MEASUREMENT OF RELATIVE LINE STRENGTHS FOR THE TRANSITION GROUP BETWEEN LEVELS BELONGING TO THE CONFIGURATION $2p^5(^2P^0_{1/2,\,3/2})$ $3d$ AND $2p^5(^2P_{1/2,\,3/2})$ $3p$ IN NeI

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Relative line intensities for the transition group between levels belonging to the configurations $2p^5(^2P^0_{1/2,\,3/2})$ $3d$ and $2p^5(^2P^0_{1/2,\,3/2})$ $3p$ in NeI have been measured by means of the photoelectric method. The sum rule was used to obtain relative line strengths. Resulting values were compared with the theoretical line strengths calculated in the $L-S$, $j-l$ and intermediate coupling approximations.

The noble gas atoms provide interesting material for studies since the spin-orbit interaction of the "luminescent" electron and its electrostatic interaction with the atomic core are of the same order. This fact does not permit the use of the vector model for the description of the noble gas electron shell.

In 1968 Murphy [1] calculated the theoretical values of the transition probabilities for the $3d-3p$ transitions in NeI. These calculations were made on the assumption of single configuration approximation in the intermediate band scheme. The aim of the present paper was the measurement of the relative strengths of these lines since the experimental values of the transition probabilities were unknown hitherto.

The transitions between the levels of the configurations $3d$ and $3p$ of NeI result in seventy six spectral lines in the wavelength range from 705 to 1169 nm.

The spectrum was measured using a DFS-13-2 grating spectrograph with reciprocal dispersion of 0.2 nm/mm and spectral range from 200 nm to 1000 nm. This spectrograph permitted the measurement of 73 out of these 76 lines. The light source was a discharge tube filled with "spec-pure" neon under the pressure of about 1 torr. The tube was supplied by stabilized d.c. ranging from 4 mA to 20 mA during different series of measurements. The radiation was registered using a RCA 7102 photomultiplier with a S1 photocathode cooled to about 240°K. The spectral sensitivity curves of the cathode were determined

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by means incandescent lamps with colour temperatures and the results were reduced using the mean values from both curves. Seven series of measurements were made for each line; the final results were obtained making use of the results of six series. The spread of the results of the particular series was less than 4% for three fourths from the total number of lines. Greater deviations from the mean were obtained for lines whose intensities were so small that the corresponding photomultiplier currents were of the order of the

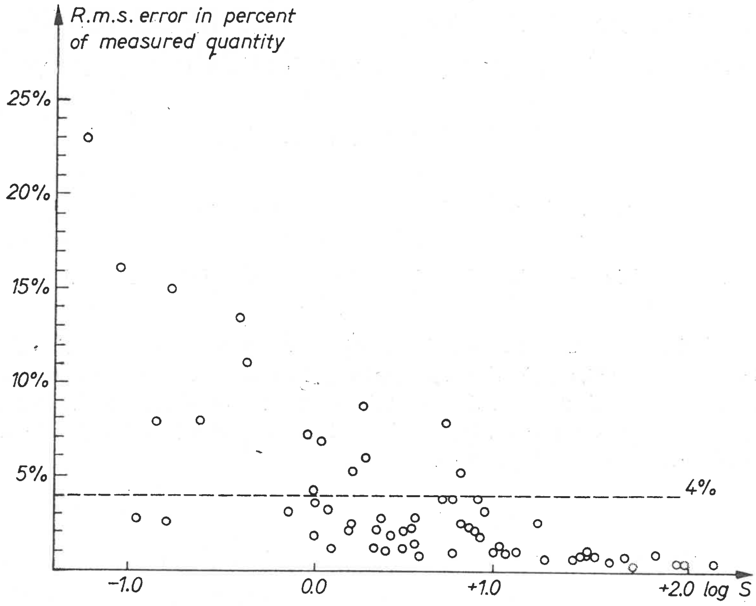

Fig. 1. R.m.s. error of the measured quantity as a function of the logarithm of the line strength

dark current and also for lines lying very close to one another which were not well separated by the spectrograph (these lines are marked with an asterisk in Table III). The r.m.s. errors of the measured quantities as a function of the logarithm of the line strength are shown in Fig. 1.

The line strengths have been calculated from the measured relative intensities using the formulae

$$\frac{S_{ij}}{S_{ik}} = \frac{\lambda_{ij}^4 I_{ij}}{\lambda_{ik}^4 I_{ik}}$$

$$\sum_j S_{ij} = \frac{2J_i+1}{2l_i+1} = S_i$$

$$\sum_i S_{ij} = \frac{2J_j+1}{2l_j+1} = S_j$$

where the subscript i enumerates the levels of the lower and j those of the upper configuration.

For 14 of the investigated lines a weak dependence of the intensity on the excitation current has been found. The intensities of these lines were reduced by means of the least squares method by linear extrapolation to zero excitation current. These lines are marked by the letter R in Table III.

The application of the sum rule in the above-mentioned form is justified by the fact that between the levels of the configuration $2p^5 3d$ and the ground state, there are only three transitions whose probabilities amount to no more than 3% of the sum of transition probabilities from a given upper level to the levels $2p^5\,3p$ [2] (Fig. 2).

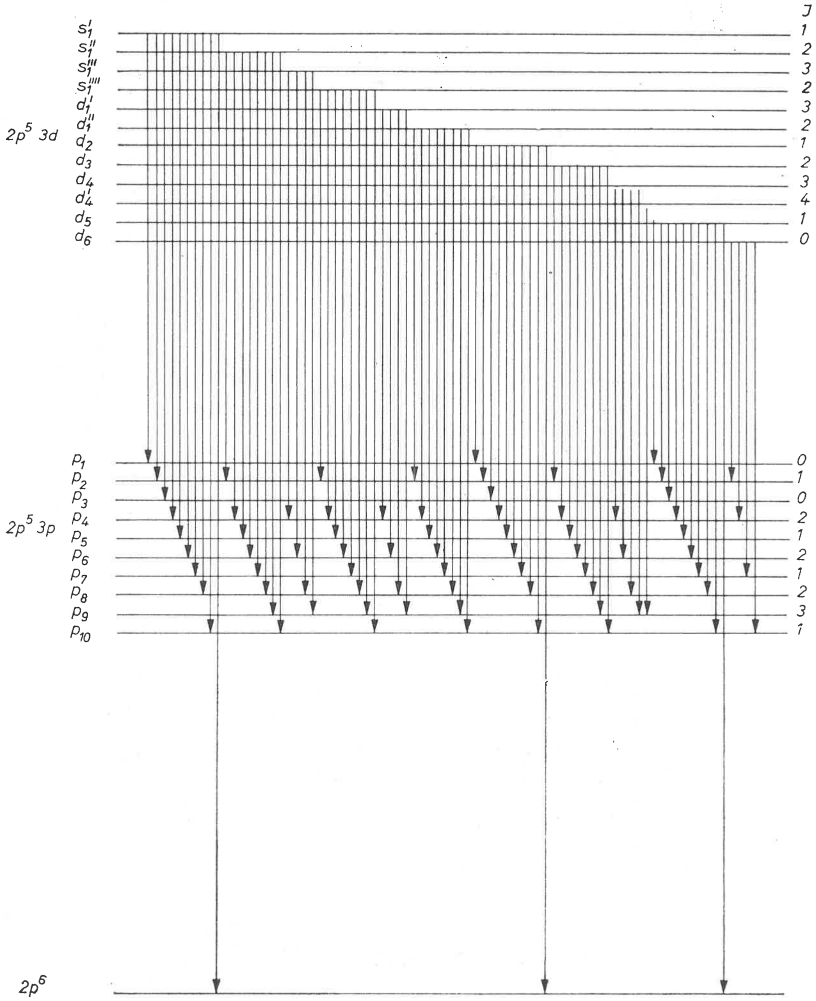

Fig. 2. Schematic diagram of energy levels of neon between which the discussed transitions occur. The three transitions between the upper configuration and the ground state are also indicated in the figure

TABLE I

Values of S_{ij} determined in the present paper in relative units[1]

	Lower level										$S_{j_{theor}}$	$S_{j_{exper.}}$	$\frac{\Delta S_j}{S_{j_{theor}}} \cdot 100\%$
Upper level	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}			
s_1'	?	10.54	11.87	0.00	2.50	0.17	3.32	0.24		1.53	45	30.17	—
s_1''		49.39		5.35	1.54	2.24	1.01	1.07	0.06	7.36	75	68.02	9.3%
s_1'''				90.40		4.82		6.75	0.14		105	102.11	2.8%
s_1''''		0.39		6.86	46.04	0.71	17.14	0.00	0.04	0.04	75	71.22	5.0%
d_1'				6.02		66.22		2.12	30.77		105	105.13	0.1%
d_1''		0.00		1.84	12.06	0.00	36.90	23.88	1.60	0.09	75	76.37	1.8%
d_2	?	0.00	7.76	0.98	10.10	0.43	14.20	2.89		2.05	45	38.41	—
d_3		3.42		8.94	1.85	28.62	2.32	1.00	3.57	28.83	75	78.55	4.7%
d_4				3.01		15.79		85.89	5.05		105	109.74	4.5%
d_4'									133.77		135	133.77	1.7%
d_5	?	7.88	5.37	1.60	0.00	6.00	0.11	1.16		25.50	45	47.62	—
d_6		3.38			0.91		0.00			9.60	15	13.89	7.4%
S_i	25.00	75.00	25.00	125.00	75.00	125.00	75.00	125.00	175.00	75.00	900	875.00	

[1] The directly measured quantities are the line intensities; the values of S_{ij} can be calculated using the well known dependence:

$$I_{ij} = \frac{N_i \cdot 64 \cdot \pi^4 \nu^4}{g_i \cdot 3c^3} S_{ij}$$

The results of measurements are listed in Table I. Since the wavelengths of three out of the 76 lines discussed were outside the range of the spectrograph their intensities were not measured. This led to the necessity of summing over j (over the upper levels) while the consistency of the sums S_j (over the lower levels) with the theoretical values may serve as a measure of the quality of measurements (under the assumption of the

TABLE II

Sum rule for the groups (J, J')

J, J'	$S(J, J')_{\text{theor}}$	$S(J, J')_{\text{exper}}$	$\frac{\Delta S(J, J')}{S(J, J')_{\text{theor}}} \cdot 100\%$
0.1	49.97	50.00	—
1.0	15.00	13.89	7.4%
1.1	71.18	77.73	9.2%
1.2	13.83	13.47	2.6%
2.1	213.76	208.38	2.5%
2.2	81.18	80.51	0.8%
2.3	4.98	5.27	5.8%
3.2	280.10	281.02	0.3%
3.3	35.00	35.96	2.7%
4.3	135.00	133.77	1.7%
	900.00	900.00	

validity of earlier approximations). Another check of the present results can be their agreement with the predictions of the sum rule for the groups (J, J'). This is shown in Table II.

The comparison of experimental results with the values of line strengths calculated under the assumption of L–S and j–l coupling as well as with the values given by Murphy [1] is given in Table III (the line strengths in this table and in the rest of the paper are given in arbitrary units). As it was expected the assumptions of L–S and j–l coupling do not give good results. On the other hand the difference between the values calculated by Murphy and ours expressed by the mean logarithm of the ratio of the greater value to the smaller is 0.20.

Mehlhorn [3] calculated the probabilities of transitions between the levels of the configurations $2p^5\,3p-2p^5\,3s$ of NeI by means of the intermediate coupling method using two methods of checking the quality of the coupling: consistency of the energy level and combined consistency of the energies and Landé factors. The discrepancies between his results and the data [4] are 0.16 and 0.12 in the same units, respectively. By analogy one can argue that the use of the intermediate coupling method modified by Mehlhorn to the calculation of the transition probabilities between the levels of the con-

TABLE III

Comparison of experimental values of line strength with the values calculated under the assumption of *L–S*, *j–l*, and intermediate coupling

Paschen notation		λ [nm]	S_{ij}			
Lower level	Upper level		*L–S*	*j–l*	*IC* [1]	exper.
p_1	s_1'	1056.2	—	25.00	9.87	—
	d_2	1153.6	25.00	—	11.63	—
	d_5	1168.8	—	—	3.60	—
			25.00	25.00	25.00	—
p_2	s_1'	877.2	14.01	12.50	10.56	10.54
	s_1''	878.4	42.26	62.50	51.72	49.39 *R*
	s_1''''	889.3	—	—	0.00	0.39
	d_1''	937.7	—	—	0.00	0.00
	d_2	943.3	—	—	0.14	0.00
	d_3	945.9	7.82	—	3.07	3.42
	d_5	953.4	4.67	—	6.44	7.88
	d_6	954.7	6.24	—	3.07	3.38
			75.00	75.00	75.00	75.00
p_3	s_1'	867.9	18.76	—	14.90	11.87
	d_2	932.7	—	12.50	5.92	7.76
	d_5	942.5	6.24	12.50	4.18	5.37
			25.00	25.00	25.00	25.00
p_4	s_1'	863.5	1.01	1.25	0.00	0.00
	s_1''	864.7	14.01	11.25	3.61	5.35
	s_1'''	865.4	—	105.00	64.35	90.40 *R*
	s_1''''	865.6	—	7.50	4.82	6.86
	d_1'	922.0	—	—	23.13	6.02*
	d_1''	922.2	—	—	3.28	1.84*
	d_2	927.6	—	—	2.90	0.98
	d_3	930.1	23.46	—	17.60	8.94
	d_4	931.4	78.70	—	1.22	3.01
	d_5	037.3	7.82	—	4.09	1.60
			125.00	125.00	125.00	125.00
p_5	s_1'	857.1	—	6.25	1.58	2.50
	s_1''	858.3	—	1.25	0.28	1.54
	s_1''''	859.1	—	67.50	34.17	46.04 *R*
	d_1''	914.9	56.25	—	21.88	12.06
	d_2	920.2	18.75	—	13.15	10.10
	d_3	922.7	—	—	2.51	1.85
	d_5	929.8	—	—	0.01	0.00
	d_6	931.1	—	—	1.42	0.91
			75.00	75.00	75.00	75.00

TABLE III (continued)

Paschen notation		λ [nm]	S_{ij}			
Lower level	Upper level		*L–S*	*j–l*	*IC* [1]	exper.
p_6	s_1'	824.9	—	—	0.00	0.17
	s_1''	825.9	—	—	6.08	2.24
	s_1'''	826.6	—	—	25.94	4.82
	s_1''''	826.7	—	—	2.43	0.71
	d_1'	878.1	105.00	73.50	49.92	66.22 *R*
	d_1''	878.2	18.75	5.25	0.01	0.00*
	d_2	883.1	1.25	4.00	0.01	0.43
	d_3	885.4	—	36.00	16.99	28.62 *R*
	d_4	886.6	—	—	20.70	15.79
	d_5	892.0	—	6.25	2.92	6.00
			125.00	125.00	125.00	125.00
p_7	s_1'	811.9	8.44	—	4.80	3.32
	s_1''	812.9	2.80	—	1.11	1.01
	s_1''''	813.6	63.00	—	33.12	17.14 *R*
	d_1''	863.5	—	47.25	25.55	36.90 *R*
	d_2	868.2	—	20.00	7.89	14.20
	d_3	870.4	0.02	4.00	1.40	2.32
	d_5	876.8	0.31	1.25	0.05	0.11
	d_6	877.9	0.43	2.50	1.08	0.00
			75.00	75.00	75.00	75.00
p_8	s_1'	792.7	2.81	—	2.66	0.24
	s_1''	793.7	13.00	—	2.37	1.07
	s_1'''	794.3	93.37	—	16.10	6.75
	s_1''''	794.4	11.65	—	0.46	0.00
	d_1'	841.7	—	1.50	2.94	2.12
	d_1''	841.8	—	21.00	8.32	23.88 *R*
	d_2	846.3	—	2.25	0.06	2.89
	d_3	848.4	0.31	0.25	1.29	1.00
	d_4	849.5	2.92	100.00	90.22	85.89 *R*
	d_5	854.5	0.94	—	0.58	1.16
			125.00	125.00	125.00	125.00
p_9	s_1''	783.3	2.92	—	0.07	0.06
	s_1'''	783.9	11.65	—	0.22	0.14*
	s_1''''	784.0	0.32	—	0.01	0.04*
	d_1'	830.0	—	30.00	29.60	30.77 *R*
	d_1''	830.2	—	1.50	1.49	1.60
	d_3	836.6	1.74	3.50	3.43	3.57
	d_4	837.6	23.37	5.00	5.18	5.05*
	d_4'	837.8	135.00	135.00	135.00	133.77 *R*
			175.00	175.00	175.00	175.00

TABLE III (continued)

Paschen notation		λ [nm]	S_{ij}			
Lower level	Upper level		L–S	j–l	IC [1]	exper.
p_{10}	s_1'	705.1	—	—	1.95	1.53
	s_1''	705.9	—	—	10.12	7.36
	s_1''''	706.5	—	—	0.00	0.04
	d_1''	743.7	—	—	0.00	0.09
	d_2	747.2	—	6.25	2.04	2.05
	d_3	748.9	41.77	31.25	28.81	28.83 *R*
	d_5	753.6	24.90	25.00	22.66	25.50 *R*
	d_6	754.4	8.33	12.50	9.42	9.60 *R*
			75.00	75.00	75.00	75.00

figurations $2p^5\,3d-2p^5\,3p$ of NeI as well as more precise measurements will permit better agreement between experimental and theoretical values to be obtained.

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