The Zeeman Effect of Krypton

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Measurements on the Zeeman effect about 130 lines in the spectrum of neutral krypton have yielded a large number of additional g values to those already given by Pogany. In several cases, our results differ sharply from Pogany's, especially in the case of $4p^55s$. The g sum rule has been verified for $4p^55s$, $4p^55p$ and for $J=2$ of $4p^56p$, but for this last configuration, interaction with $4p^55f$ causes the breakdown of the rule for $J=1$. Other anomalies in the g values are also discussed.

THE classification of the first spectrum of krypton has been carefully carried out by Meggers, deBruin and Humphreys[1] and their classifications have been verified with few exceptions.

The earliest experimental work on the Zeeman effect of krypton was done by Bakker[2] in 1931 and extended by Pogany[3] in 1933 and 1935. Lörinczi[4] has made some calculations of the g factors for the $4p^55p$ and $4p^56p$ configurations. Green[5] has carried out the calculations of the g values of the $4p^55p$ configuration with results differing somewhat from Lörinczi's.

The present investigation covers about 150 lines in the first spectrum of krypton covering the region λλ3400–8950. The source and magnet were the same as that used by Green and Peoples[6] in previous work on the Zeeman effect of neon. In the present investigation the gas pressure was about 10 mm and the carbon trap was removed from the system in an attempt to eliminate some troublesome bands. A gas mixture of 95 percent helium and 5 percent krypton was used. Eastman special spectroscopic plates were used and developed in Edwal 12 developer. All the dyed plates were sensitized for one minute in a four-percent aqueous ammonia solution. Two sets of exposures were about 48 hours, the third 75 hours, and the fourth and the fifth taken in the perpendicular polarization with the aid of a calcite crystal lasted 98 and 111 hours, respectively.

Table I gives a summary of the patterns measured in the arc spectrum of krypton and of the g values calculated from these patterns. In certain cases where the pattern is not resolved the better known g value is assumed in order to calculate the other.

Table II is a summary of the average g values observed. In the cases of the $1s_2$, $1s_4$, $1s_5$, $2p_3$, $2p_4$, $2p_8$, $2p_9$, $2p_{10}$, $3p_4$, $3p_7$, and $3p_{10}$ levels only resolved patterns were averaged. For the remaining levels the values obtained from unresolved patterns were given only half the weight of the values obtained from the resolved patterns. The average values obtained from resolved patterns only are probably accurate to about 0.5 percent.

Tables III, IV, and V show the individual g values and the g sums for the $4p^55s$, $4p^55p$, and $4p^56p$ configurations with comparisons between the calculated values of Lörinczi, Green and the authors and the observed values of Pogany and the authors.

In the $4p^55s$ configuration the authors' observed g values for the s_4 and s_2 levels are in agreement with the calculated values but are opposite in relative magnitude to those observed by Pogany. (See Fig. 1.)

The authors' experimental results for the $4p^55p$ configuration are not in agreement with Pogany's results nor Lörinczi's theoretical results. However, the agreement with Green's calculated results and with the g sum rule is much better.

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TABLE I. *Summary of Zeeman patterns.*

λ	Classification	J Values	Pattern	g_a	g_b
‡8928.693	$1s_5-2p_{10}$	2, 1	(0), (0.396), **1.105**, 1.494, 1.886	1.497	1.889
‡8776.790	$1s_4-2p_8$	1, 2	(0), (0.147), **0.950**, 1.094, 1.228	1.243	1.100
‡8508.874	$1s_2-2p_4$	1, 1	(–), 0.645, 1.256	1.256	0.645
‡8298.109	$1s_4-2p_1$	1, 1	(0.235), 1.006, 1.241	1.241	1.006
‡8281.06	$1s_2-2p_3$	1, 1	(0.191), 1.257, 1.448	1.257	1.448
‡*8263.241	$1s_2-2p_2$	1, 2	(0), 1.123	*1.258*	1.168
‡8190.057	$1s_4-2p_6$	1, 2	(0), (0.157), 1.225, 1.370, **1.530**	1.242	1.381
8112.902	$1s_5-2p_9$	2, 3	(0), (0.174), (0.363), **0.983**, 1.170, 1.338, 1.507, 1.676	1.507	1.338
8104.02	$1s_5-2p_8$	2, 2	(–), (–), –, **1.101**, **1.500**, 1.898	1.500	1.101
8059.505	$1s_3-2p_4$	0, 1	(0), 0.647	0/0	0.647
*7928.602	$2p_8-4d_4$	2, 3	(0), 0.999	*1.101*	1.050
7913.443	$2p_{10}-4d_5$	1, 1	(–), 1.098, 1.901	1.901	1.098
7854.823	$1s_3-2p_3$	0, 1	(0), 1.452	0/0	1.452
7746.831	$2p_{10}-4d_6$	1, 0	(0), 1.897	1.897	0/0
7741.37	$2p_9-4d_1'$	3, 3	(0.252), (–)	*1.336*	1.243
7694.540	$1s_5-2p_7$	2, 1	(0), (0.508), 1.006, 1.498, **1.993**	1.496	1.000
7685.247	$1s_2-2p_1$	1, 0	(0), 1.260	1.260	0/0
†7601.547	$1s_5-2p_6$	2, 2	(0.236), 1.451	1.516	1.386
7587.414	$1s_4-2p_5$	1, 0	(0), 1.244	1.244	0/0
7494.15	$2p_8-3s_5$	2, 2	P.B.	*1.100*	1.492
7493.58	$2p_8-4d_2$	2, 1	P.B.	*1.100*	0.935
7487.12	$2p_9-4d_2$	3, 1	P.B.	*1.333*	0.935
	forbidden		P.B.		
7486.850	$2p_9-3s_5$	3, 2	P.B.	*1.333*	1.500
*7425.54	$2p_8-3s_4$	2, 1	(0), 1.102	*1.101*	1.098
7287.262	$2p_{10}-2s_2$	1, 1	(–), 1.018, 1.895	1.895	1.018
7224.109	$2p_{10}-4d_3$	1, 2	(–), (–), –, **0.697**, 1.297, 1.888	1.890	1.295
7143.45	$2p_{10}-4d_1''$	1, 2	(0), [0.105], 1.011, –	1.896	1.006
7000.79	$2p_5-4s_4$	0, 1	(0), 1.160	0/0	1.160
6904.68	$2p_{10}-3s_5$	1, 2	P.B.	1.898	1.496
6904.22	$2p_{10}-4d_2$	1, 1	P.B.	1.898	0.940
*6869.63	$2p_6-5d_5$	2, 1	(0), 1.403	*1.387*	1.355
6846.40	$2p_{10}-3s_4$	1, 1	(0.792), 1.093, 1.894	1.892	1.096
6829.09	$2p_7-5d_6$	1, 0	(0), 1.009	1.009	0/0
†6813.10	$2p_6-5d_3$	2, 2	(0.127), 1.352	1.387	1.317
6740.10	$2p_7-5d_3$	1, 2	(0), (0.317), –, –, **1.630**	1.000	1.315
*6652.24	$2p_7-5d_1''$	1, 2	(0), 0.964	*1.005*	0.978
†6576.42	$2p_6-4s_5$	2, 2	(0.212), 1.457	1.398	1.516
†6536.55	$2p_7-5d_2$	1, 1	(0.183), 0.914	1.005	0.823
6504.89	$2p_8-5d_5$	2, 1	(0), (0.252), **0.840**, 1.072, –	1.094	1.344
†6488.07	$2p_7-4s_4$	1, 1	(0.157), 1.101	1.022	1.179
*6456.293	$2p_9-5d_4'$	3, 4	(0), 1.052	*1.337*	1.231
*6448.78	$2p_9-5d_3$	3, 2	(0), 1.349	*1.337*	1.325
*6421.028	$2p_8-5d_4$	2, 3	(0), 1.041	*1.102*	1.071
6415.65	$2p_9-5d_4$	3, 3	(0.262), (**0.550**), –, 0.808, **1.074**, **1.338**, 1.600, 1.868	1.337	1.074
6410.17	$2p_5-6d_2$	0, 1	(0), 0.797	0/0	0.797
†6373.58	$2p_8-5d_1''$	2, 2	(0.255), 1.023	1.094	0.952
*6351.90	$2p_8-5d_1'$	2, 3	(0), 1.441	*1.101*	1.271
†6346.66	$2p_9-5d_1'$	3, 3	(0.272), –	*1.336*	1.237
6241.39	$2p_8-4s_5$	2, 2	(0.398), (–), 0.716, **1.106**, **1.503**, 1.895	1.107	1.502
6236.34	$2p_9-4s_5$	3, 2	(0), (0.173), (0.341), **1.004**, 1.173, –, –, –.	1.334	1.502
*6222.71	$2p_8-4s_4$	2, 1	(0), 1.064	*1.101*	1.169
*ˣ6163.65	$2p_6-6d_5$	2, 1	(0), 1.392	*1.387*	1.377
†6151.38	$2p_6-6d_3$	2, 2	(0.122), 1.354	1.388	1.320
6091.81	$2p_7-6d_3$	1, 2	(0), (0.310), 1.031, 1.322, **1.627**	1.020	1.322
6082.85	$2p_{10}-5d_6$	1, 0	(0), 1.898	1.898	0/0
‡6075.24	$2p_6-6d_1'$	2, 3	(0), (0.170), (0.356), **0.866**, 1.043, 1.245, 1.413, –.	1.397	1.218
‡6056.11	$2p_{10}-5d_5$	1, 1	(0.551), 1.348, 1.895	1.896	1.346
*6035.82	$2p_7-6d_1''$	1, 2	(0), 0.930	*1.008*	0.956
6012.111	$2p_{10}-5d_3$	1, 2	(0), (0.576), **0.740**, 1.318, 1.895	1.895	1.318
5993.850	$1s_4-2p_4$	1, 1	(–), 0.647, 1.244	1.243	[0.647
†5977.65	$2p_7-6d_2$	1, 1	(0.208), 0.892	0.996	0.798
‡5879.89	$1s_4-2p_3$	1, 1	(0.217), 1.247, 1.457	1.243	1.456
*5870.915	$1s_4-2p_2$	1, 2	(0), 1.150	*1.242*	1.181
‡5866.74	$1s_2-3p_{10}$	1, 1	(0.576), 1.266, 1.834	1.264	1.836
*5832.85	$2p_9-6d_4'$	3, 4	(0), 1.066	*1.337*	1.228
5827.07	$2p_{10}-4s_5$	1, 2	(0), (0.411), 1.101, 1.515, 1.902	1.914	1.510
*5824.50	$2p_8-6d_4$	2, 3	(0), 1.072	*1.102*	1.086
5820.10	$2p_9-6d_4$	3, 3	(–), (0.490), (**–**), –, –, **1.098**, **1.344**, 1.600, 1.827	1.344	1.098
5810.80	$2p_{10}-4s_4$	1, 1	(–), 1.178, 1.890	1.890	1.178
†5805.53	$2p_8-6d_1''$	2, 2	(0.260), 1.020	1.096	0.952
*5788.24	$2p_8-6d_1'$	2, 3	(–), 1.389	*1.101*	1.245
*5783.89	$2p_9-6d_1'$	3, 3	(–), 1.291	*1.337*	1.245
*5750.57	$2p_6-7d_1'$	2, 3	(0), 1.066	*1.385*	1.227
5723.56	$1s_2-3p_7$	1, 1	(0.221), 1.034, 1.267	1.263	1.036
*5721.88	$2p_8-5s_4$	2, 1	(0), 1.064	*1.102*	1.174
5707.51	$1s_2-3p_6$	1, 2	(0), (0.148), –, 1.405, **1.548**	1.257	1.403
*5702.19	$2p_7-7d_1''$	1, 2	(0), 1.003	*1.008*	1.005
5672.45	$1s_5-2p_4$	2, 1	(0), 0.647, (–), 1.503, **2.356**	1.502	0.648
†5662.67	$2p_7-6s_4$	1, 1	(0.176), 1.073	0.985	1.161
‡5649.563	$1s_3-3p_{10}$	0, 1	(0), 1.834	0/0	1.834
†5611.82	$2p_8-4s_1''$	2, 2	(0.382), –.	*1.101*	0.889
5580.39	$1s_2-3p_5$	1, 0	(0), 1.257	1.257	0/0
*5575.6	$2p_8-4s_1'''$	2, 3	(0), 1.179	*1.101*	1.140
*5570.289	$1s_5-2p_3$	2, 1	(0), 1.530	*1.502*	1.444
5562.225	$1s_5-2p_2$	2, 2	(0.315), (**0.635**), 0.863, **1.180**, **1.500**, 1.821	1.499	1.181
*5520.52	$2p_9-7d_4'$	3, 4	(0), 1.083	*1.336*	1.236
5516.66	$1s_3-3p_7$	0, 1	(0), 1.039	0/0	1.039
5504.34	$2p_{10}-6d_6$	1, 0	(0), 1.897	1.897	0/0
*5504.04	$2p_8-7d_4$	2, 3	(0), 0.973	*1.101*	1.037
ˣ5500.71	$2p_{10}-6d_5$	1, 1	(0.547), 1.345, 1.887	1.888	1.344
5490.94	$2p_{10}-6d_3$	1, 2	(0), (0.582), **0.722**, 1.303, 1.894	1.891	1.306
5379.64	$2p_{10}-5s_5$	1, 2	(0), (0.411), **1.092**, 1.486, –.	1.898	1.495
*5339.13	$2p_9-8d_4'$	3, 4	(0), 1.086	*1.336*	1.182
5279.84	$2p_{10}-4s_1''''$	1, 2	(0), **0.446**, (0.722), 1.169, –.	1.891	1.169
5274.61	$2p_{10}-4s_1''$	1, 2	(0), (–), –, 0.904, –.	—	0.904
5228.18	$2p_{10}-7d_5$	1, 1	(0.625), 1.301, 1.903	1.906	1.294
5215.81	$2p_{10}-7d_6$	1, 0	(0), 1.899	1.899	0/0
5058.08	$2p_{10}-8d_6$	1, 0	(0), 1.915	1.915	0/0
5040.34	$2p_{10}-8d_5$	1, 1	(0.691), 1.205, 1.903	1.899	1.208
4812.607	$1s_3-4X$	0, 1	(0), 0.517	0/0	0.517
4724.89	$1s_2-4p_{10}$	1, 1	(0.544), 1.254, 1.792	1.253	1.792
4636.14	$1s_2-4p_5$	1, 0	(0), 1.265	1.265	0/0
4550.295	$1s_4-3p_{10}$	1, 1	(0.599), 1.250, 1.835	1.246	1.839
‡4463.6897	$1s_4-3p_7$	1, 1	(0.212), 1.030, 1.242	1.242	1.030
‡4454.9183	$1s_4-3p_6$	1, 2	(0), (0.184), 1.211, 1.375, **1.586**	1.214	1.401
‡4425.1909	$1s_2-3p_4$	1, 1	(–), 0.647, 1.253	1.253	0.647
4418.769	$1s_2-5Z$	1, 2	(0), 0.98	*1.26*	1.08
4416.88	$1s_2-5X$	1, 1	(–), 0.61, 1.25	1.25	0.61
†4410.369	$1s_2-3p_3$	1, 1	(0.145), 1.336	1.264	1.408
*4399.9675	$1s_2-3p_2$	1, 2	(0), 1.101	*1.258*	1.153
4376.1217	$1s_4-3p_5$	1, 0	(0), 1.246	1.246	0/0
‡4362.6429	$1s_5-3p_{10}$	2, 1	(0), (0.331), **1.168**, 1.498, 1.828	1.498	1.828
4351.3605	$1s_2-3p_1$	1, 0	(0), 1.259	1.259	0/0
4319.5798	$1s_5-3p_9$	2, 3	P.B.	*1.502*	1.333
4318.5523	$1s_5-3p_8$	2, 2	P.B.	*1.502*	1.107
‡4300.4877	$1s_3-3p_4$	0, 1	(0), 0.649	0/0	0.649
‡4286.4875	$1s_3-3p_3$	0, 1	(0), 1.402	0/0	1.402
‡4282.9686	$1s_5-3p_7$	2, 1	(0), (0.472), 1.032, 1.503, **1.975**	1.503	1.031
‡†4273.9705	$1s_5-3p_6$	2, 2	(0.196), 1.455	1.509	1.401
4263.29	$1s_2-5p_5$	1, 0	(0), 1.256	1.256	0/0
4184.48	$1s_3-5p_{10}$	0, 1	(0), 1.794	0/0	1.794
3800.55	$1s_4-4p_7$	1, 1	(0.203), 1.025, 1.247	1.242	1.030
*3796.88	$1s_4-4p_6$	1, 2	(0), 1.508	*1.242*	1.417
3773.43	$1s_4-4p_5$	1, 0	(0), 1.236	1.236	0/0
3668.74	$1s_5-4p_7$	2, 1	(0), (0.461), –, 1.502, **1.963**	1.502	1.041
†3665.33	$1s_5-4p_6$	2, 2	(0.208), 1.448	1.506	1.390
*3628.17	$1s_4-5Z$	1, 2	(0), 1.031	*1.242*	1.101
*3615.48	$1s_4-3p_2$	1, 2	(0), 1.124	*1.242*	1.163
*3540.97	$1s_4-5p_7$	1, 1	(0), 1.128	*1.242*	1.014
*3539.55	$1s_4-5p_6$	1, 2	(0), 1.500	*1.242*	1.414
3522.68	$1s_4-5p_5$	1, 0	(0), 1.242	1.242	0/0
3502.56	$1s_5-3p_3$	2, 1	(0), 1.558	*1.502*	1.390
*3431.75	$1s_5-5p_9$	2, 3	(0), 1.032	*1.502*	1.267
†3424.97	$1s_5-5p_6$	2, 2	(0.179), 1.458	1.508	1.406

* Unresolved patterns.
Numbers in italics—Assumed value used to obtain other *g* value.
ˣ Slightly perturbed.
† Partially resolved patterns.
‡ Also measured by Pogany.
[ ] Mixed polarization.

FIG. 1. Upper λ8298 $1s_4-2p_1$ (components $1\rightarrow6=1s_4$). Lower λ8281 $1s_2-2p_3$ (components $2\rightarrow5=1s_2$). Both photographs have exactly the same magnification, and even though the dispersion favors the longer wave-length line (proportional to λ^2), the separation of $1s_2$ is greater than $1s_4$. On the particular plate from which the enlargements were made, these separations were 2.251 mm and 2.260 mm, respectively. If Pogany's results were correct, the spread of the indicated components in the upper picture would be much larger than in the lower.

The $4p^56p$ configuration shows quite serious disagreement in all observed and calculated results and shows the breakdown of the g sum rule for $J=1$. Practically the entire discrepancy is to be attributed to the low g value of $2p_3$. The explanation for this discrepancy becomes obvious when we examine the energy level diagram. The lower states of $4p^55f$ intermingle with the upper states of $4p^56p$, so that the levels $3p_3$ and $5X$ are only 33.5 cm^{-1} apart. These two levels belong to configurations of the same parity

TABLE II. *Average observed g values.*

LEVEL	J	1	2	3	4	5	6	7	8
s_5	2	1.502	—	1.496	1.506	1.495			
s_4	1	1.242	—	1.097	1.171	1.174	1.161		
s_2	1	1.259	1.018						
Σg		2.501							
p_9	3		1.336	1.333					
p_8	2		1.099	1.107					
p_6	2		1.388	1.403	1.403	1.411			
p_2	2		1.181	1.158					
Σg			3.668	3.668					
p_{10}	1		1.898	1.834	1.795	1.795			
p_7	1		1.004	1.034	1.041	1.014			
p_4	1		0.647	0.648					
p_3	1		1.452	1.401					
Σg			5.001	4.917					
d_4'	4					1.231	1.228	1.236	
d_4	3				1.050	1.073	1.094	1.037	
d_1'	3				1.243	1.254	1.231	1.227	
s_1'''	3				1.140				
Σg					3.433				
d_3	2				1.295	1.318	1.315		
d_1''	2				1.006	0.965	0.954	1.005	
s_1''	2				0.899				
s_1''''	2				1.169				
Σg					4.371				
d_5	1				1.098	1.348	1.355	1.294	1.208
d_2	1				0.935	0.823	0.797		
s_1'	1				—	—	—		
Σg					—	—	—		

(even) and both have $J=1$, so that they may perturb each other. In addition, the level $5X$ is the only level of $4p^55f$ with $J=1$ so that its g value should be $0.50(^3D_1)$. The only line involving this level available for measurement was λ4417, which was rather faint. This yielded a g value for $5X$ of 0.61 (with an accuracy of about 2 percent), which is 0.11 in excess of the theoretical value. The g sum for $J=1$ of $4p^56p$ is, according to our measurements, 0.083 less than the theoretical value, so that the total g sum is 5.527 instead of 5.500. These results are probably the same within experimental error. (It is interesting to note that if we use Pogany's g sum, the total g sum is 4.995.)*

The only other g sums available are for the $4p^55d$ configuration for $J=3$ and $J=2$. Here, the theoretical sums are 3.417 and 4.333, respectively, compared with 3.433 and 4.371 from

TABLE III. *$4p^55s$ g values.*

J	LEVEL	OBS. POGANY	OBS. AUTHORS	CALC.*
2	s_5	1.50	1.502	1.500
1	s_4	1.256	1.242	1.243
1	s_2	1.239	1.259	1.257
	Σg	2.495	2.501	2.500

* W. V. Houston, Phys. Rev. **33**, 297 (1929).

TABLE IV. *$4p^55p$ g values.*

J	LEVEL	CALC. LÖRINCZI	CALC. GREEN	OBS. POGANY	OBS. AUTHORS
1	p_3	1.392	1.461	1.425	1.452
1	p_4	0.708	0.653	0.631	0.647
1	p_7	1.041	1.002	1.028	1.004
1	p_{10}	1.907	1.884	1.891	1.898
	Σg	5.048	5.000	4.975	5.001
2	p_2	1.194	1.179	1.163	1.181
2	p_6	1.396	1.365	1.400	1.388
2	p_8	1.08	1.123	1.116	1.099
	Σg	3.670	3.667	3.679	3.668
3	p_9	1.333	1.333	1.33	1.336

* It should be pointed out that both $3p_3$ and $3p_4$ are perturbed by $5X$. $5X$ lies at 4434, $3p_3$ at 4400 and $3p_4$ at 4476. The tendency of the perturbation due to $5X$ is to push $3p_3$ and $3p_4$ farther apart than they would normally be, and to cause the g values of $3p_3$ and $3p_4$ to become smaller. But since the g value of $5X$ and $3p_4$ are nearly the same, the effect on its g value should be much smaller than on that of $3p_3$. The fact that $3p_4$ seems to be unperturbed must be regarded as fortuitous.

experiment. We are inclined to believe that these agree within experimental error.

Only one serious error occurs in the classification of the spectrum. This is the assignment of $4s_1'$. The level so classified has $J=2$ and hence is more probably $4s_1''''$ which has not been assigned. This level has a g value of 1.169 consistent with that classification, but it would be better to interchange the names $4s_1''$ and $4s_1''''$ to give uniformity to all of the rare gas spectrum classifications. With this change, we are left without any level assigned to $4s_1'$. This level should have a value of about 2200 cm^{-1}, and form a combination $2p_{10}-4s_1'$ at about 19,500 cm^{-1}. The only unclassified line in this neighborhood is λ5109.81 (ν19,564.76) which gives a value for $4s_1'$ of 2181.63. In the ultraviolet absorption spectrum, Beutler[7] finds a weak line λ903.10 which yields a term value of 2184. This level he has temporarily assigned to $3s_2$. There are, unfortunately, no data on the Zeeman effect to support either classification.[8]

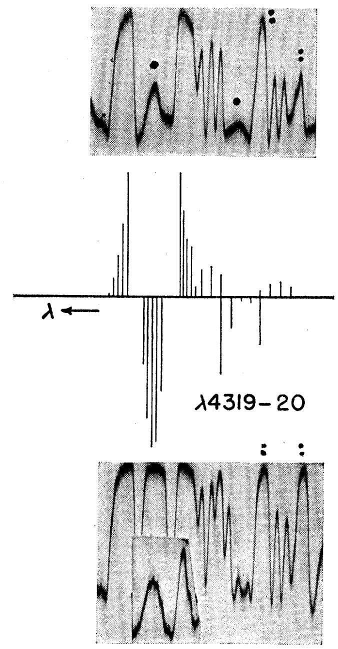

FIG. 2. λλ4319–20. Upper: perpendicular polarization. Lines marked with single dot represent parallel polarization "leaking" through. λ4320 was much over-exposed to bring out weak lines of λ4319. Lines with two dots are KrII. Middle: calculated pattern with perpendicular components above and parallel components below. Bottom: unpolarized pattern. The insert is the trace taken from a ghost to show the structure in the middle component of λ4320. Lines with two dots are KrII.

TABLE V. $4p^56p$ g values.

J	Level	Calc. Lőrinczi	Calc.* Authors	Obs. Pogany	Obs. Authors
1	p_3	1.448	1.493	1.384	1.401
1	p_4	0.614	0.649	0.635	0.648
1	p_7	1.084	1.030	1.046	1.034
1	p_{10}	1.812	1.828	1.820	1.834
	Σg	4.958	5.000	4.885	4.917
2	p_2	1.168	1.169	—	1.158
2	p_6	1.343	1.379	1.406	1.403
2	p_8	1.156	1.119	1.110	1.107
	Σg	3.667	3.667	—	3.668
3	p_9		1.333	1.33	1.333

* These results were determined from a least-squares calculation yielding the following parameters: $F_0=-2034.09$, $F_2=45.09$, $G_0=204.07$, $G_2=12.71$, $\alpha=873.60$, $\beta=904.77$.

TABLE VI. Partial g sums.

Config.	J	jj coupling	Obs.	Config.	J	jj coupling	Obs.
$4p^57p$	1	2.833	2.836	$4p^56d$	2	2.277	2.283
$4p^58p$	1	2.833	2.809	$4p^57d$	2	2.277	2.269
$4p^55d$	1	2.167	2.023	$4p^56d$	3	2.306	2.327
$4p^56d$	1	2.167	2.171	$4p^57d$	3	2.306	2.325
$4p^57d$	1	2.167	2.152	$4p^58d$	3	2.306	2.264

TABLE VII. g values for $4p^5ms$.

Level	Theory[7]	Observed	Level	Theory[7]	Observed
$2s_2$	1.320	1.018	$4s_4$	1.170	1.171
$3s_5$	1.500	1.496	$5s_5$	1.500	1.495
$3s_4$	1.172	1.097	$5s_4$	1.169	1.174
$4s_5$	1.500	1.506	$6s_4$	1.168	1.161

Attempts at a least-squares calculation of the configuration $4p^55d$ led nowhere; the levels are so badly perturbed that no agreement worth considering was obtained.

All of the rare gases show spectra which are very close to those due to jj-coupling; the upper state, in general, lead to very diffuse lines only very few of which have been found, so that it has not been possible to find total g sums. Partial g sums for the lower states yield the following results compared with theory. (See Table VI.)

In the case of the $4p^5ms$ levels, it was found that all of the s_5 levels were normal, with g values equal to 1.500 within experimental error. Both the $2s_2$ and the $3s_4$ levels showed serious perturbations. A comparison of the theoretical and observed patterns is given in Table VII.

The discrepancy in $3s_4$ may be accounted for by configuration interaction. It is only 122 cm^{-1} from $4d_2$ which itself shows a higher g value

[7] H. Beutler, Zeits. f. Physik **93**, 177 (1934–5).

[8] Dr. J. C. Boyce, (private communication) finds a weak line at λ901.86 which yields a term value of 2032 cm^{-1} which fits the series of s_2 terms much better than 2182 cm^{-1}.

than any d_2 thus far found among the rare gases, and reacts with $3s_5$ (from which it is separated by only 1 cm^{-1}) to produce Paschen-Back effects.*

The very large discrepancy in $2s_2$ is not so easy to account for. It looks, almost, as if the level were improperly classified, although it appears to be in about the correct position. Perhaps $2s_2$ and $3s_1'$ should be interchanged.

The level $4d_5$ seems to have an abnormally low value when compared with the other rare gases, all of which have values about 1.4. Not too much importance can be placed on this point, however, for this configuration is badly distorted. Indeed, $4d_5$ seems to be far below its usual position, being lower than $4d_6$ which is usually the lowest level of the p^5d configuration.

The levels $3p_8$ and $3p_9$ are only 5.5 cm^{-1} apart and perturb each other sufficiently to distort the patterns of lines involving them. Their g values were determined by methods already described.[9] (See Fig. 2.)

* The calculations of the Paschen-Back interaction of $3s_5$ and $4d_2$ will be discussed in a separate communication.

[9] J. B. Green and J. F. Eichelberger, Phys. Rev. **56**, 51 (1939); J. B. Green and J. A. Peoples, *ibid.* **56**, 54 (1939).

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Field Dependence of the Intrinsic Domain Magnetization of a Ferromagnet

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In this paper, the variation of the intrinsic domain magnetization of a ferromagnetic with the external magnetic field, is obtained. The basis of the treatment is the exchange interaction model amplified by explicit consideration of the dipole-dipole interaction between the atomic magnets. Approximations appropriate to low temperatures and equivalent to those used by Bloch in his derivation of the $T^{\frac{3}{2}}$ law, are introduced. The resultant expression for the intrinsic volume susceptibility decreases slowly with increasing field; at high fields the functional dependence is as the inverse square root of the field. The variation with temperature is linear; at room temperature and for fields of about 4000 gauss, the order of magnitude of the (volume) susceptibility is 10^{-4}. The results are compared with experiment and satisfactory agreement is found.

I. Introduction

Closely allied to the problem of the temperature variation of the intrinsic magnetization, **M**, of a ferromagnetic body, is the problem of its variation with an external magnetic field, **H**. This intrinsic magnetization is characteristic of a single ferromagnetic domain and is identical with the experimentally observed magnetization when "technical saturation" has been achieved, i.e., when all of the domains in all of the individual crystal grains of the specimen have parallel magnetization vectors.[1]

When technical saturation has been reached, there are still, as a result of temperature agitation, some atomic magnetic moments which are not oriented in the direction of **H**. Further increase of magnetization is then to be ascribed to the progressive alignment of the temperature disoriented atomic magnets by an increasing field. The phenomenon is physically similar to that which obtains in the magnetization of a paramagnetic substance; however, the existence of the strong ferromagnetic coupling forces between the atomic magnets changes completely[2] both the magnitude of the effect, and its de-

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[1] "Technical saturation" is achieved at fields of 2000–4000 gauss, depending on the metallurgical treatment of the (polycrystalline) specimen.

[2] Cf. Eq. (30), (31) below.

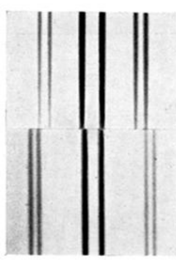

FIG. 1. Upper $\lambda 8298$ $1s_4-2p_1$ (components $1\rightarrow 6=1s_4$). Lower $\lambda 8281$ $1s_2-2p_3$ (components $2\rightarrow 5=1s_2$). Both photographs have exactly the same magnification, and even though the dispersion favors the longer wave-length line (proportional to λ^2), the separation of $1s_2$ is greater than $1s_4$. On the particular plate from which the enlargements were made, these separations were 2.251 mm and 2.260 mm, respectively. If Pogany's results were correct, the spread of the indicated components in the upper picture would be much larger than in the lower.

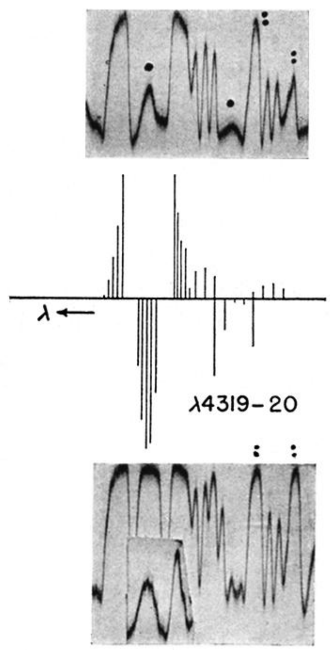

FIG. 2. λλ4319–20. Upper: perpendicular polarization. Lines marked with single dot represent parallel polarization "leaking" through. λ4320 was much over-exposed to bring out weak lines of λ4319. Lines with two dots are KrII. Middle: calculated pattern with perpendicular components above and parallel components below. Bottom: unpolarized pattern. The insert is the trace taken from a ghost to show the structure in the middle component of λ4320. Lines with two dots are KrII.