The Zeeman Effect of Xenon

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Measurements of the Zeeman effects of about 125 lines in the spectrum of XeI have been made. The g sum rule is violated by both of the completely known configurations, and in some cases may be accounted for by configuration interaction. For other configurations, where only the lower levels are known, the J of the core is shown to be a "good" quantum number.

PRELIMINARY classifications in the spectrum of xenon were first given by Meggers *et al.*[1] and were later extended by Gremmer[2] and Rasmussen.[3] The subsequent improvement in photographic techniques enabled Humphreys and Meggers[4] to list further lines and classifications.

Measurements of the Zeeman effect of a few lines of XeI were first carried out by Pogány,[5] and were later supplemented by the addition of fifteen more lines by Lörinczi.[6] The present investigation covers the measurements on about 125 lines, of which those associated with transitions involving the $5p^5mf$ configurations will be discussed at a later date, because of their bearing on a problem of some theoretical importance. Our experimental results are in many cases at considerable variance with Lörinczi's, more so than in the case of krypton[7] and we are unable to account for these discrepancies. Only one error in Humphreys and Meggers'[4] classification has been found, an inversion of the classification of $8d_5$ and $8d_6$. Zeeman effect data clearly show that the H-M $8d_6$ has $J=1$. This modification inverts the usual order of the d_5 and d_6 levels, which also occurs in the case of $5d_5$ and $5d_6$.

The apparatus was the same as that used in our previous work.[7] A mixture of 5 percent Xe and 95 percent He was employed in the discharge tube. Eastman Special Spectroscopic plates were used for wave-lengths greater than 6800A. Eastman 40's were used from λ3200–λ4800; Eastman IG from λ4800–λ5800 and Eastman Superpanchromatic Press were found especially suitable in the region λ5800–λ6800. All plates except the 40's were presensitized by bathing for one minute in a cold 4-percent aqueous ammonia solution.

Exposures varied from 48 hours to 100 hours and in all cases one discharge tube served for a complete exposure.

Table I is a summary of the measurements with the exception of those involving the $5p^5mf$ levels which are indicated by the notation PB (beginning Paschen-Back effect). Parallel polarizations are enclosed in parentheses, mixed polarizations in square brackets; in the fourth column, bold face indicates strongest components, in the last two columns, italics indicate assumed values obtained from other lines.

Table II is a summary of the averages of the g values taken from the last two columns of Table I. Whenever possible, these averages represent only resolved patterns.

Only two configurations of XeI are completely known, $5p^56s$ and $5p^56p$. The comparisons between experiment and theory are given in Tables III and IV. An inspection of these tables shows that XeI is the bad boy of the rare gas spectra. Even the lowest configurations are perturbed enough so that the g sum rule is violated. In all of the other rare gas spectra the g sum rule is accurately verified for all of the low configurations for all values of J. In the XeI spectrum, only $J=2$ of $5p^56p$ satisfies this rule.

The discrepancy in the $5p^56s$ configuration is real and is probably caused by the near presence of the upper levels of $5p^55d$. Pogány's[5] results are based on an assumed value of 1.50 for $1s_5$, and while this appears to be correct, no independent

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4 C. J. Humphreys and W. F. Meggers, Bur. Stand. J. Research **10**, 139 (1933).
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6 K. Lörinczi, Dissertation, Budapest (1937).
7 Green, Bowman and Hurlburt, Phys. Rev. **58**, 1094 (1940).

TABLE I. *Observed Zeeman patterns in xenon.*

WAVE-LENGTH	COMBI-NATION	J VALUES	OBSERVED ZEEMAN PATTERN	g_a	g_b
*3685.90	$1s_5-5p_6$	2, 2	(0.225), 1.448	1.510	1.386
*3693.49	$1s_5-5p_8$	2, 3	(0.000), 1.113	*1.500*	1.307
3809.84	$1s_4-5p_5$	1, 0	(0.000), 1.200	1.200	0/0
*3950.925	$1s_5-4p_6$	2, 2	(0.210), 1.451	1.509	1.392
*3967.541	$1s_5-4p_8$	2, 3	(0.000), 1.044	*1.500*	1.272
3974.417	$1s_5-4p_9$	2, 2	(—), [0.767], **1.103**, **1.490**, 1.876	1.490	1.103
3985.202	$1s_5-4p_{10}$	2, 1	(**0.000**), (0.301), **1.193**, 1.493, —	1.493	1.794
4078.821	$1s_4-4p_5$	1, 0	(0.000), 1.205	1.205	0/0
*4109.709	$1s_4-4p_6$	1, 2	(0.000), 1.495	*1.204*	1.398
*4116.115	$1s_4-4p_7$	1, 1	(0.166), 1.120	1.203	1.036
*4135.134	$1s_4-4p_9$	1, 2	(0.000), 0.992	*1.204*	1.062
4193.01	$1s_5-4V$	2, 2 }	(PB)**	*1.502*	0.86
4193.530	$1s_5-4U$	2, 3 }		*1.502*	1.18
*4500.977	$1s_5-2p_2$	2, 1	(0.000), 1.481	*1.500*	1.537
4524.681	$1s_5-2p_3$	2, 2	(—), (**0.601**), 0.878, **1.195**, **1.501**, 1.823	1.502	1.195
4582.747	$1s_4-2p_1$	1, 0	(0.000), 1.206	1.206	0/0
4611.890	$1s_5-3p_7$	2, 1	(**0.000**), (0.601), —, 1.502, **2.098**	1.501	0.902
4624.276	$1s_5-3p_6$	2, 2	(0.122), (**0.302**), 1.186, **1.341**, **1.512**, 1.664	1.509	1.345
4671.226	$1s_5-3p_8$	2, 3	(**0.000**), (0.177), (0.437), **0.976**, 1.170, 1.348, 1.516, —	1.516	1.348
4690.971	$1s_5-2p_4$	2, 1	(**0.000**), (0.719), —, 1.498, **2.202**	1.494	0.786
4697.020	$1s_5-3p_9$	2, 2	(0.378), (**0.750**), —, **1.123**, **1.497**, 1.866	1.498	1.124
*4734.152	$1s_4-2p_3$	1, 2	(0.000), 1.183	*1.205*	1.190
4792.619	$1s_5-3p_{10}$	2, 1	(**0.000**), (0.215), **1.268**, 1.517, —	1.500	1.732
4807.019	$1s_4-3p_5$	1, 0	(0.000), 1.207	1.207	0/0
4829.709	$1s_4-3p_7$	1, 1	(0.300), 0.903, 1.198	1.202	0.900
‡4843.294	$1s_4-3p_6$	1, 2	(**0.000**), (0.152), —, 1.344, **1.508**	1.192	1.350
4916.508	$1s_4-2p_4$	1, 1	(0.417), 0.797, 1.204	1.206	0.794
*4923.152	$1s_4-3p_9$	1, 2	(0.000), 1.078	*1.204*	1.120
5028.280	$1s_4-3p_{10}$	1, 1	(0.522), 1.203, 1.722	1.203	1.723
[a]5392.795	$1s_3-6X$	0, 1	PB	0/0	0.50
5394.738	$2p_{10}-8d_5$	1, 1	(0.550), 1.311, 1.851	1.853	1.308
*5488.555	$2p_9-9d_4$	2, 3	(0.000), 1.059	*1.106*	1.082
5552.385	$2p_{10}-7d_3$	1, 2	(**0.000**), [0.607], 1.302, 1.847	1.847	1.302
5566.615	$2p_{10}-7d_5$	1, 1	(0.629), 1.217, 1.845	1.845	1.217
5581.781	$2p_{10}-7d_6$	1, 0	(0.000), 1.859	1.859	0/0
*5618.878	$2p_9-8d_4$	2, 3	(0.000), 1.056	1.106	1.081
5688.373	$1s_2-6V$	1, 2	PB	*1.321*	0.87
*5722.14	$2p_9-6s_4$	2, 1	(0.000), 1.065	*1.106*	1.188
[b]5823.89	$1s_3-5X$	0, 1	PB	0/0	0.50
*5824.80	$2p_9-7d_4$	2, 3	(0.000), 1.050	*1.106*	1.078
5894.988	$2p_{10}-6d_5$	1, 1	(0.181), 1.185, 1.835	1.855	1.185
5931.241	$2p_{10}-6d_6$	1, 0	(0.000), 1.852	1.852	0/0
*5934.172	$2p_8-7d_4'$	3, 4	(0.000), 1.088	*1.336*	1.237
*5998.115	$2p_9-5s_4$	2, 1	(0.000), 1.081	1.109	1.164
*6111.759	$2p_7-7d_1''$	1, 2	(0.000), 0.959	*1.022*	0.980
*6152.069	$2p_9-6d_1'$	2, 3	(0.000), 1.424	*1.106*	1.265
6163.935	$1s_2-5V$	1, 2	PB	*1.32*	0.87
6178.302	$1s_2-5Y$	1, 2 }	PB	1.326	1.10
6179.665	$1s_2-5X$	1, 1 }			0.50
*6182.420	$2p_9-6d_4$	2, 3	(0.000), 1.041	1.110	1.076
6189.10	$2p_{10}-4s_4$	1, 1	(0.712), 1.154, 1.839	1.845	1.148
6198.260	$2p_{10}-4s_5$	1, 2	(**0.000**), (0.360), **1.140**, 1.499, 1.852	1.854	1.497
6200.890	$2p_6-7d_1'$	2, 3	(**0.000**), (—), (—), **0.916**, —, —, —, —	*1.379*	1.225
*6206.297	$2p_9-6d_5$	2, 1	(0.000), 1.071	*1.106*	1.176
*6224.169	$2p_6-7d_3$	2, 2	(0.153), 1.333	1.376	1.290
*6261.212	$2p_8-6d_1'$	3, 3	(0.283), 1.283	1.338	1.228
6265.301	$1s_3-4p_{10}$	0, 1	(0.000), 1.808	0/0	1.808
6292.649	$2p_8-6d_4$	3, 3	(—), [0.528], [**0.790**], **1.077**, **1.339**, 1.596, 1.856	1.337	1.076
*6294.45	$2p_8-6d_3$	3, 2	(0.000), 1.357	*1.336*	1.316
*6314.97	$2p_7-5s_4$	1, 1	(0.144), 1.092	1.020	1.164
*6318.062	$2p_8-6d_4'$	3, 4	(0.000), 1.085	*1.336*	1.236
*6430.155	$2p_6-5s_5$	2, 2	(0.220), 1.450	1.389	1.512
†6469.705	$2p_{10}-5d_3$	1, 2	(**0.000**), **0.459**, (0.703), 1.192, 1.849	1.849	1.192
6472.841	$2p_{10}-5d_2$	1, 1	0.812, (1.040), 1.852	1.852	0.812
6487.765	$2p_{10}-5d_1''$	1, 2	(**0.000**), **0.300**, (0.780), 1.080, 1.863	1.860	1.080
*6498.718	$2p_7-6d_1''$	1, 2	(0.000), 0.969	*1.022*	0.987
6500.37	$2p_5-7d_2$	0, 1	(0.000), 0.899	0/0	0.899
6521.508	$2p_7-6d_3$	1, 2	(**0.000**), (0.269), —, 1.290, **1.573**	1.020	1.296
*6533.159	$2p_9-4s_4$	2, 1	(0.000), 1.080	*1.106*	1.158
6543.360	$2p_9-4s_5$	2, 2	(0.401), (**0.767**), **1.098**, **1.495**, 1.887	1.098	1.495
6668.920	$2p_{10}-5d_6$	1, 0	(0.000), 1.862	1.862	0/0
6728.008	$2p_{10}-5d_5$	1, 1	(0.581), 1.273, 1.853	1.854	1.273
6827.315	$1s_3-4X$	0, 1	(0.000), 0.505	0/0	0.505
‡*6846.613	$2p_9-5d_3$	2, 2	(0.167), 1.211	*1.106*	1.199
‡6850.13	$2p_9-5d_2$	2, 1	(**0.000**), (0.280), —, —, **1.383**	1.103	0.823
6863.20	$2p_5-6d_2$	0, 1	(0.000), 0.914	0/0	0.914
*6866.838	$2p_9-5d_1''$	2, 2	(0.066), 1.089	1.107	1.071
*6882.155	$2p_9-5d_4$	2, 3	(0.000), 0.947	*1.106*	1.026
*6910.82	$2p_7-4s_4$	1, 1	(0.142), 1.111	*1.022*	1.164
6925.53	$3d_3-6U$	2, 3	PB	*1.376*	1.17
6935.62	$3d_3-6Y$	2, 2	PB	*1.376*	1.09
*6976.182	$2p_8-5d_1'$	3, 3	(0.198), 1.301	1.339	1.263
*6982.05	$2p_8-5d_3$	3, 2	(0.000), 1.596	*1.336*	1.076
7019.02	$2p_8-5d_4$	3, 3	(0.290), (0.566), (0.860)	*1.336*	1.026
*7047.37	$2p_6-4s_5$	2, 2	(0.217), 1.426	1.365	1.486
*7119.598	$2p_8-5d_4'$	3, 4	(0.000), 1.039	*1.336*	1.217
*7257.94	$3d_4-6Z$	3, 4	PB	(1.01)	(*1.02*)
‡7262.54	$2p_7-5d_3$	1, 2	(**0.000**), (0.178), —, —, **1.379**	1.023	1.201
7266.49	$2p_7-5d_2$	1, 1	(0.198), 0.822, 1.029	1.026	0.824
*7285.301	$2p_7-5d_1''$	1, 2	(0.000), 1.092	*1.022*	1.069
†‡7316.272	$1s_2-4Y$	1, 2	(**0.000**), (0.232), **0.885**, 1.115, 1.35	1.342	1.110
7321.452	$1s_2-4X$	1, 1	0.506, (0.814), 1.316	1.318	0.504
*7336.480	$2p_9-3s_1'''$	2, 3	(0.000), 1.151	*1.106*	1.128
[c]7355.58	$3d_6-5X$	0, 1	PB		0.50
7386.002	$2p_{10}-3s_5$	1, 2	(**0.000**), (0.383), **1.084**, 1.464, 1.851	1.848	1.465
7400.41	$2p_6-5d_3$	2, 2	(0.181), (**0.379**), 1.002, **1.189**, **1.388**, 1.579	1.384	1.194
7424.05	$2p_6-5d_1''$	2, 2	(0.320), (**0.629**), (—), **1.068**, **1.376**, 1.673	1.376	1.068
7451.00	$3d_5-5V$	1, 2	PB	1.40	0.85
7472.01	$3d_5-5Y$	1, 2 }	PB	1.395	1.10
7474.01	$3d_5-5X$	1, 1 }	PB		0.50
7492.23	$2p_8-3s_1'''$	3, 3	(0.176), (0.413), (**0.636**), 0.910, **1.125**, **1.339**, 1.549, 1.754	1.338	1.125
7501.13	$2p_9-3s_1''''$	2, 2	(—), (**0.338**), 0.934, **1.101**, **1.278**, 1.442	1.105	1.274
7514.54	$2p_7-5d_6$	1, 0	(0.000), 1.022	1.022	0/0
7642.025	$1s_3-2p_2$	0, 1	(0.000), 1.553	0/0	1.553
7643.91	$3d_3-5U$	2, 3	PB	*1.376*	1.17
7664.56	$3d_3-5Y$	2, 2	PB	1.376	1.10
*7802.651	$2p_9-3s_4$	2, 1	(0.000), 1.068	*1.106*	1.182
‡7887.395	$1s_2-2p_1$	1, 0	(0.000), 1.313	1.313	0/0
7967.314	$1s_3-3p_7$	0, 1	(0.000), 0.906	0/0	0.906
8206.341	$1s_3-2p_4$	0, 1	(0.000), 0.790	0/0	0.790
8266.519	$1s_2-2p_2$	1, 1	(0.232), 1.324, 1.549	1.321	1.551
8280.116	$1s_4-2p_5$	1, 0	(0.000), 1.206	1.206	0/0
8346.823	$1s_2-2p_3$	1, 2	(**0.000**), (0.146), **1.060**, 1.201, —	1.345	1.201
‡8409.190	$1s_5-2p_7$	2, 1	(**0.000**), (0.474), 1.043, 1.493, **1.961**	1.497	1.034
8819.412	$1s_5-2p_8$	2, 3	(**0.000**), (0.171), (0.347), **1.014**, 1.164, 1.332, 1.493, 1.657	1.499	1.330
9045.446	$1s_5-2p_9$	2, 2	(0.394), (**0.776**), —, —, —, —	*1.500*	1.109

* Pattern was not resolved.
** PB Pattern unsymmetrical due to Paschen-Back effect.
† Almost symmetrical patterns whose separations were badly disturbed by beginning PB effect.
‡ Pattern was partly obscured by other lines (i.e., Xe spark line or He line or ghost of He line).
[a] Forbidden line $1s_3-6Y$ also appeared.
[b] Forbidden line $1s_3-5Y$ also appeared.
[c] Forbidden line $3d_6-5Y$ also appeared.

TABLE II. *Average g values of* XeI.

j	TERM	1	2	3	4	5	6	7	8	9
2	s_5	1.500		1.465	1.496	1.512*				
1	s_4	1.204		1.182*	1.154	1.164	1.188			
1	s_2	1.321								
0	s_3	0/0								
3	p_8		1.336	1.348	1.272*	1.307*				
2	p_9		1.106	1.123	1.103					
2	p_6		1.379	1.347	1.395*	1.386*				
2	p_3		1.195							
1	p_{10}		1.852	1.728	1.801					
1	p_7		1.022	0.903	1.036*					
1	p_4		0.790							
1	p_2		1.552							
0	p_5		0/0	0/0	0/0	0/0				
0	p_1		0/0							
4	d_4'					1.217	1.236	1.237*		
3	d_4			0.01		1.026	1.076	1.078*	1.081*	1.082*
3	d_1'					1.263*	1.246*	1.225*		
3	s_1'''			1.126						
2	d_3			1.376†		1.196	1.303	1.298		
2	d_1''					1.073	0.987*	0.980*		
2	s_1''									
2	s_1''''			1.274						
1	d_5			1.395†		1.273	1.180*	1.217	1.308	
1	d_2					0.819	0.914	0.899		
1	s_1'									
0	d_6			0/0		0/0	0/0	0/0		
3	U				1.18†	1.17†				
2	Y				1.11†	1.10†	1.09†			
2	V				0.86†	0.87†	0.87†			
1	X				0.504†	0.50†	0.50†			

* Obtained only from unresolved patterns.
† Obtained only from perturbed patterns.

TABLE III. *g values for* Xe $5p^56s$.

J	LEVEL	OBSERVED (POGÁNY)	OBSERVED (AUTHORS)	CALCULATED (HOUSTON)[8]
1	$1s_4$	1.20	1.204	1.221
	$1s_2$	1.30	1.321	1.279
Σg		2.50	2.525	2.500
2	$1s_5$		1.500	1.500

measures of $1s_2$ and $1s_4$ are indicated. Lörinczi's[6] results also appear to be unreliable as indicated by the large error in $2p_{10}$.

Partial g sums based on jj-coupling may be obtained for several configurations, and these are listed in Table V.

Inspection shows that except for the case of $5p^57p$ $(J=1)$, the spectrum of XeI is remarkably close to jj-coupling, at least insofar as we may say that the J of the core is a "good" quantum number. In the particular case of $5p^57p$ $(J=1)$ both of the levels $3p_{10}$ and $3p_7$ have g values smaller than the neighboring $5p^56p$ and $5p^58p$ levels, their sum being 0.202 less than for jj-coupling, while $5p^56p$ $(J=1)$ has a g sum 0.217 in excess of the theoretical g sum. The energy levels concerned are:

$2p_2$ 8555	$3p_{10}$ 9907
$2p_4$ 9455	$3p_7$ 9089

so that both configuration interaction and the sharing of g values by the two configurations are extremely probable.

TABLE IV. *g values for* Xe $5p^56p$.

J	LEVEL	OBSERVED (POGÁNY)[5]	OBSERVED (LÖRINCZI)[6]	CALCULATED (LÖRINCZI)[6]	CALCULATED (GREEN)[9]	OBSERVED (AUTHORS)
1	$2p_2$			1.424	1.494	1.552
	$2p_4$		0.781	0.733	0.639	0.790
	$2p_7$	1.02	1.009	1.099	1.029	1.022
	$2p_{10}$		1.75	1.689	1.838	1.852
	Σg			4.945	5.000	5.216
2	$2p_3$	1.183	1.178	1.169	1.178	1.195
	$2p_6$	1.402	1.381	1.407	1.391	1.379
	$2p_9$	1.113	1.113	1.096	1.098	1.106
	Σg	3.698	3.672	3.672	3.667	3.680
3	$2p_8$				1.333	1.336

TABLE V. *Partial g sums in* XeI.

CONFIGURATION	J	jj COUPLING	OBSERVED
$5p^57p$	1	2.833	2.631
$5p^58p$	1	2.833	2.837
$5p^57p$	2	2.500	2.470
$5p^58p$	2	2.500	2.498
$5p^55d(s_1''')$	3	1.111	1.126
$5p^55d(s_1'''')$	2	1.289	1.274
$5p^57d$	1	2.167	2.092
$5p^58d$	1	2.167	2.094
$5p^59d$	1	2.167	2.116
$5p^57d$	2	2.277	2.269
$5p^58d$	2	2.277	2.290
$5p^59d$	2	2.277	2.278
$5p^57d$	3	2.306	2.289
$5p^58d$	3	2.306	2.322
$5p^59d$	3	2.306	2.303

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

[9] J. B. Green, Phys. Rev. **52**, 736 (1937).