aluminum secondaries. But the primary particles would have to be exceptionally soft to be absorbed by 8 cm of aluminum, and so this explanation contradicts the fact that they were penetrating enough to go through 7 cm of Pb.

Another explanation is that these particles are some kind of radiation excited in the lead block. It has been shown that lead secondaries are not effective in the usual experiments. However, these particles from the lead might be of a non-ionizing nature. Then, they would not be effective in the previous experiment. In this case the non-ionizing particles would have an opportunity to excite ionizing particles in the aluminum. Then, these particles could produce the usual showers in the lead scatterer. This explanation seems rather complex; but it is the only one evident at present.

The non-ionizing character of the rays from the lead block was investigated in the usual way. An aluminum block 2.54 cm thick, was first placed above the top counter and then below it. The same scatterer, a 0.63 cm Pb sheet, was used in both cases. The two counts were: 18.1 ± 0.4 with the aluminum above the top counter and 14.5 ± 0.4 with the aluminum below the top counter which is equal to the chance count. Thus the rays from the lead do not affect the top counter, but they produce rays in the aluminum which do effect it. The rays from the lead must therefore be non-ionizing rays, possibly neutrons.

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The Deep Configurations of Cobalt

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The energy matrix of electrostatic and magnetic spin-orbit interaction is set up for d^7s^2, d^8s and d^9, taking into account the mutual interactions of these configurations. The secular equations are fitted to the deep configurations of Co I, separately, by selecting suitable values for the interaction parameters. The uncertainty existing concerning the assignments of a^2D, a^2G and b^2D is removed. The g-factors for the Zeeman effect in intermediate coupling are calculated for comparison with experimental values presented in the following paper. The mutual interactions of $3d^84s$ with $3d^74s^2$ and $3d^9$ are found to be relatively insignificant. The secular equations are fitted to $3d^74s^2$ and $3d^9$ together, tentatively, in order to observe the effect of mutual interaction upon the values of certain terms which have not yet been discovered, and upon the g-factors. The interaction parameters are compared with those of the deep configurations of Ni I.

THE deep electron configurations of the cobalt atom are $3d^74s^2$, $3d^84s$ and $3d^9$, according to Hund's theory. The most extensive classification of the Co I spectrum has been given by Catalán,[1] who has assigned the deep terms to $3d^74s^2$ and $3d^84s$. The assignments of the quartet and doublet F and P terms, based upon the intensities of their numerous combinations with terms which belong to the intermediate configurations $3d^74s4p$ and $3d^84p$, are certain. The combinations of the other deep terms are both few in number and weak. The assignments of a^2D to $3d^74s^2$, and a^2G and b^2D to $3d^84s$ are tentative. This appears to have been overlooked by Kayser and Konen,[2] who have taken these assignments as assured. Bacher and Goudsmit[3] have assigned a^2G definitely and a^2D tentatively to $3d^74s^2$, and b^2D definitely to $3d^9$.

Such uncertainty concerning the assignment of multiplets is by no means uncommon where two or more configurations overlap. The theoretical study of the configurations d^7s^2, d^8s and d^9, which is presented in this paper, shows that it is possible to remove the uncertainty when the departure from LS coupling is not extreme.

[1] Catalán, An. soc. espan. fis. y quim. **27**, 832 (1929).

[2] Kayser and Konen, *Handbuch der Spektroscopie*, VIII, p. 501.

[3] Bacher and Goudsmit, *Atomic Energy States*, p. 150.

The Energy Matrix

The energy matrix in LS coupling of a configuration which contains an almost complete electron shell can be computed rather simply[4] with the aid of the eigenfunctions of the corresponding configuration which contains an almost empty shell. The matrices of d^7s^2, d^8s and d^9 are identical in form with those of d^3, d^2s and ds^2, except for the constant parts of their diagonal elements. The elements of electrostatic interaction of the latter group are known.[5] The elements of mutual electrostatic interaction between the configurations have been given by Ufford.[6]

[4] Shortley, Phys. Rev. **40**, 185 (1932); Johnson, Phys. Rev. **43**, 632 (1933).
[5] Condon and Shortley, Phys. Rev. **37**, 1025 (1931); Ufford and Shortley, Phys. Rev. **42**, 167 (1932).
[6] Ufford, Phys. Rev. **44**, 732 (1933).

The deep configurations of cobalt deviate sufficiently from LS coupling so that the complete matrices are needed. Consequently, the first order eigenfunctions of d^3, d^2s and ds^2 were set up in exact accord, as to the phases of their components, with those employed by Ufford, and the spin-orbit matrices were computed. The elements of electrostatic interaction were taken from the references. The matrices are valid for d^7s^2, d^8s and d^9.

The diagonal elements of electrostatic interaction of the first-order eigenfunctions of d^7s^2, referred to ^4F as zero, are

^2H: $9F_2+60F_4$, ^2F: $24F_2-15F_4$, ^4P: $15F_2-75F_4$,
^2G: $4F_2+85F_4$, $^2D^a$: $22F_2+135F_4$, ^2P: $9F_2+60F_4$,
^4F: 0, $^2D^b$: $18F_2+15F_4$,

and the non-diagonal element between the two ^2D multiplets is

$$(^2D^a|e^2/r_{ij}|^2D^b)=(189)^{\frac{1}{2}}(F_2-5F_4).$$

The matrix of spin-orbit interaction for d^7s^2, factored according to values of J, is

$J=11/2$

	^2H
^2H	$\frac{1}{2}a$

$J=9/2$

	^2H	^2G	^4F
^2H	$-(3/5)a$	$(66/25)^{\frac{1}{2}}a$	0
^2G	$(66/25)^{\frac{1}{2}}a$	$(3/5)a$	$(5/2)^{\frac{1}{2}}a$
^4F	0	$(5/2)^{\frac{1}{2}}a$	$(3/2)a$

$J=7/2$

	^2G	^4F	^2F
^2G	$-(3/4)a$	$(5/8)^{\frac{1}{2}}a$	$(15/16)^{\frac{1}{2}}a$
^4F	$(5/8)^{\frac{1}{2}}a$	0	$-(3/8)^{\frac{1}{2}}a$
^2F	$(15/16)^{\frac{1}{2}}a$	$-(3/8)^{\frac{1}{2}}a$	$-(1/4)a$

$J=5/2$

	^4F	^2F	$^2D^a$	$^2D^b$	^4P
^4F	$-(7/6)a$	$-(5/18)^{\frac{1}{2}}a$	$-(14/15)^{\frac{1}{2}}a$	$(10/9)^{\frac{1}{2}}a$	0
^2F	$-(5/18)^{\frac{1}{2}}a$	$(1/3)a$	$(7/3)^{\frac{1}{2}}a$	$(1/3)a$	0
$^2D^a$	$-(14/15)^{\frac{1}{2}}a$	$(7/3)^{\frac{1}{2}}a$	$(1/2)a$	$-(7/12)^{\frac{1}{2}}a$	$-(12/5)^{\frac{1}{2}}a$
$^2D^b$	$(10/9)^{\frac{1}{2}}a$	$(1/3)a$	$-(7/12)^{\frac{1}{2}}a$	$-(1/6)a$	0
^4P	0	0	$-(12/5)^{\frac{1}{2}}a$	0	$(1/2)a$

$J=3/2$

	^4F	$^2D^a$	$^2D^b$	^4P	^2P
^4F	$-2a$	$-(21/10)^{\frac{1}{2}}a$	$(5/2)^{\frac{1}{2}}a$	0	0
$^2D^a$	$-(21/10)^{\frac{1}{2}}a$	$-(3/4)a$	$(21/16)^{\frac{1}{2}}a$	$-(2/5)^{\frac{1}{2}}a$	$-(7/8)^{\frac{1}{2}}a$
$^2D^b$	$(5/2)^{\frac{1}{2}}a$	$(21/16)^{\frac{1}{2}}a$	$(1/4)a$	0	$(27/8)^{\frac{1}{2}}a$
^4P	0	$-(2/5)^{\frac{1}{2}}a$	0	$-(1/3)a$	$-(35/9)^{\frac{1}{2}}a$
^2P	0	$-(7/8)^{\frac{1}{2}}a$	$(27/8)^{\frac{1}{2}}a$	$-(35/9)^{\frac{1}{2}}a$	$(1/3)a$

$J=1/2$

	^4P	^2P
^4P	$-(5/6)a$	$-(14/9)^{\frac{1}{2}}a$
^2P	$-(14/9)^{\frac{1}{2}}a$	$-(2/3)a$

The diagonal elements of electrostatic interaction of d^8s, referred to ^4F as zero, are:

^2G: $12F_2'+10F_4'+G_2'$, ^2D: $5F_2'+45F_4'+G_2'$, ^2P: $15F_2'-75F_4'+3G_2'$,
^4F: 0, ^4P: $15F_2'-75F_4'$, ^2S: $22F_2'+135F_4'+G_2'$.
^2F: $3G_2'$,

The matrix of spin-orbit interaction for d^8s, factored according to values of J, is

$J=9/2$

	^2G	^4F
^2G	0	$-a'$
^4F	$-a'$	$(3/2)a'$

$J=7/2$

	^2G	^4F	^2F
^2G	0	$-(1/2)a'$	$-(3/4)^{\frac{1}{2}}a'$
^4F	$-(1/2)a'$	0	$(3/4)^{\frac{1}{2}}a'$
^2F	$-(3/4)^{\frac{1}{2}}a'$	$(3/4)^{\frac{1}{2}}a'$	a'

$J=5/2$

	^4F	^2F	^2D	^4P
^4F	$-(7/6)a'$	$(5/9)^{\frac{1}{2}}a'$	$(16/15)^{\frac{1}{2}}a'$	0
^2F	$(5/9)^{\frac{1}{2}}a'$	$-(4/3)a'$	$-(4/3)^{\frac{1}{2}}a'$	0
^2D	$(16/15)^{\frac{1}{2}}a'$	$-(4/3)^{\frac{1}{2}}a'$	0	$(21/10)^{\frac{1}{2}}a'$
^4P	0	0	$(21/10)^{\frac{1}{2}}a'$	$(1/2)a'$

$J=3/2$

	^4F	^2D	^4P	^2P
^4F	$-2a'$	$(12/5)^{\frac{1}{2}}a'$	0	0
^2D	$(12/5)^{\frac{1}{2}}a'$	0	$(7/20)^{\frac{1}{2}}a'$	$(7/4)^{\frac{1}{2}}a'$
^4P	0	$(7/20)^{\frac{1}{2}}a'$	$-(1/3)a'$	$(5/36)^{\frac{1}{2}}a'$
^2P	0	$(7/4)^{\frac{1}{2}}a'$	$(5/36)^{\frac{1}{2}}a'$	$(1/3)a'$

$J=1/2$

	^4P	^2P	^2S
^4P	$-(5/6)a'$	$(1/18)^{\frac{1}{2}}a'$	$-2a'$
^2P	$(1/18)^{\frac{1}{2}}a'$	$-(2/3)a'$	$(2)^{\frac{1}{2}}a'$
^2S	$-2a'$	$(2)^{\frac{1}{2}}a'$	0

In d^9, the diagonal element of spin-orbit interaction for $^2D_{5/2}$ is a'' and that for $^2D_{3/2}$ is $-3/2a''$. The parameters a, a' and a'' are the negatives of the spin-orbit interaction integrals for a d electron of d^7s^2, d^8s and d^9, respectively.

The electrostatic interaction elements between the first order eigenfunctions of multiplets in different configurations are

$$(d^7s^2\ ^2G\ |e^2/r_{ij}|\ d^8s\ ^2G)=(50)^{\frac{1}{2}}{}'R_2,$$
$$(d^7s^2\ ^4F\ |e^2/r_{ij}|\ d^8s\ ^4F)=0,$$
$$(d^7s^2\ ^2F\ |e^2/r_{ij}|\ d^8s\ ^2F)=(90)^{\frac{1}{2}}{}'R_2,$$
$$(d^7s^2\ ^2D^a|e^2/r_{ij}|\ d^8s\ ^2D)=-(35/2)^{\frac{1}{2}}{}'R_2,$$
$$(d^7s^2\ ^2D^b|e^2/r_{ij}|\ d^8s\ ^2D)=(135/2)^{\frac{1}{2}}{}'R_2,$$
$$(d^7s^2\ ^4P\ |e^2/r_{ij}|\ d^8s\ ^4P)=0,$$
$$(d^7s^2\ ^2P\ |e^2/r_{ij}|\ d^8s\ ^2P)=(315)^{\frac{1}{2}}{}'R_2,$$
$$(d^7s^2\ ^2D^a|e^2/r_{ij}|\ d^9\ ^2D)=2''G_2,$$
$$(d^7s^2\ ^2D^b|e^2/r_{ij}|\ d^9\ ^2D)=0,$$
$$(d^8s\ ^2D\ |e^2/r_{ij}|\ d^9\ ^2D)=(70)^{\frac{1}{2}}{}''R_2,$$

where $'R_2=(d^7s^2,\ d^8s)(1/35)R^2(nd,\ nd;\ nd,\ n's)$,
$''R_2=(d^8s,\ d^9)(1/35)R^2(nd,\ nd;\ nd,\ n's)$

in terms of Ufford's integrals,[6] and

$$''G_2=(d^7s^2,\ d^9)(1/5)G^2(nd,\ n's).$$

The interaction elements are zero between multiplets which have unequal S or L quantum numbers. There are no spin-orbit interactions between these configurations.

The Cobalt Configurations

The complete energy matrices were set up for the configurations separately, as the first step, by adding the electrostatic elements to the corresponding elements of spin-orbit interaction. The secular equations, formed by subtracting the term value symbol W from each diagonal element and equating the resulting determinant

to zero, factor according to values of J. The degree of each equation is determined by the number of rows in the corresponding matrix.

The roots of these equations were fitted to the empirical term values by selecting appropriate values for the interaction parameters. Since the departure of these configurations from LS coupling is moderate, approximate values of the parameters were found by ignoring the non-diagonal matrix elements. The complete secular equations were then employed, and the values of the parameters were adjusted so that the deviations of the computed term values from the empirical values were fairly well balanced. The values of the parameters are $F_2=1522$, $F_4=112.3$, $a=-520$ for $3d^74s^2$; $F_2'=1225$, $F_4'=110.9$, $G_2'=1290$, $a'=-465$ for $3d^84s$; and $a''=-493$ for $3d^9$.

The calculated term values are compared with the empirical values given by Catalán, in Table I. In the last two columns the g-factors in intermediate coupling, computed by the method previously described by the author,[7] are compared with their values in LS coupling.

The values of the parameters F_2 and F_4 are determined by the intervals b^4P-a^4F and b^2P-a^4F. When calculated from these values, a^2G fits into $3d^74s^2$ nicely, but $^2D^-$ and $^2D^+$ fall so high that a^2D and b^2D cannot belong to this configuration. The multiplet a^2D is assigned to $3d^84s$ because, like ^2D of that configuration, it is not inverted. The assignment is confirmed by the reasonable values obtained for F_2' and F_4'. This leaves b^2D to be assigned to $3d^9$. The assignments to configurations, except that of a^2D, agree with those of Bacher and Goudsmit.

The deep cobalt configurations appear to be rather strongly perturbed, the calculated term values differing from the empirical values by several hundred units in a few instances. Since their mutual interactions do not affect their quartets directly, the distortions of a^4P and b^4P and their displacements relative to a^4F and b^4F

[7] Marvin, Phys. Rev. **44**, 818 (1933).

TABLE I. *Term values and g-factors for cobalt, without configuration interaction.*

Configuration	Term	W(cm^{-1}) obs.	W(cm^{-1}) calc.	g LS	g calc.	Configuration	Term	W(cm^{-1}) obs.	W(cm^{-1}) calc.	g LS	g calc.
$3d^74s^2$	$a^4F_{9/2}$	0	0	1.333	1.330	$3d^84s$	$b^4F_{9/2}$	3483	3483	1.333	1.333
	$a^4F_{7/2}$	816	808	1.238	1.238		$b^4F_{7/2}$	4143	4145	1.238	1.237
	$a^4F_{5/2}$	1407	1402 (1402)*	1.029	1.030 (1.030)*		$b^4F_{5/2}$	4690	4683	1.029	1.028
	$a^4F_{3/2}$	1809	1808 (1808)	0.400	0.401 (0.401)		$b^4F_{3/2}$	5076	5079	0.400	0.402
	$b^4P_{5/2}$	15184	14955 (14936)	1.600	1.597 (1.597)		$a^2F_{7/2}$	7442	7629	1.143	1.142
	$b^4P_{3/2}$	15774	15205 (15204)	1.733	1.720 (1.720)		$a^2F_{5/2}$	8461	8679	0.857	0.859
	$b^4P_{1/2}$	16196	15590	2.667	2.645		$a^4P_{5/2}$	13795	13857	1.600	1.579
	$a^2G_{9/2}$	16468	16051	1.111	1.112		$a^4P_{3/2}$	14036	14355	1.733	1.719
	$a^2G_{7/2}$	17234	16838	0.889	0.889		$a^4P_{1/2}$	14399	14598	2.667	2.664
	$b^2P_{3/2}$	20501	20878 (20850)	1.333	1.282 (1.272)		$a^2D_{5/2}$	16778	16799	1.200	1.219
	$b^2P_{1/2}$	21216	21665	0.667	0.689		$a^2D_{3/2}$	16471	16440	0.800	0.879
	$^2H_{11/2}$		20992	1.091	1.091		$a^2P_{3/2}$	18390	18194	1.333	1.268
	$^2H_{9/2}$		21695	0.909	0.913		$a^2P_{1/2}$	18775	18415	0.667	0.671
	$^2D^-_{5/2}$		22962 (23843)	1.200	1.202 (1.202)		$^2G_{9/2}$		21294	1.111	1.111
	$^2D^-_{3/2}$		24130 (24882)	0.800	0.863 (0.824)		$^2G_{7/2}$		21298	0.889	0.890
	$^2F_{7/2}$		35798	1.143	1.143		$^2S_{1/2}$		47421	2.000	2.000
	$^2F_{5/2}$		35478 (35471)	0.857	0.857 (0.856)	$3d^9$	$b^2D_{5/2}$	21920	21920 (21918)	1.200	1.200 (1.200)
	$^2D^+_{5/2}$		56272 (56371)	1.200	1.200 (1.200)		$b^2D_{3/2}$	23153	23153 (23165)	0.800	0.800 (0.850)
	$^2D^+_{3/2}$		55920 (56021)	0.800	0.800 (0.800)						

* Term values and g-factors calculated with configuration interaction between $3d^74s^2$ and $3d^9$ are in parentheses.

may perhaps be ascribed to the influence of intermediate or high configurations which, having sextets, are capable of interacting with the quartets of other configurations. These interactions cannot be studied until the eigenfunctions of certain five-electron systems are developed.

The mutual interaction between $3d^74s^2$ and $3d^84s$ is so small that it is masked by other effects. The calculated values of a^2P and b^2P, which would be pushed apart most vigorously by this interaction, are already farther apart than the empirical values in Table I. The interaction parameter $'R_2$ must be small. This is in accord with the results of Ufford[6] for Ti II and Zr II. The parameter $''R_2$ of interaction between $3d^84s$ and $3d^9$ is probably of the same order of magnitude. The effect of this interaction is probably insignificant, since the D doublets which are directly affected are far apart.

The interaction between $3d^74s^2$ and $3d^9$ should be considerable, since $''G_2$ should be not much smaller than G_2'. Unfortunately, the number of secular equations is insufficient to evaluate the unknown parameters. A calculation was deemed worth while, nevertheless, in order to study the effect of the interaction on the d doublets and the g-factors. The matrices, each six elements square, were set up for the terms with $J=5/2$ and $J=3/2$ with the elements of configuration interaction included. A parameter, denoted by B, was added to the diagonal elements for $^2D_{5/2}$ and $^2D_{3/2}$ of $3d^9$ in order to place this multiplet relative to a^4F of $3d^74s^2$. A reasonable value was *assumed* for $''G_2$, the parameters of $3d^74s^2$ were retained unchanged, and the secular equations were fitted to the empirical term values by adjusting the parameters B and a''. The values of the parameters are $''G_2=1000$, $B=22{,}510$ and $a''=-440$.

The term values and g-factors for the terms affected by configuration interaction are given in parentheses in Table I. The multiplets b^2D and $^2D^-$ are pushed apart about 1000 units by the interaction which has been assumed, and the other terms involved are displaced by lesser amounts. The values given for the $^2D^-$ terms must be considered uncertain to the extent of several hundred units, owing to the fact that $''G_2$ may actually be considerably larger or smaller than the value assumed. These terms should be sought in the region 23,500–25,500 cm^{-1}. The assignment of b^2D to $3d^9$ was confirmed by solving the secular equations by approximations, considering that configuration interaction adds an increment to each term value. The ^2D terms of $3d^9$ are displaced downward and those of $3d^74s^2$ are raised.

The g-factors in intermediate coupling, without configuration interaction, are near to their values for LS coupling, except for a few terms with low values of J which exhibit moderate deviations. Configuration interaction between $3d^74s^2$ and $3d^9$ tends to reduce these deviations. The calculated g-factors for the F and G terms agree very well with the experimental values presented in the following paper. The considerable discrepancies which are found for the P and D terms are further evidence of unidentified perturbations.

The interaction parameters are collected in Table II, together with the parameters of the deep configurations of nickel.[8] The parameters calculated with configuration interaction are in parentheses. The parameters of cobalt are smaller than those of nickel, as the smaller atomic number leads one to expect. Corresponding parameters diminish in magnitude as the number of $3d$ electrons is increased. The fact that $''G_2$ and a'' are smaller than G_2' and a', respectively, when calculated with configuration interaction,

TABLE II. *Interaction parameters of the deep configurations of cobalt and nickel.*

Cobalt		Nickel	
$3d^74s^2$	$F_2=1522$ $F_4=112.3$ $a=-520$	$3d^84s^2$	$F_2=1653$ $F_4=124.0$ $a=-655.8$
$3d^84s$	$F_2'=1225$ $F_4'=110.9$ $G_2'=1290$ $a'=-465$	$3d^94s$	$G_2'=1334$ $a'=-603.6$
$3d^9$	$a''=-493$ (-440)*		
$3d^74s^2-3d^9$	$''G_2=(1000)$ $B=(22510)$		

* With configuration interaction.

[8] Marvin and Baragar, Phys. Rev. **43**, 973 (1933). F_2 and F_4 of Ni $3d^84s^2$ are calculated from the constants, which should be labelled δ, γ, β, α, in the order in which they appear, to agree with Johnson's notation. G_2' of Ni $3d^94s$ is equal to one-half of the a^1D-a^3D interval, and $a'=2\gamma$.

indicates that the interaction assumed is of the right order of magnitude.

Merrill[9] has considered Co I $3d^8(^3F)4s$ as a three-vector problem, assuming Russell-Saunders coupling in the parent ion. His $2A=-456.34$ compares favorably with $a'=-465$ for the interaction integral for the $3d$ electrons. His $-B/2=1210.9$, calculated from the interval a^2F-b^4F, is considerably less than $G_2'=1290$, which is influenced by a^2D and a^2P as well as by a^2F. While the approximations made in the three vector problem have some effect, the difference between the values of these parameters is ascribed mainly to the influence of second order interactions which have not yet been identified.

[9] Merrill, Phys. Rev. **46**, 487 (1934).

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Zeeman Effect in the Arc Spectrum of Cobalt

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Zeeman patterns for 151 lines in the range λ3200 to λ6500 are measured and g-factors for 100 terms are determined. All the experimental g-factors are compared with their theoretical values for LS coupling and those for the deep even terms are compared with theoretical values for intermediate coupling. The experimental values for the multiplets, b^4P, a^2D, m^2D°, y^4F° and m^2P° deviate rather widely from the theoretical values. The Zeeman patterns indicate changes in classifications for λ4549.67 and λ6450.24 and decide the quantum numbers for two incompletely analyzed terms.

ANALYSIS of the cobalt arc spectrum[1, 2] has been extended to include more than twelve hundred lines and many of the terms have been assigned to electron configurations. This analysis makes possible a study of the Zeeman effect in electron coupling intermediate between the LS and (jj) types for even multiplicity. No extensive work has been done on the Zeeman effect in the cobalt arc spectrum. Unresolved Zeeman separations have been measured for a number of lines by several observers,[3, 4] but the data are neither sufficiently accurate nor complete to permit the determination of g-factors.

This article presents an investigation of the Zeeman effect for 151 lines in the range λ3200 to λ6500 from which the g-factors for 100 terms are calculated. The experimental values for the deep, even terms are compared with the theoretical g-factors given by Marvin in the preceding article. Zeeman patterns calculated from the g-factors are compared with the resolved patterns observed by Rybár.[4]

The spectrograph, an Anderson 21-foot concave grating on a Paschen mounting, as well as the magnet, and Gaertner comparator were those used by Marvin and Baragar[5] in their investigation on nickel. The quartz lens and calcite plate were also used to form separate images of the components of vibration parallel and perpendicular to the magnetic field, in order that they might be photographed separately. Strips of carbon and electrolytic cobalt, crossing each other at right angles between the magnetic poles, were used for arc electrodes. The cobalt electrode was fixed in position and insulated from the magnet pole by a fused quartz disk. The carbon electrode was vibrated by means of a cam arrangement to produce an intermittent arc. To prevent excessive heating and melting of the cobalt due to continuous arcing the cam was arranged to keep the electrodes separated during

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[1] M. A. Catalán, Zeits. f. Physik **47**, 89 (1928).

[2] An. soc. espán. fis y quim. **27**, 832 (1929).

[3] N. A. Kent, Astrophys. J. **13**, 289 (1901); I. M. Graftdijk, Arch. neérlandaises, Series 3a, **2**, 192 (1912).

[4] Rybár, Physik. Zeits. **12**, 889 (1911).

[5] H. H. Marvin and A. E. Baragar, Phys. Rev. **43**, 973 (1933).