be determined directly from the voltage applied to the tube, it may be calculated from observed hydrogen displacements, and the high current density in the constricted space above the cathode surface gives much greater light intensity than can be secured from the canal-ray source. This is a particularly valuable feature in studying the spectra of the rare gases, where many of the lines showing the most pronounced Stark effect are weak members of the diffuse and Bergmann series. Another important advantage of the Lo Surdo method is that it shows the complete variation of the displacement with the field strength from zero to maximum field. This is particularly valuable in the analysis of those components which reverse the direction of their displacement before maximum field strength is reached.

The discharge tube as shown in fig. 1 consisted of a pyrex glass tube containing at the upper end a highly polished aluminium anode connected to the outside by a heavy tungsten wire. The discharge reached the cathode through a hole 1·5 mm. in diameter bored off the axis through the lavite and reamed out at the anode end. The aluminium cathode was surrounded by a lavite cylinder sealed in the tube, and the light from the bright beam which traverses the Crookes dark space passed through a slit 1 mm. wide to the window shown on the left. The cathode, 7 mm. in diameter, was held in place by the set-screw, spring, and slotted rod as shown, while a ground glass joint allowed the rotation of the cathode during operation. Connexion at the lower end was made through a spring spot-welded to a tungsten wire which was sealed in the end of the tube. The cathode surface was polished with rouge and oil, then cleaned thoroughly with alcohol before the tube was assembled. In adjusting the position of the cathode, care was taken to leave about 0·3 mm. clearance between the upper surface and the lavite shoulder. The cathode section of the tube was cooled by a blast of compressed air.

The Optical System

The spectra were analysed with a six-prism glass spectrograph described elsewhere (Foster, 1924). This instrument with its dispersion of 4·1 A/mm. at H_β and high resolving power is particularly well adapted to work on the Stark effect in the visible region.

The light from the discharge tube was focussed on the slit by an *f* 1·9 lens of 3-in. focal length, giving a magnification of about 1·7. A quartz Wollaston prism was used to separate the components polarized, parallel, and perpendicular to the field. A small quartz plate was placed in the path of the parallel beam to rotate the plane of polarization 90 degrees for a line at the centre of the plate, and so reduce loss of intensity by reflexion at the prism faces.

Eastman spectroscopic plates, type 1 J, were used in the region 4700–5300 A., and type 1 D in the region 5300–6600 A.

The High Potential Source

The high potential source used throughout these experiments was the so-called " Proton Apparatus ", manufactured by Kipp and Zonen, and capable of delivering 40 mA at 25 kV. The potential across the tube was measured by an electrostatic voltmeter and was kept constant during an exposure by varying a resistance in the primary of the transformer. A water resistance of about one megohm and a milliammeter was connected in the circuit between the output and the tube.

Experimental Procedure

After the discharge tube had been assembled, the system was evacuated and then washed out several times with hydrogen. It was then pumped down as far as the Hyvac would take it, and the charcoal bulb and lavite cylinder containing the cathode was heated with an air-gas flame to drive out adsorbed gases. After these had been pumped out the charcoal bulb was immersed in liquid air. This was allowed to stand for about ten minutes and was then shut off from the rest of the system. Hydrogen was then admitted and the discharge turned on for a short time. With a pressure of about 0·5 mm. of Hg the tube would usually be quite hard (about 0·5 mA at 15 kV), but would soften rapidly due to emission of gas from the electrodes and lavite under bombardment. This gas was removed from time to time by the charcoal bulb and fresh hydrogen admitted. During this stage the light was focussed on the slit of the spectrograph and the Wollaston prism and the quartz plate adjusted. The above de-gassing process was continued until, after ten minutes' operation, no air lines could be seen in the spectrum.

The charcoal bulb was then shut off and enough helium admitted to the system to give a pressure of about 0·25 mm. of Hg. The inert gas under investigation was then admitted until the total pressure reached about 2·0 mm. of Hg. Under these conditions the voltage across the tube was commonly 12 kV, and the current from 2 to 3 mA. With a little experience, it was possible to estimate the field strength approximately from the appearance of H_β and the voltage was adjusted to give slightly over 100 kV/cm.

The exposure was then started and the voltage maintained as constant as possible by varying the resistance in the primary circuit. When running satisfactorily, the discharge was very steady, a fine pencil of bluish light extending from the centre of the anode surface down to the cathode. Due to the pitting of the cathode surface and sputtering of the surrounding lavite walls, the voltage tended to drop and flashes of white light filled the tube. When this occurred, it was necessary to shut off the potential and rotate the cathode, thus presenting a fresh surface to the ion beam. On readjusting the voltage to its former value, the field in the tube usually returned to its former distribution. This rotation of the cathode easily trebled the life of a tube and hence the length of an exposure. The best photographs were secured with exposures from two to three hours.

Measurement of Plates

The plates were enlarged by a factor of seven on Eastman Process film and the displacements measured directly on the enlargements at a field strength of 100 kV/cm. This field strength was determined from the measured separation of the components of H_β.

EXPERIMENTAL RESULTS AND DESCRIPTION OF TABLES

Tables II and III give the displacements from zero field position and the splitting of the observed levels of argon and krypton. These displacements have been measured directly at 100 kV/cm., hence no assumptions have been made with regard to the dependence of displacement on the field strength. Observations on most of the levels have been made through several lines. In no case has the observed splitting indicated a number of components in excess of that expected from the *j* value of the level. There may be some doubt as to the existence of certain undisplaced components. The occurrence of occasional flashes in the tube during an exposure tends to produce weak undisplaced lines. When two or more components of a line have approximately the same displacement in the field and are not resolved in the photographs, these weak undisplaced lines may be misinterpreted as components.

A minus sign before a displacement indicates a decrease in wave number of the level, *i.e.*, a displacement of the line toward the violet. An R refers to small displacements of the line toward the red ; *r* written after a measurement indicates that the displacement reverses with increasing field, while an asterisk placed above the number indicates that the measurement was made at the point of reversal and not at 100 kV/cm. Lines which fade out at high field are indicated by an *f*.

In Table III the line listed as $2p_8 - 8d_3$ may arise from $2p_8 - 8d_4$, since Meggers, de Bruin, and Humphreys (1931) were not able to resolve the levels $8d_3$ and $8d_4$, and the *j* value of the final state $2p_3$ is 2, hence it may combine with either $8d_3$ or $8d_4$. Similarly $6p_8$ and $6p_9$, appearing in combination lines with $2p_8$ and $2p_9$, lie too close together to be resolved in our photographs which, of course, do not show the lines at zero field. Any other symbols appearing in the tables are self-explanatory.

Figs. I and II (Plate 5) show the more interesting regions of the argon spectrum between λ 4746 and λ 5521. The maximum field strength is 101 kV/cm. Figs. III and IV (Plate 6) cover the region λ 4988 to λ 5674 of the krypton spectrum. The maximum field is 108 kV/cm.

Discussion

With the exception of the spectrum of hydrogen where the principal quantum number *n* may be regarded as the splitting factor, there is no marked regularity in Stark displacements ; they depend almost entirely on the character and separation of the initial levels. If these levels occur in close groups, well separated from other groups of different principal quantum number, their displacements in the field may be deduced from a comparatively simple approximate mathematical expression, and may be described as a result of mutual repulsion of the levels. While this repulsion maintains a symmetry with regard to the displacements within the group it is clear that the shift for any individual level will depend upon its position relative to other members of the group. With increasing principal quantum number a level of type *q*, say, will make its initial appearance normally at the upper edge of the group and will certainly be displaced upward by the field. As *n* increases, however, levels of new types will be added above this *q* representative in each group until this type of level is eventually displaced downward. There will, therefore, always be a progressive change in the displacements of members of a series A — *nq*. If the levels appear in their normal order, *s*, *p*, *d*, *f*, etc., it is clear that the sharp, principal, and diffuse series members will be shifted towards the red, with slight exceptions which are obvious from the above discussion. In a spectrum of this simple character, one is justified in concluding that a line which appears in the normal spectrum and is displaced strongly to the red by the field probably is a member of a diffuse series. The number of components observed may make the identification certain, but generally speaking the evidence in practice is less definite for purposes of identification than that obtained by Zeeman effects. Apart from the number of components, which frequently are not fully resolved, one is not justified in claiming a certain Stark effect for a line of a specific series unless the claim is substantiated by some knowledge of the related initial levels and their

Table II—Stark Displacements in the Argon Spectrum

(Field strength, 100 kV/cm.)

Notation	j, j'	λ (A)	Δ*v* for Initial Term. (cm.$^{-1}$)		Mean Δ*v*. (cm.$^{-1}$)
			π components	σ components	
$2p_{10} - 3s_3$	1, 0	5882·62	0·0	0·0	0·0
$2p_{10} - 3s_2$	1, 1	5860·31	0·0	0·0	0·0
$2p_6 - 4s_5$	2, 2	6170·18	0·0, 3·2	0·0, 3·2	0·0, 3·2, 6·9
$2p_8 - 4s_5$	2, 2	5942·67	6·8	6·8	
$2p_9 - 4s_5$	3, 2	5888·59	0·0, 6·5	0·0, 6·5	
$2p_{10} - 4s_5$	1, 2	5451·66	0·0, 7·3	0·0, 7·3	
$2p_6 - 4s_4$	2, 1	6155·23	0·0, 7·7	0·0, 7·7	0·0, 8·1
$2p_7 - 4s_4$	1, 1	6098·81	0·0, 8·3	0·0, 8·3	
$2p_8 - 4s_4$	2, 1	5928·82	8·2	8·2	
$2p_{10} - 4s_4$	1, 1	5439·97	0·0, 8·4	0·0, 8·4	
$2p_4 - 4s_3$	1, 0	5971·59	10·0	10·0	9·6
$2p_7 - 4s_3$	1, 0	5620·89	9·8	9·8	
$2p_{10} - 4s_3$	1, 0	5056·53	9·2	9·2	
$2p_3 - 4s_2$	2, 1	6025·14	9·2	9·2	0·0, 9·9
$2p_7 - 4s_2$	1, 1	5617·97	10·4	10·4	
$2p_8 - 4s_2$	2, 1	5473·44	0·0, 10·1	0·0, 10·1	
$2p_{10} - 4s_2$	1, 1	5054·18	0·0, 9·8	0·0, 9·8	
$2p_{10} - 4s'_1$	1, 1	5912·09	0·0, 4·5	4·5	0·0, 4·5
$2p_{10} - 4s''_1$	1, 2	6025·72	0·0	0·0	0·0
$2p_{10} - 4s''''_1$	1, 2	6059·38	0·0	0·0	0·0
$2p_6 - 5s_5$	2, 2	5659·13	0·0, 18·4	0·0, 18·4	0·0, 18·0, 21·9
$2p_7 - 5s_5$	1, 2	5611·35	0·0, 22·4	0·0 ?	
$2p_8 - 5s_5$	2, 2	5467·13	0·0, 17·4	0·0, 22·4	
$2p_9 - 5s_5$	3, 2	5421·36	0·0, 22·2	0·0, 22·2	
$2p_{10} - 5s_5$	1, 2	5048·81	0·0, 21·4	0·0, 18·0 21·4	
$2p_3 - 5s_2$	2, 1	5534·45	25·9	25·9	0·0, 26·7
$2p_4 - 5s_2$	1, 1	5486·47	26·8	26·8	
$2p_6 - 5s_2$	2, 1	5229·86	0·0, 27·0	0·0, 27·0	
$2p_{10} - 5s_2$	1, 1	4704·35	0·0, 27·2	0·0, 27·2	
$2p_{10} - 5p_{10}$	1, 1	5242·3	14·4	14·4	14·4
$2p_9 - 5p_9$	3, 3	5634·5	15·6	15·6	15·6

TABLE II—(continued)

Notation	j,i'	λ(A)	Δv for Initial Term. (cm.$^{-1}$)		Mean Δv. (cm.$^{-1}$)
			π components	σ components	
$2p_{10} - 5p_8$	1, 2	5229·0	27·9	27·9	27·9
$2p_{10} - 5p_7$	1, 1	5219·6	?	17·0	17·0
$2p_{10} - 5p_6$	1, 2	5217·9	?	13·3	13·3
$2p_{10} - 5p_5$	1, 0	5184·4	—	16·7	16·7
$2p_{10} - 5d_6$	1, 0	5650·71	0·0	0·0	0·0
$2p_{10} - 5d_5$	1, 1	5606·74	R	R	R
$2p_9 - 5d'_4$	3, 4	6032·13	4·9	4·9	4·9
$2p_{10} - 5d_3$	1, 2	5558·71	3·9	3·9	3·9
$2p_8 - 5d_4$	2, 3	6043·22	0·0, 6·9	0·0, 6·9	0·0, 4·9, 6·9
$2p_9 - 5d_4$	3, 3	5987·29	0·0, 4·9	0·0, 4·9	
$2p_7 - 5d''_1$	1, 2	6173·10	0·0, 7·3	0·0, 7·3	0·0, 7·1
$2p_8 - 5d''_1$	2, 2	5999·00	6·9	6·9	
$2p_8 - 5d'_1$	2, 3	5981·90	0·0, 4·7	0·0, 4·7	0·0, 4·7
$2p_8 - 5d_2$	2, 1	5916·58	0·0, 16·0	0·0, 16·0	0·0, 16·0
$2p_5 - 5s'_1$	0, 1	5964·56	5·2	0·0	0·0, 5·2
$2p_6 - 5s''_1$	2, 2	5834·26	−14·4	−4·8	0·0, −5·0 −14·9
$2p_{10} - 5s''_1$	1, 2	5187·75	0·0, −5·3	0·0, −5·3 −15·5	
$2p_3 - 5s'''_1$	2, 3	6145·43	4·1	4·1	4·7
$2p_6 - 5s'''_1$	2, 3	5772·12	4·0	4·0	
$2p_8 - 5s'''_1$	2, 3	5572·55	5·2	5·2	
$2p_9 - 5s'''_1$	3, 3	5524·93	5·5	5·5	
$2p_4 - 5s''''_1$	1, 2	6105·64	3·6	3·6	3·6
$2p_7 - 5s''''_1$	1, 2	5739·52	3·6	3·6	
$2p_8 - 5s''''_1$	2, 2	5588·69	3·7	3·7	
$2p_6 - 6s_5$	2, 2	5393·97	44·2f	44·2	44·6, 58·2, 73·2
$2p_8 - 6s_5$	2, 2	5219·30	58·5	45·0	
$2p_9 - 6s_5$	3, 2	5177·54	72·6	72·6	
$2p_{10} - 6s_5$	1, 2	4836·69	73·8	57·8	
$2p_6 - 6s_4$	2, 1	5390·72	55·2	55·2?	0·0, 54·9
$2p_7 - 6s_4$	1, 1	5347·41	54·7	54·7	
$2p_8 - 6s_4$	2, 1	5216·28	0·0, 55 f?	0·0, 55 f?	
$2p_{10} - 6s_4$	1, 1	4834·10	0·0, 55 f?	0·0, 55 f?	
$2p_{10} - 6p_{10}$	1, 1	4946·8	31·2	31·2	31·2
$2p_9 - 6p_9$	3, 3	5293·4	33·2, 41·8	33·2, 41·8	33·2, 41·8
$2p_{10} - 6p_9$	1, 3	4937·6	41·9	41·9	
$2p_8 - 6p_8$	2, 2	5334·8	31·4	31·4	31·2
$2p_9 - 6p_8$	3, 2	5291·2	30·6	—	
$2p_{10} - 6p_8$	1, 2	4935·7	31·2	31·2	
$2p_8 - 6p_7$	2, 1	5329·3	36·8	36·8	37·3
$2p_{10} - 6p_7$	1, 1	4931·0	37·7	37·7	
$2p_8 - 6p_6$	2, 2	5327·9	32·5	—	32·5, 42·3
$2p_{10} - 6p_6$	1, 2	4929·8	—	42·3	
$2p_{10} - 6p_5$	1, 0	4915·6	—	45·2	45·2
$2p_{10} - 6d_6$	1, 0	5151·39	−4·3	−4·3	−4·3

TABLE II—(continued)

Notation	j, j'	λ (A)	Δ*v* for Initial Term. (cm.$^{-1}$)		Mean Δ*v*. (cm.$^{-1}$)
			π components	σ components	
$2p_5 - 6d_5$	0, 1	6090·76	—4·2	0·0	0·0, —4·4
$2p_6 - 6d_5$	2, 1	5802·08	—4·8	—4·8	
$2p_8 - 6d_5$	2, 1	5600·43	—4·1	—4·1	
$2p_{10} - 6d_5$	1, 1	5162·29	0·0,—4·3	0·0,—4·4	
$2p_9 - 6d'_4$	3, 4	5495·87	0·0, 11·7	0·0, 11·7	0·0, 11·7
$2p_6 - 6d_3$	2, 2	5689·64	0·0, 25·4	0·0, 25·4	0·0, 20·1, 25·4
$2p_7 - 6d_3$	1, 2	5641·34	0·0, 25·2	0·0, 19·8	
$2p_{10} - 6d_3$	1, 2	5073·08	0·0, 25·4	0·0, 20·4	
$2p_6 - 6d_4$	2, 3	5700·86	0·0, 24·2	0·0, 17·7*f*?	0·0, 17·7, 23·9
$2p_8 - 6d_4$	2, 3	5506·11	0·0, 23·5	0·0, 17·7 23·5	
$2p_7 - 6d''_1$	1, 2	5635·54	0·0, 30·8	0·0, 30·8	0·0, 26·6 31·0
$2p_8 - 6d''_1$	2, 2	5490·13	0·0, 31·2	0·0, 26·6	
$2p_{10} - 6d''_1$	1, 2	5068·39	0·0, 30·3	0·0, 30·3	
$2p_6 - 6d'_1$	2, 3	5681·90	0·0, 32·8	0·0, 27·7	0·0, 27·8 32·8
$2p_9 - 6d'_1$	3, 3	5442·22	0·0, 27·8	0·0, 27·8	
$2p_3 - 6d_2$	2, 1	6005·74	9·4?	9·4	10·1, 16·5
$2p_4 - 6d_2$	1, 1	5949·26	15·9	15·9	
$2p_6 - 6d_2$	2, 1	5648·66	16·5	16·5	
$2p_7 - 6d_2$	1, 1	5601·08	17·0	17·0	
$2p_8 - 6d_2$	2, 1	5457·37	16·6	16·6	
$2p_{10} - 6d_2$	1, 1	5040·51	10·9	10·9	
$2p_7 - 6s''_1$	1, 2	5267·48	*59·6*r*?	*59·6*r*	*58·7*r*
$2p_{10} - 6s''_1$	1, 2	4768·67	*57·8*r*	?	
$2p_3 - 6s'''_1$	2, 3	5597·46			*See* Fig. I (Plate 5).
$2p_6 - 6s'''_1$	2, 3	5286·08			
$2p_8 - 6'''s_1$	2, 3	5118·20			
$2p_9 - 6s'''_1$	3, 3	5078·03			
$2p_7 - 6s''''_1$	1, 2	5254.47	*(— 3 + 4*f*)*r*	*(— 3 + 4*f*)*r*	*(— 3 + 4*f*)*r*
$2p_8 - 6s''''_1$	2, 2	5127·78	*(— 3 + 4*f*)*r*	*(— 3 + 4*f*)*r*	
$2p_6 - 7s_5$	2, 2	5236·21	0·0, 80·2?	0·0, 80·2?	0·0, 80·0
$2p_9 - 7s_5$	3, 2	5032·02	0·0, 78·9	0·0, 78·9	
$2p_{10} - 7p_{10}$	1, 1	4774·6	*47·8*r*	—	*47·8*r*
$2p_8 - 7p_9$	2, 3	5143·4	*57·8*r*	—	*56·2*r*
$2p_9 - 7p_9$	3, 3	5102·9	*56·2*r*	—	
$2p_{10} - 7p_9$	1, 3	4771·4	*56·9*r*	—	
$2p_8 - 7p_8$	2, 2	5141·9	*54·8*r*	—	*54·2*r*
$2p_{10} - 7p_8$	1, 2	4770·1	—	*53·8*r*	
$2p_{10} - 7p_7$	1, 1	4767·3	*—14·0*r*	*—20·7*r*	*14·7*r*, *—20·7*r*
$2p_{10} - 7p_6$	1, 2	4766·7	*—17·3*r*	*—26·0*r*	*17·3*r*, *—26·0*r*
$2p_{10} - 7p_5$	1, 0	4755·9		53·2	53·2
$2p_{10} - 7d_6$	1, 0	4894·69	7·0	7·0	7·0
$2p_{10} - 7d_5$	1, 1	4887·95	12·0	15·4	12·0, 15·4

* Measured at points of reversal, about 72 kV/cm.

TABLE II—(continued)

Notation	j, j'	λ (A)	Δv for Initial Term. (cm.$^{-1}$)		Mean Δv. (cm.$^{-1}$)
			π components	σ components	
$2p_9 - 7d'_4$	3, 4	5221·27	0·0, 33·1	0·0, 33·1	0·0, 33·1
$2p_9 - 7d_3$	3, 2	5222·90	0·0, 32·3	0·0, 32·3	0·0, 17·8, 32·9
$2p_{10} - 7d_3$	1, 2	4876·26	0·0, 33·5	0·0, 17·8	
$2p_8 - 7d_4$	2, 3	5252·79	0·0, 54·6	0·0, 54·6	0·0, 46·7, 54·6
$2p_9 - 7d_4$	3, 3	5210·49	0·0, 46·7	0·0, 46·7	
$2p_7 - 7d''_1$	1, 2	5373·49	0·0, 74·1	0·0, 74·1f?	0·0, 74·1
$2p_6 - 7d'_1$	2, 3	5410·47	0·0, 92·2	0·0, 92·2	0·0, 92·6
$2p_8 - 7d'_1$	2, 3	5234·74	0·0, 91·8	0·0, 91·8f?	
$2p_9 - 7d'_1$	3, 3	5192·72	0·0, 93·7	0·0, 93·7	
$2p_5 - 7d_2$	0, 1	5637·29	30·0	—	29·8, 60·0
$2p_6 - 7d_2$	2, 1	5389·10	60·0	60f?	
$2p_7 - 7d_2$	1, 1	5345·81	59·8	59·8	
$2p_8 - 7d_2$	2, 1	5214·77	29·6, 61·1	42·5	
$2p_{10} - 7d_2$	1, 1	4832·79	60f?	60f?	
$2p_2 - 7s''''_1$	1, 2	5387·37	0·0, 10·3, 12·3	29·6	0·0, 10·3, 12·3
$2p_{10} - 7f_1$	1, 1	4816·72	42·5, 48·6	12·3	42·5, 48·6
$2p_6 - 8s_5$	2, 2	5134·17	102f	102f ?	102f
$2p_6 - 8s_4$	2, 1	5132·61	103f	103f	103
$2p_7 - 8s_4$	1, 1	5093·32	103	103	
$2p_8 - 8p_{10}$	2, 1	5026·7	160	160	160
$2p_8 - 8p_9$	2, 3	5022·6	153	—	154
$2p_9 - 8p_9$	3, 3	4984·4	155	155	
$2p_8 - 8p_8$	2, 2	5021·8	86·0	86·0	86·0
$2p_8 - 8p_7$	2, 1	5020·1	66·2	—	66·2
$2p_8 - 8p_6$	2, 2	5019·6	62·3	62·3	62·3
$2p_{10} - 8d_6$	1, 0	4746·82	*(−5·2, >30)r	*(−5·2, 30>)r	*(−5·2, >30)r
$2p_6 - 8d_5$	2, 1	5290·00	*(−11·0, 37·2)r	*(−11·0, 37·2)r	*(−11·2, 37·2?)r
$2p_{10} - 8d_5$	1, 1	4752·94	*(−11·2,>30f)r	*(−11·2,>30f)r	
$2p_9 - 8d'_4$	3, 4	5060·08	0·0, 105	0·0, 105f?	0·0, 105
$2p_{10} - 8d_3$	1, 2	4719·94	157	157	157
$2p_8 - 8d_4$	2, 3	5087·09	0·0, 123	0·0, 123f?	0·0, 123
$2p_6 - 8d''_1$	2, 2	5246·76	61·4	61·4	61·9, 124
$2p_8 - 8d''_1$	2, 2	5081·44	62·4	62·4	
$2p_{10} - 8d''_1$	1, 2	4718·10	124	124	
$2p_6 - 8d'_1$	2, 3	5246·24	0·0, 23·2	0·0, 23·2	0·0, 23·2
$2p_7 - 8d_2$	1, 1	5194·77	103	0·0, 103	0·0, 103
$2p_8 - 8f_6$	2, 3	5055·2	8·6	8·6	8·6
$2p_6 - 9s_5$	2, 1	5063·99	40·4	7·1	7·1, 40·4
$2p_9 - 9d'_4$	3, 4	4956·75	0·0, >48f	0·0, >48f	0·0, >48f
$2p_6 - 9d_3$	2, 3	5153·11	0·0, 46·2	0·0, 46·2	0·0, 46·2
$2p_8 - 9d_4$	2, 3	4989·94	0·0, >77f	0·0, >77f	0·0, >77f
$2p_7 - 9d''_1$	1, 2	5104·74	⩾38f	⩾38f	⩾38f

* Measured at points of reversal, about 72 kV/cm.

TABLE III—STARK DISPLACEMENTS IN THE KRYPTON SPECTRUM

(Field Strength, 100 kV/cm.)

Notation	j, j'	λ (A)	Δv for Initial Term. (cm.$^{-1}$)		Mean Δv. (cm.$^{-1}$)
			π components	σ components	
$1s_4 - 2p_4$	1, 1	5993·85	0·0	0·0	0·0
$1s_5 - 2p_4$	2, 1	5672·45	0·0	0·0	
$1s_4 - 2p_3$	1, 1	5879·89	0·0	0·0	0·0
$1s_5 - 2p_3$	2, 1	5570·29	0·0	0·0	
$1s_4 - 2p_2$	1, 2	5870·91	0·0	0·0	0·0
$1s_5 - 2p_2$	2, 2	5562·23	0·0	0·0	
$1s_2 - 3p_{10}$	1, 1	5866·74	0·0	0·0	0·0
$1s_3 - 3p_{10}$	0, 1	5649·56	0·0	0·0	
$1s_3 - 3p_7$	0, 1	5516·66	0·0	0·0	0·0
$1s_2 - 3p_6$	1, 2	5707·51	0·0	0·0	0·0
$1s_2 - 3p_5$	1, 0	5580·39	0·0	0·0	0·0
$2p_7 - 4s_5$	1, 2	6508·37	0·0	0·0, 3·2	0·0, 3·2, 5·4
$2p_8 - 4s_5$	2, 2	6241·39	3·2	3·2	
$2p_9 - 4s_5$	3, 2	6236·34	0·0, 3·4	0·0, 3·4	
$2p_{10} - 4s_5$	1, 2	5827·07	5·4	0·0, 5·4	
$2p_7 - 4s_4$	1, 1	6488·07	0·0, 6·2	6·2	0·0, 6·4
$2p_8 - 4s_4$	2, 1	6222·71	0·0, 6·4	0·0, 6·4	
$2p_{10} - 4s_4$	1, 1	5810·80	0·0	0·0	
$2p_6 - 4s''_1$	2, 2	5887·70	0·0, 28·2, 15·8	0·0, 15·8	0·0, 16·0, 28·0
$2p_7 - 4s''_1$	1, 2	5833·10	16·0	16·0	
$2p_9 - 4s''_1$	3, 2	5613·65	—	27·2	
$2p_{10} - 4s''_1$	1, 2	5279·84	0·0, 16·2	16.2, 28.4	
$2p_6 - 4s'''_1$	2, 3	5841·59	0·0, 34·6	0·0, 12·5, 34·6	0·0, —9·2, 12·6, 34.4
$2p_8 - 4s'''_1$	2, 3	5575·75	34·2	—9·2, 12·6 34·2	
$2p_6 - 4s''''_1$	2, 2	5881·27	—	15·3	0·0, 11·9, 15·0
$2p_8 - 4s''''_1$	2, 2	5611·90	11·9	11·9	
$2p_9 - 4s''''_1$	3, 2	5607·80	0·0	0·0, 11·9	
$2p_{10} - 4s''''_1$	1, 2	5274·66	0·0, 14·8	0·0, 11·7	
$1s_2 - 4f_1$	1, 1	4969·08	0·0	0·0	0·0
$1s_2 - 4f_5$	1, 2	4955·27	0·0	0·0	0·0
$2p_8 - 4f'_1$	2, 2	5241·45	0·0, —19·2	0·0, —19·2, 18·8r	0·0, —19·2, 18·8r
$2p_8 - 5s_5$	2, 2	5730·86	25·2	25·2	0·0, 17·2, 25·5
$2p_9 - 5s_5$	3, 2	5726·59	25·0	16·6, 25·0	
$2p_{10} - 5s_5$	1, 2	5379·64	0·0, 25·8	0·0, 17·8, 25·8	

TABLE III—(continued)

Notation	j, j'	λ (A)	Δv for Initial Term. (cm.^{-1})		Mean Δv. (cm.^{-1})
			π components	σ components	
$2p_6 - 5s_4$	2, 1	6002·19	0·0, 22·2	22·2	0·0, 22·4
$2p_7 - 5s_4$	1, 1	5945·44	0·0, 23·0	0·0, 23·0	
$2p_8 - 5s_4$	2, 1	5721·88	0·0, 22·4	22·4	
$2p_{10} - 5s_4$	1, 1	5371·74	0·0, 21·8	0·0, 21·8	
$2p_7 - 5p_{10}$	1, 1	6202·4	—	32·6	32·5
$2p_{10} - 5p_{10}$	1, 1	5580·6	—	32·4?	
$2p_7 - 5p_9$	1, 3	6194·5	—	26·6	26·9
$2p_9 - 5p_9$	3, 3	5947·6	—	27·2	
$2p_8 - 5p_8$	2, 2	5951·3	—	11·8	11·8
$2p_8 - 5p_7$	2, 1	5935·8	—	20·4	20·4
$2p_9 - 5p_6$	3, 2	5927·3	—	18·6, 27·8	17·9, 28·0
$2p_{10} - 5p_6$	1, 2	5556·4	—	17·3, 28·2	
$2p_{10} - 5d_6$	1, 0	6082·85	R	R	R
$2p_8 - 5d_5$	2, 1	6504·89	R	R	R
$2p_{10} - 5d_5$	1, 1	6056·11	R	R	
$2p_9 - 5d'_4$	3, 4	6456·29	0·0, 3·0	0·0, 3·0	0·0, 3·0
$2p_9 - 5d_3$	3, 2	6448·78	0·0	0·0	0·0, 16·3, 23·8
$2p_{10} - 5d_3$	1, 2	6012·11	0·0, 16·3	0·0, 23·8	
$2p_8 - 5d_4$	2, 3	6421·03	0·0, 4·0	0·0, 4·0	0·0, 4·0
$2p_9 - 5d_4$	3, 3	6415·65	0·0, 4·0	0·0, 4·0	
$2p_8 - 5d''_1$	2, 2	6373·58	5·0	5·0	0·0, 5·7, 17·0
$2p_9 - 5d''_1$	3, 2	6368·26	5·4	5·4	
$2p_{10} - 5d''_1$	1, 2	5942·13	0·0, 17·0	0·0, 17·0	
$2p_8 - 5d'_1$	2, 3	6351·90	0·0, 5·5	0·0, 5·5	0·0, 5·7
$2p_9 - 5d'_1$	3, 3	6346·66	0·0, 5·9	0·0, 5·9	
$2p_7 - 5d_2$	1, 1	6536·55	0·0	15·2	0·0, 15·9
$2p_8 - 5d_2$	2, 1	6267·33	?	15·8	
$2p_{10} - 5d_2$	1, 1	5849·66	0·0, 16·3	16·3	
$2p_8 - 5f_4$	2, 4	6178·69	25·9, 32·8	25·9, 32·8	0·0, 26·4, 33·1
$2p_9 - 5f_4$	3, 4	6173·64	0·0, 26·8 33·4	0·0, 26·8 33·4	
$2p_6 - 6s_5$	2, 2	5717·61	0·0, 45·3	0·0, ?	0·0, 44·3, 57·0
$2p_9 - 6s_5$	3, 2	5458·80	0·0, 56·8	0·0, 43·6, 56·8	
$2p_{10} - 6s_5$	1, 2	5142·70	0·0, 57·2	0·0, 44·2 57·2	
$2p_6 - 6s_4$	2, 1	5714·11	0·0	0·0, ?	0·0, 51·5
$2p_7 - 6s_4$	1, 1	5662·67	0·0, 51·0	51·0	
$2p_{10} - 6s_4$	1, 1	5139·90	0·0	51·8	
$2p_{10} - 6p_{10}$	1, 1	5258·5	—	27·1, 46·2	27·1, 46·2
$2p_8 - 6p_q$*	2, j	5584·4	—	41·0	41·0
$2p_9 - 6p_q$*	3, j	5580·3	—	41·0	
$2p_{10} - 6p_7$	1, 1	5243·4	—	33·8, 48·2	33·8, 48·2
$2p_{10} - 6d_6$	1, 0	5504·34	—4·5	—4·5	—4·5

* $q = 8$ or 9. *See* p. 478.

TABLE III—(continued)

Notation	j, j'	λ (A)	Δv for Initial Term. (cm.^{-1})		Mean Δv. (cm.^{-1})
			π components	σ components	
$2p_5 - 6d_5$	0, 1	6555·56	—	—6·2	0·0, —5·9
$2p_6 - 6d_5$	2, 1	6163·65	—5·8	—5·8	
$2p_7 - 6d_5$	1, 1	6103·86	—6·3	—6·3	
$2p_{10} - 6d_5$	1, 1	5500·71	0·0, —5·5	0·0, —5·5	
$2p_9 - 6d'_4$	3, 4	5832·85	0·0, 6·2, 13·5	0·0, 6·2, 13·5	0·0, 6·2, 13·5
$2p_6 - 6d_3$	2, 2	6151·38	0·0, —13·0	0·0, —13·0	0·0, —12·5
$2p_7 - 6d_3$	1, 2	6091·81	0·0, ?	0·0, —12·0	
$2p_9 - 6d_3$	3, 2	5852·86	0·0, —12·5	0·0, —12·5	
$2p_{10} - 6d_3$	1, 2	5490·93	0·0	0·0, —12·6	
$2p_6 - 6d_4$	2, 3	6115·23	9·6	9·6	0·0, 9·6
$2p_8 - 6d_4$	2, 3	5824·50	0·0, 9·2	9·2	
$2p_9 - 6d_4$	3, 3	5820·10	0·0, 9·8	0·0, 9·8	
$2p_6 - 6d''_1$	2, 2	6094·31	12·3	12·3	0·0, 12·6, 20·8?
$2p_7 - 6d''_1$	1, 2	6035·82	0·0, 13·1	0·0, 13·1	
$2p_8 - 6d''_1$	2, 2	5805·53	12·0	12·0	
$2p_{10} - 6d''_1$	1, 2	5445·43	20·8?	20·8?	
$2p_6 - 6d'_1$	2, 3	6075·24	0·0, 20·6	0·0, 20·6	0·0, 20·6
$2p_8 - 6d'_1$	2, 3	5788·24	0·0, 20·2	0·0, 20·2	
$2p_9 - 6d'_1$	3, 3	5783·89	0·0, 21·0	0·0, 21·0	
$2p_5 - 6d_2$	0, 1	6410·17	0·0	42·8	0·0, 42·2
$2p_7 - 6d_2$	1, 1	5977·65	0·0, 41·6	41·6	
$2p_6 - 6f_1$	2, 1	5981·77	6·0	6·0	5·9
$2p_8 - 6f_1$	2, 1	5703·28	5·9	5·9	
$2p_6 - 6f_5$	2, 2	5975·99	R	R	R
$2p_7 - 6f_5$	1, 2	5919·72	R	R	
$2p_8 - 6f_5$	2, 2	5698·06	R	R	
$2p_{10} - 6f_5$	1, 2	5350·74	R	R	
$2p_{10} - 6f_4$	1, 4	5353·16	R	R	R
$2p_6 - 6f_6$	2, 3	5972·82	—5·0	—5·0	—4·8
$2p_8 - 6f_6$	2, 3	5695·15	—4·6	—4·6	
$2p_9 - 6f_6$	3, 3	5690·97	—4·8	—4·8	
$2p_9 - 7s_5$	3, 2	5300·74	0·0, ?	0·0, 78*f*?	0·0, 78 ?, 105 ?
$2p_{10} - 7s_5$	1, 2	5002·14	0·0, ?	105*f*?	
$2p_8 - 7s_4$	2, 1	5299·79	?	77·0	76·3
$2p_{10} - 7s_4$	1, 1	4998·02	?	75·5	
$2p_9 - 7p_{10}$	3, 1	5381·2	—	*65·0*r*	*64·9*r*
$2p_{10} - 7p_{10}$	1, 1	5073·7	—	*64·8*r*	
$2p_9 - 7p_9$	3, 3	5374·4	—	*80·0*r*	*79·7*r*
$2p_{10} - 7p_9$	1, 3	5067·7	—	*79·5*r*	
$2p_9 - 7p_6$	3, 2	5368·6	—	35·0?	35·0 ?, *94·2*r*
$2p_{10} - 7p_6$	1, 2	5062·5	—	*94·2*r*	
$2p_{10} - 7d_6$	1, 0	5228·18	—33·4*r*	—33·4*r*	—33·4*r*

* Measured at points of reversal, about 80 kV/cm.

TABLE III—(continued)

Notation	j, j'	λ (A)	Δν for Initial Term. (cm.⁻¹)		Mean Δν. (cm.⁻¹)
			π components	σ components	
$2p_{10} - 7d_5$	1, 1	5215·81	− 7·4r	− 7·4r	− 7·4r
$2p_9 - 7d'_4$	3, 4	5520·52	0·0, 14·2, 17·3, 22·0	14·2, 22·0, 36·6	0·0, 14·2, 17·3, 22·0, 36·6
$2p_6 - 7d_3$	2, 2	5749·02	?	65·7	0·0, 65·9
$2p_8 - 7d_3$	2, 2	5491·33	64·9	64·9	
$2p_{10} - 7d_3$	1, 2	5168·06	0·0, 66·5	0·0, 66·5	
$2p_6 - 7d_4$	2, 3	5762·90	54·2	54·2	0·0, 53·9
$2p_8 - 7d_4$	2, 3	5504·02	0·0, 53·7	0·0, 53·7	
$2p_7 - 7d''_1$	1, 2	5702·19	0·0	0·0, 58·3	0·0, $\ngtr$ 50f, 58·8
$2p_8 - 7d''_1$	2, 2	5496·21	0·0. $\ngtr$ 50f	0·0, 59·5	
$2p_{10} - 7d''_1$	1, 2	5172·36	0·0, $\ngtr$ 50f	0·0, 59·0	
$2p_6 - 7d'_1$	2, 3	5750·57	0·0, 65·7	0·0, 65·7	0·0, 66·8
$2p_9 - 7d'_1$	3, 3	5488·85	0·0, 68·0	0·0, 68·0	
$2p_7 - 7d_2$	1, 1	5696·54	37·8	44·1	37·8, 44·1
$2p_6 - 7f_1$	2, 1	5702·30	65·5	65·5	0·0, 64·2
$2p_{10} - 7f_1$	1, 1	5130·26	0·0, 63·0	0·0, 63·0	
$2p_7 - 7f_5$	1, 2	5647·76	38·0	38·0	37·8
$2p_8 - 7f_5$	2, 2	5445·63	37·6	37·6	
$2p_{10} - 7f_5$	1, 2	5127·55	38·2	38·2	
$2p_8 - 7f_4$	2, 4	5447·17	35·8	35·8	35·9
$2p_{10} - 7f_4$	1, 4	5128·90	36·0	36·0	
$2p_8 - 7f_6$	2, 3	5443·98	−40·5	−40·5	−40·1
$2p_9 - 7f_6$	3, 3	5440·14	−39·6	−39·6	
$2p_{10} - 7f_6$	1, 3	5125·05	−39·8	−39·8	
$2p_9 - 8s_5$	3, 2	5197·82	?	>110f	>110f
$2p_{10} - 8d_6$	1, 0	5058·82	*(−15·1r, 33·8)	*(−15·1r, 33·8)	*(−15·1r, 33·8)
$2p_{10} - 8d_5$	1, 1	5040·34	0·0, (−3·2r, >54f)	*(−3·2r, >54f) 105	0·0, 105, *(−3·2r, >54f)
$2p_9 - 8d'_4$	3, 4	5339·13	0·0	0·0, 108, 121	0·0, 108, 121
$2p_7 - 8d_3$†	1, 2	5528·63	?	108	0·0, 82·4, 110
$2p_8 - 8d_3$†	2, 2	5334·78	0·0, 83·5	112	
$2p_{10} - 8d_3$†	1, 2	5029·15	0·0, 81·2	110	
$2p_7 - 8d''_1$	1, 2	5521·17	?	105	105?
$2p_8 - 8d''_1$	2, 2	5327·87	?	102	
$2p_{10} - 8d''_1$	1, 2	5022·99	?	105f?	
$2p_8 - 8f_1$	2, 1	5295·41	?	88·5	89·0
$2p_{10} - 8f_1$	1, 1	4994·15	—	89·6	
$2p_{10} - 8f_5$	1, 2	4992·61	—	Large † ive	
$2p_{10} - 8f_4$	1, 4	4993·35	—	Large † ive	
$2p_8 - 8f_6$	2, 3	5291·72	—	Two components cut off by unknown *d* line	*See* Fig. IV (Plate 6).
$2p_9 - 8f_6$	3, 3	5288·09	—		
$2p_{10} - 8f_6$	1, 3	4990·78	—		

* Measured at points of reversal, about 80 kV/cm.

† $8d_4$ may be coincident with $8d_3$. *See* p. 478.

separation. Moreover, the above regularity with regard to the behaviour of series lines which may be expected under the most favourable structure of the energy level diagram is limited in its application to low principal quantum numbers and fields of such strength that Stark displacements are small compared with the separation of adjacent groups of levels. As the limit of applicability is approached and passed, new regularities—having as origin the repulsion of levels of different principal quantum number—will make their appearance, and eventually the whole Stark effect will be wiped out through ionization. Examples of these features appear in the spectra of hydrogen (von Traubenberg, 1928), helium (Foster, 1927), and neon (Foster and Rowles, 1929) under fields that have been realized in the laboratory.

In the Stark effect for the rare gases, apart from helium, there is superimposed upon the above regularities some less regular or almost random features which arise from the relatively wide separation of the levels of the same principal quantum number and consequent probability that a level, n, will appear in the midst of a close group n'. The results are then often quite striking and have led Ryde to speak of certain " umkehrenden terme " which reverse the sign of their displacement with increasing field. Nevertheless, the observations fall within the general theory of the Stark effect, as is clear if in a discussion of these spectra one considers the energy level diagram as a whole.

The Stark analyses give some indication of the extent to which the interactions between neighbouring rare gas terms with different limits may be neglected in Stark effect. Some of the more interesting regions of the energy diagrams for normal neon, argon, krypton, and xenon atoms are shown in figs. 2–5 together with the Stark effects in a field up to 100 kV/cm. The Stark data for the neon and xenon diagrams were taken from earlier papers by Foster and Rowles (1929) and by Harkness and Heard (1933) respectively. Since the low final states are not appreciably affected by the external field, the preparation of the diagram for initial states amounts to the reproduction of observed line displacements. With the gradual opening up of the multiplet structures in this series of diagrams, one may expect gradual increases in the interactions. At the top of fig. 2 the neon terms of higher limit cross those of lower limit without noticeable effect. Especially the crossing of $6g'$, $6h'$ over $7d$ terms is a strong indication that the interactions are small. In the middle of fig. 3 a somewhat similar assortment of argon terms occurs with interesting displacements and intensity relations which indicate a comparatively strong interaction. Owing to the relatively wide separation of the $^2P_{\frac{3}{2},\frac{1}{2}}$ doublets for the krypton and xenon cores the terms with the higher limit, which correspond to the above neon and argon levels, are not found.

The influence of the above doublet separation upon Stark effects is rather interesting. The appearance of the argon term $6s'''_1$ near $8d$ terms may be described as resulting from the relatively high energy of the core $^2P_{\frac{1}{2}}$ together with an outer configuration involving what should be called a $6d$ electron. From an older point of view, one might expect that the core would have little to do with the Stark effect

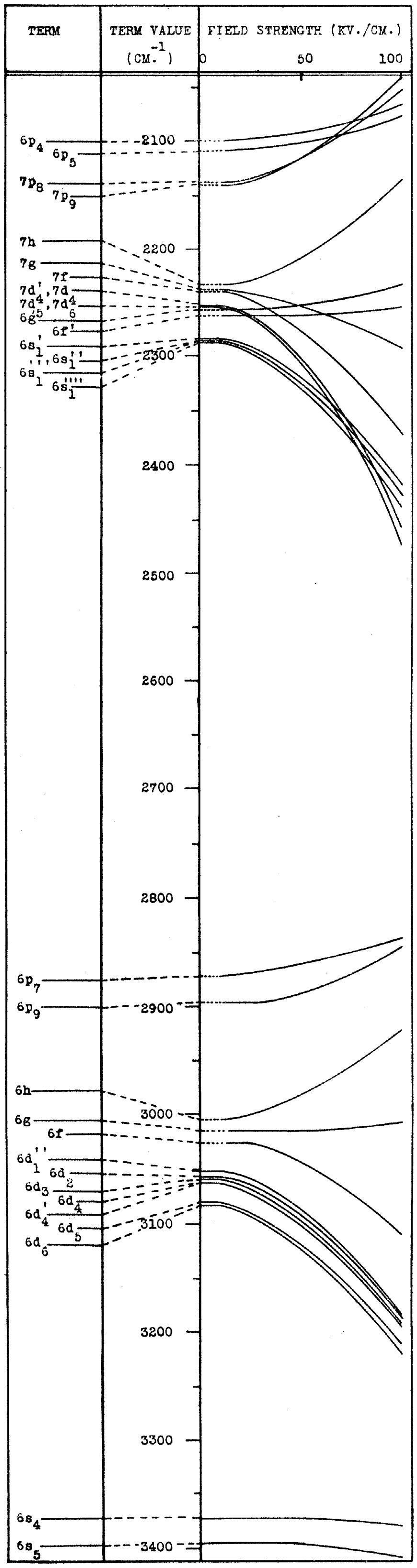

FIG. 2—Selected terms in neon.

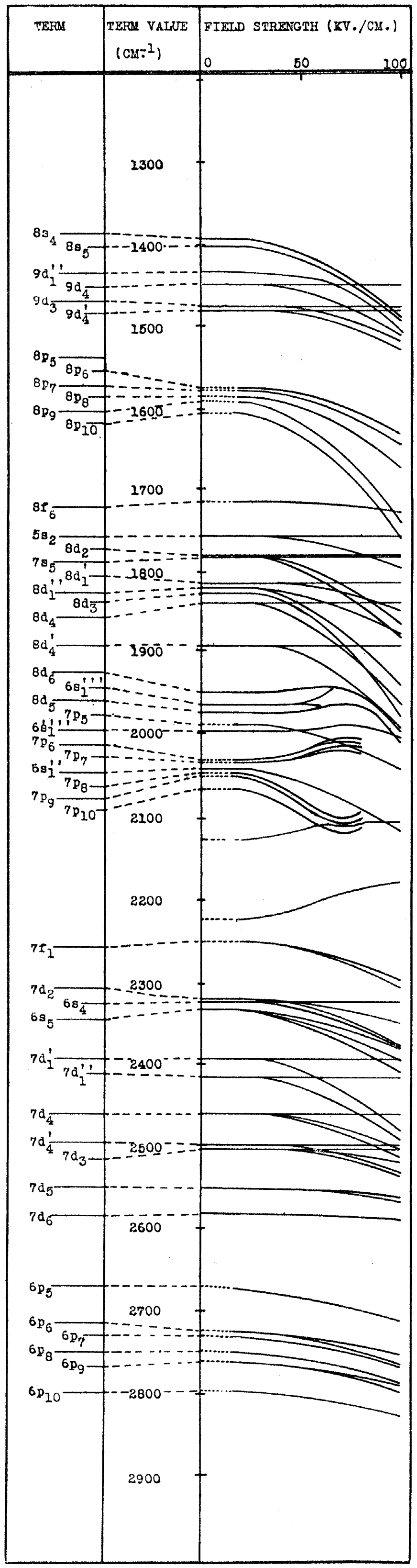

FIG. 3—Selected terms in argon.

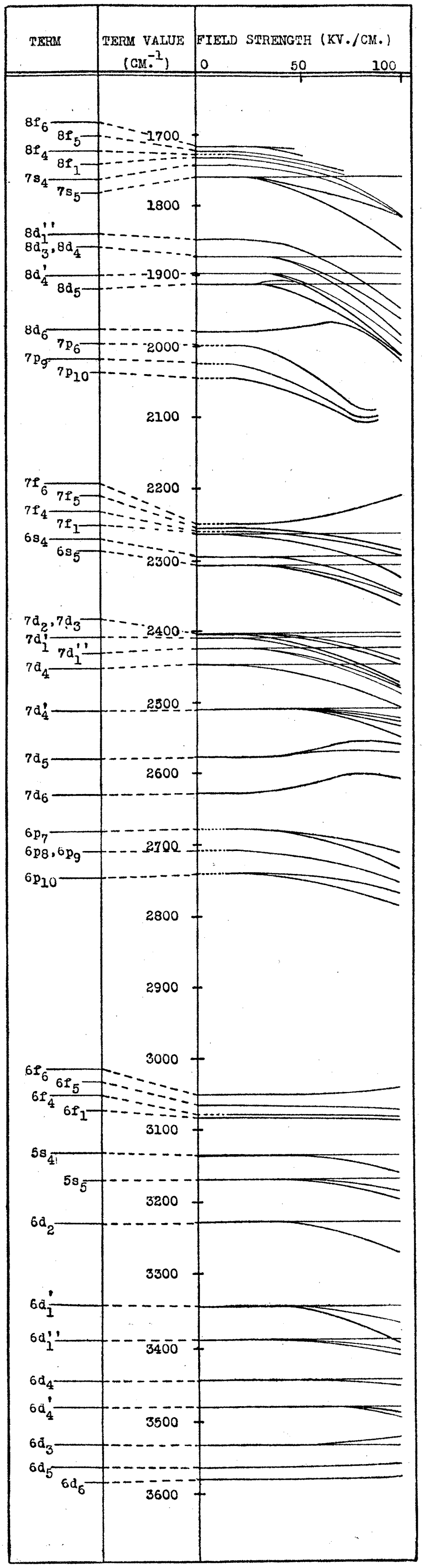

FIG. 4—Selected terms in krypton.

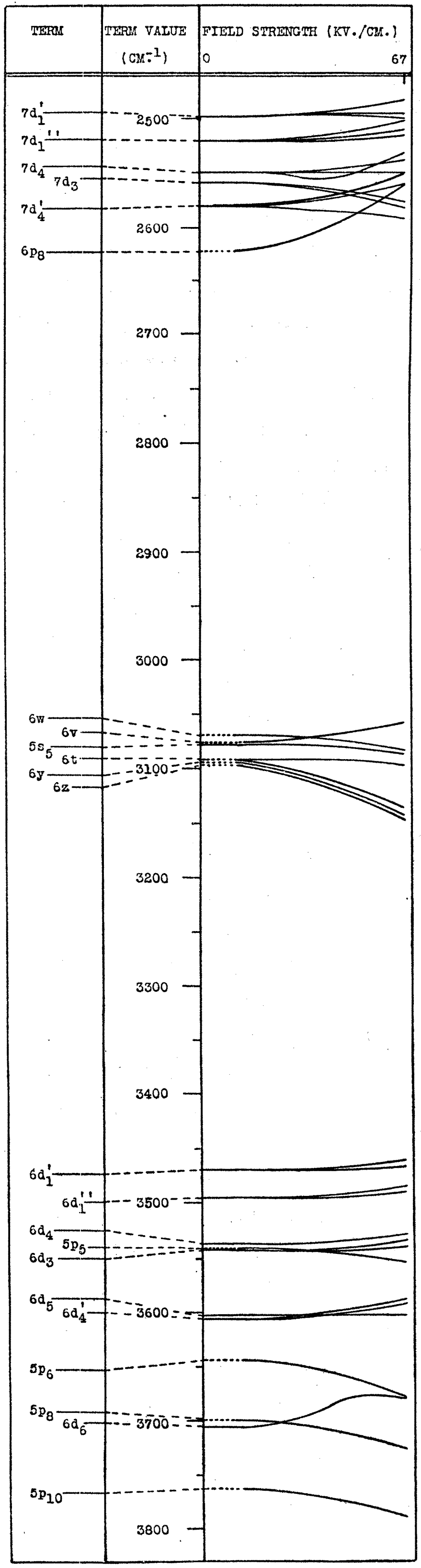

FIG. 5—Selected terms in xenon.

since the latter would be determined mainly by the outer configuration. In agreement with formal theory, however, the plates show that the two elements entering into the $6s'''_1$ term value must not be separated ; the Stark effect is characteristic of the actual term value however that is determined. Thus the $6s'''_1$ displacement is scarcely typical of a diffuse series, though in neon the s'-$''''_1$ terms were identified as diffuse terms through their typical Stark effects which result from a few fortunate conditions including finer multiplet structure and small interactions.

Multiplet terms of a given spectral type (*e.g.*, d terms) have no great influence on each other in Stark effects, but a small indirect influence may be expected. The number, position, and magnitude of the non-vanishing terms of the matrix H_1 will be determined by *all* the neighbouring multiplet terms, subject only to restrictions imposed by a constant m value, and even including some terms which may not be represented in a particular group of lines upon which the attention may be fixed.

In neon (fig. 2) the f, g, ... terms lie very close to the d levels, and the p terms of next lower principal quantum number are far below. Hence the $6d$'s and $7d$'s, are all shifted downward by the field in the manner generally considered characteristic of diffuse series. In argon the $6p$'s approach nearer the $7d$'s, so that while the higher $7d$ terms are strongly displaced downward the $7d_5$ and $7d_6$ at the lower edge of the group (nearest the $6p$'s) have very small displacements. The progressive change is carried a step further in krypton even at lower quantum numbers. Here the $6d_5$ and $6d_6$ levels are actually displaced upward by the $5p$ terms (not shown). Finally, in xenon the $6d$ and $5p$ groups are overlapping. The $6d_6$ starts upward, but on approaching the $5p_6$ level—now above it—is repelled downward. This series of observations offers a further illustration of the fact that the Stark effect is not determined by the type of level alone.

The reversal of a term may be shown in a relatively simple theoretical case. In fig. 6 the terms 5 (P, D, F, G) with $m = 1$ have been given separations 30, 10, and 1 cm.$^{-1}$ respectively. Using hydrogenic matrix terms, the resulting quartic secular equation has been solved to give the displacements which are graphically represented. It may be noticed that in low fields the F level is repelled by the G and forced toward the D level. Upon close approach to the latter it reverses its direction and at 100 kV/cm. has crossed its zero field position.

In a close structure many reversals may occur at about the same point. For example, in argon at λ 4750 (*see* Plate 5), RYDE (1937) has reported reversals involving the lines $2p_{10} - 8d_6$, $2p_{10} - 8d_4$, $2p_{10} - 6s''_1$. We believe that some of the components which he attributed to $6s''_1$ actually belong to $7p_6$, $7p_7$, $7p_8$, $7p_9$, $7p_{10}$; the final level in each case is $2p_{10}$. The lines $2p_{10} - 7p_6$, $2p_{10} - 7p_7$, $2p_{10} - 8d_5$, $2p_{10} - 8d_6$ are displaced toward the violet in low fields, but in higher fields they approach $2p_{10} - 8d''_1$, $2p_{10} - 8d_3$ and are repelled with them toward the red by some common influence. On the other side the remaining $p - p$ combinations $2p_{10} - 7p_8$, $2p_{10} - 7p_9$, $2p_{10} - 7p_{10}$ are displaced toward the red until they approach and are repelled by unidentified terms lying below the $7p$'s in the energy level diagram. The above Stark effects are, of course, characteristic of initial terms only and are therefore repeated with slight modifications (which result from selection rules) at λ 5120* and at λ 5287* where the transitions are to the final states $2p_8$ and $2p_6$ respectively.

Reversals in the krypton spectrum occur at λ 5100† and λ 5400.† The details for the terms $8d_5$, $8d_6$, $7p_6$, $7p_9$, and $7p_{10}$ are not so clear as in argon and the perturbation seems to arise largely from an unknown term or close structure below the $7p$'s. At least one such level is represented in the normal spectrum by the line λ 5109 unclassified by MEGGERS, DE BRUIN, and HUMPHREYS (1931). From its position in the energy diagram and Stark splitting we can state that its running quantum number is seven, the term value 2181 cm.$^{-1}$, and the j value at least two or three.

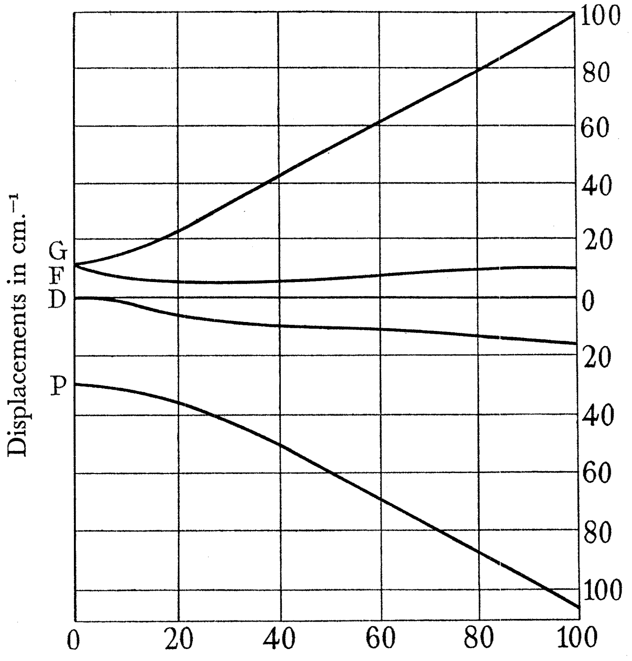

FIG. 6

Comparing the present displacements with those recorded by RYDE for terms of low quantum number at 100 kV/cm., moderately good agreement is found. Corrections to the earlier work are needed for $7d_2$ in argon and $6p_7$, $7s_5$, $4p_5$ in krypton, since in these cases RYDE has calculated displacements at 100 kV/cm. from single observations on the assumptions that the displacements are proportional to the square of the applied field. It is abundantly evident that it is not safe to rest on this assumption.

Although RYDE has reported two sub-levels originating in $3s_3$, $j = 0$ in argon, and more than $j + 1$ sub-levels for six normal levels of krypton, we have not been able to verify these reports. Among the 161 levels examined in the two gases no

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* *See* Plate 5.

† *See* Plates 5 and 6.

case has appeared for which the number of sub-levels is in excess of the number of absolute *m* values obtained by resolving the *j* of the initial state along the field. It seems not unlikely that in the earlier work entirely separate electric combination or other lines have been misinterpreted as components of lines arising from initial argon terms $4s''_1$, $5f_1$, $5s_4$, and $6s_5$. Moreover, sub-levels for certain terms were deduced by RYDE from plots against the field of all observations into which a given initial term entered. Apparent difficulties have arisen from his acceptance of sub-levels with separations less than the errors of observation, and without the splitting of any line being actually observed.

It would be a matter of special interest if the observed sub-levels could be labelled with their *m* values, for it is only the sub-levels of constant *m* value which affect one another. Unfortunately, it is possible only to begin this work. A few sub-levels with $m = 0$ may be found from the π components of lines resulting from transitions between terms either of which has a zero *j* value.

Through Stark effects we have been able to identify a few lines of the normal spectrum in argon and krypton which had been listed as doubtful in former analyses. The results which we give in Table IV also include corrections to a few misprints in the earlier classification.

TABLE IV—IDENTIFICATION OF LINES

Argon

λ	MEISSNER	FOSTER and HORTON
5068·39	$2p_{10} - 6d'_1$	$2p_{10} - 6d''_1$
5192·72	$2p_{10} - 7d'_1$	$2p_9 - 7d'_1$
5597·46	$2p_3 - 6s''''_1$	$2p_3 - 6s'''_1$
6043·224	$2p_8 - 5d_4$ $2p_3 - 6d'_1$	$2p_8 - 5d_4$
6090·76	$2p_5 - 6d_5$ $2p_1 - 8d_5$?	$2p_5 - 6d_5$
6155·23	$2p_6 - 4s_4$ $2p_4 - 5s''_1$	$2p_6 - 4s_4$

Krypton

λ	MEGGERS, DE BRUIN, and HUMPHREYS	
5490·94	$2p_{10} - 6d_3$ $2p_7 - 7s_4$	$2p_{10} - 6d_3$
6012·11	$2p_{10} - 5d_3$ $2p_6 - 5s_5$	$2p_{10} - 5d_3$
6035·82	$2p_8 - 6d''_1$	$2p_7 - 6d''_1$
6103·86	$2p_6 - 6d_5$	$2p_7 - 6d_5$

Numerous lines belonging to the second spectra, A II and Kr II, appear on the plates. None of these shows displacement in the field, though they are broadened at the base due probably to the greater percentage of ions near the cathode surface.

SUMMARY

In a field of 100 kV/cm. Stark effects have been observed for 86 normal levels in argon, and for 75 levels in krypton.

Thirty-four electric combination lines have been found in argon and 48 in krypton.

Typical sections of the energy level diagrams for Ne, A, Kr, and Xe are drawn to represent the normal levels and their Stark effects. The diagrams serve as a basis for the qualitative explanation of the main features observed.

Since intercombinations between terms of high and low limit respectively are much weaker in neon than in argon, it is found that in the former gas the Stark effects for the two sets of terms are much more nearly independent.

The reversal of the direction of displacement of several terms in argon and krypton with increasing field is discussed.

The number of Stark levels deduced from observations in the field are never greater than the number of *m* values allowed by the *j* value of the term.

Several lines in the arc spectra of argon and krypton are identified by their Stark effects.

No Stark effects were observed for the spark lines which appear on the plates.

Certain corrections to the earlier work by RYDE are suggested.

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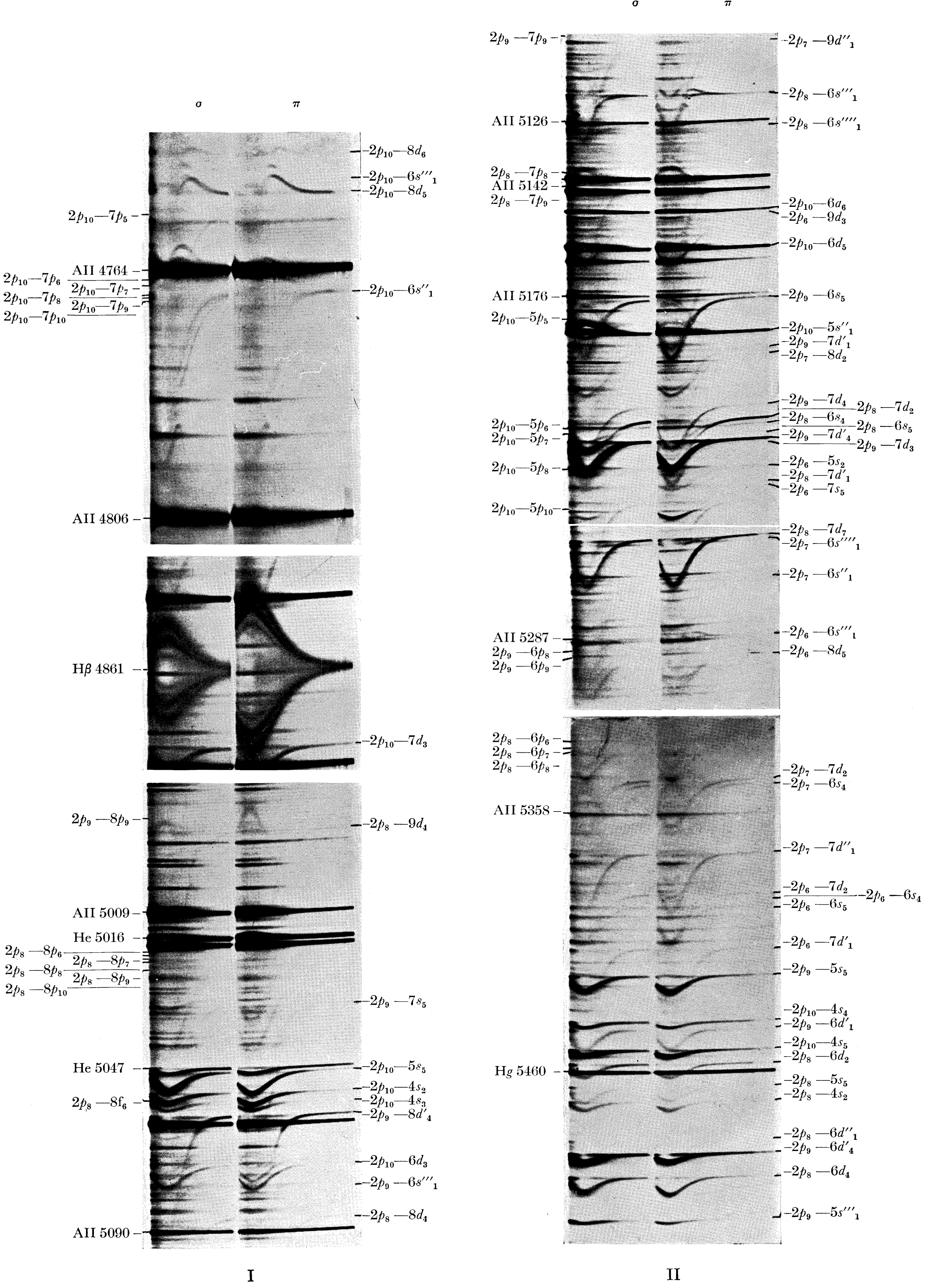
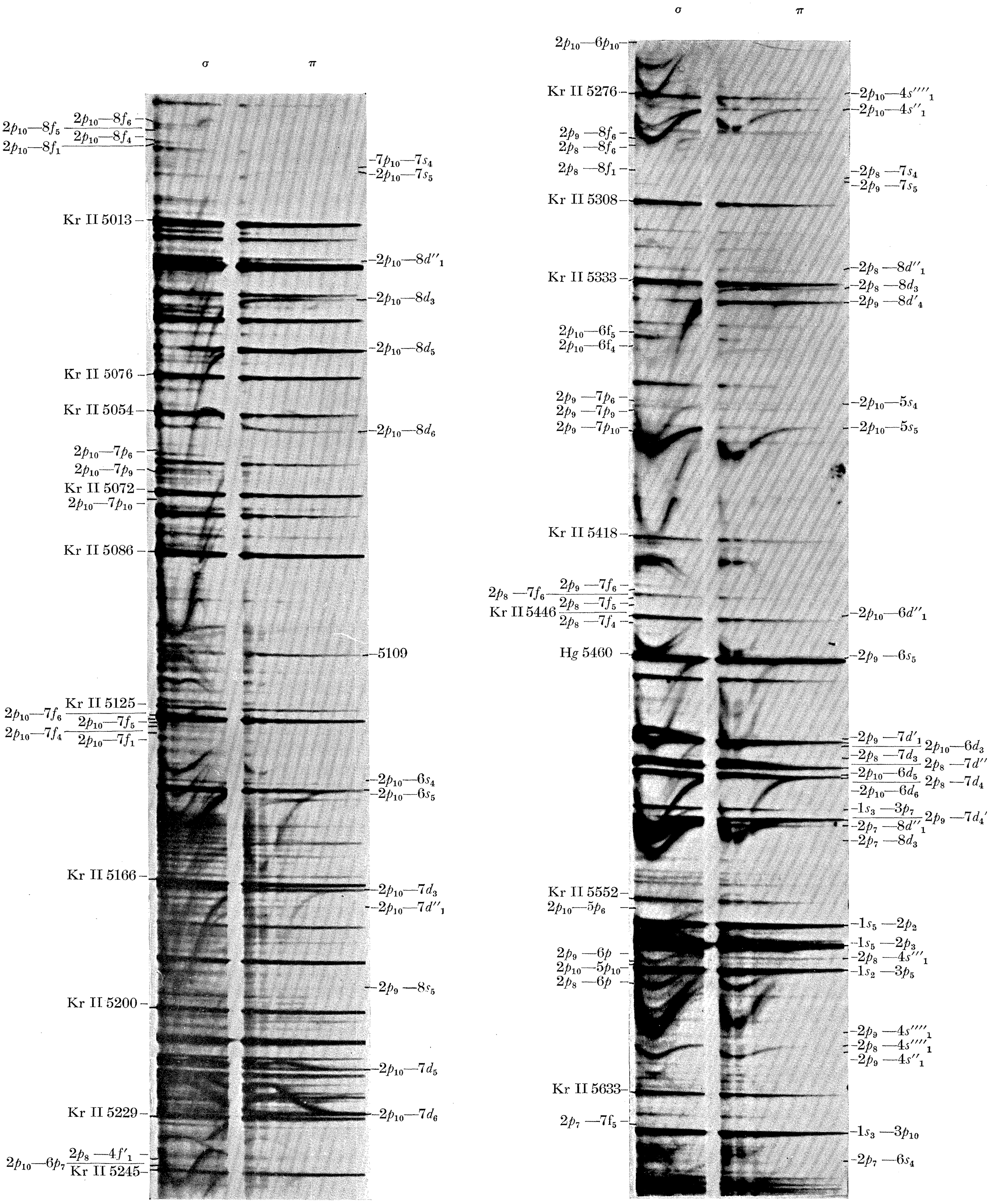


Argon Spectrum in Maximum Field of 101 kV/cm.



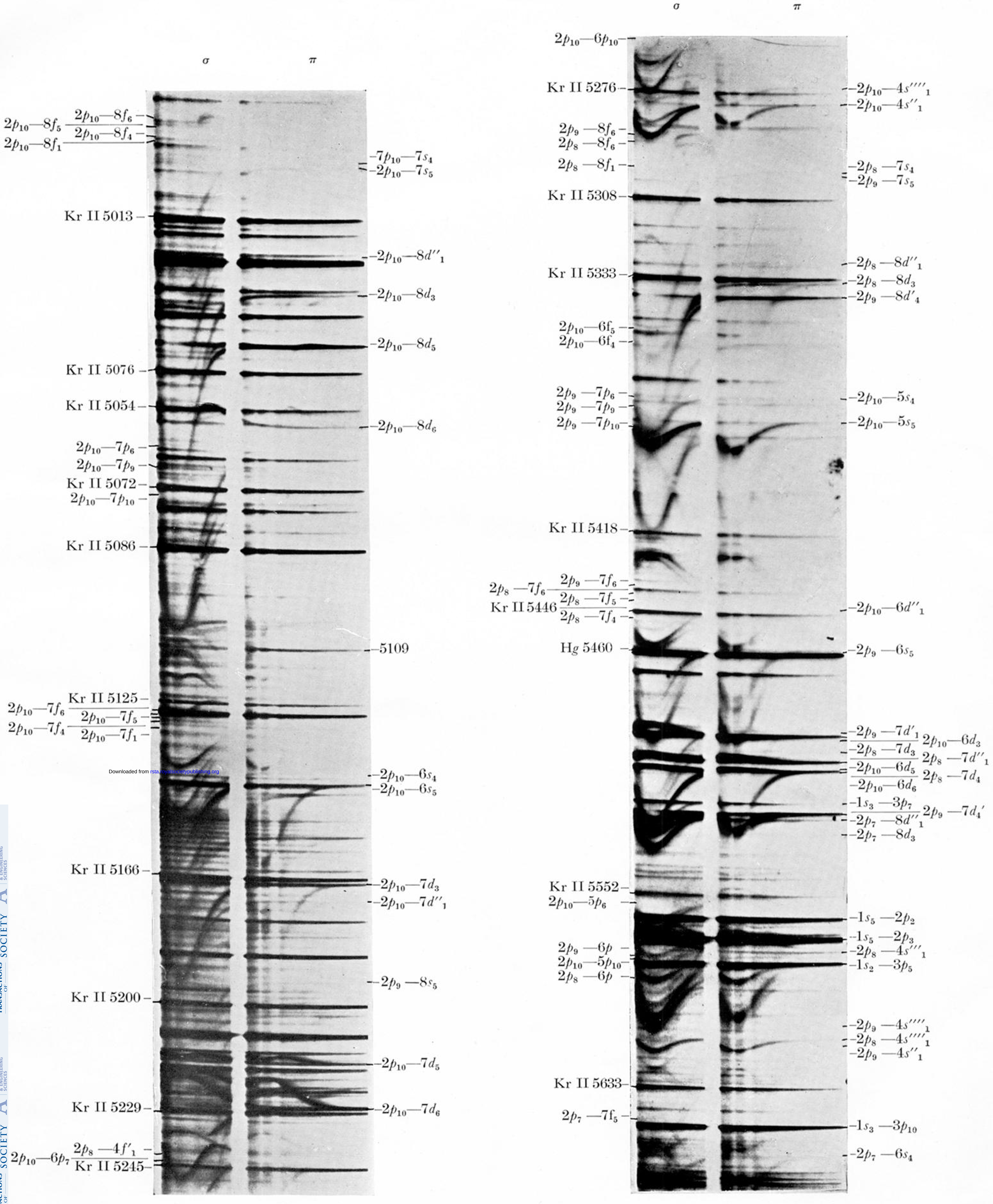
III IV

Krypton Spectrum in Maximum Field of 108 kV/cm.

I

II

Argon Spectrum in Maximum Field of 101 kV/cm.



III

IV

Krypton Spectrum in Maximum Field of 108 kV/cm.