Physics. — "*The Anomalous* ZEEMAN-*Effect.*" By Dr T. VAN LOHUIZEN. (Communicated by Prof. H. A. LORENTZ).

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Different attempts have already been made to explain the ZEEMAN-Effect from the atom model of BOHR [1]). As yet only the normal LORENTZ triplet has been explained, often with superfluous components, which however have disappeared in the theory of RUBINOWICZ.

The theory of the anomalous ZEEMAN-effect has not yet advanced much, nor is the explanation of the PASCHEN-BACK-effect much further.

It may, however, be tried to bring one of the parts of the problem to a solution, so that possibly the results obtained in this way might be serviceable for the complete solution of the problem.

One of the questions that presents itself here, and which I have set myself the task to answer, is this:

Does the magnetic splitting up exclusively depend on the initial and the final path in which the electron moves, or does the transition play a part in it?

In other words:

Is in the presence of a magnetic field the formula:

$$\nu = \frac{W_1 - W_2}{h} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

valid, or should it be replaced by a formula as e.g.

$$\bar{\nu} = \frac{W_1 - W_2}{h} \pm \frac{eM}{4\pi\, mc} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

as BOHR [2]) thinks he has to assume.

I will put the question into still another form, because expressed in these words the solution is easiest to give.

It is known that the frequency of the vibrations of every spectrum line may be represented as the difference of two functions, so-called "sequences", e.g.:

[1]) N. BOHR, Phil. Mag. 27, p. 506. 1914.
K. HERZFELD, Phys. Zs. 15, p. 193. 1914.
P. DEBEYE, Gött. Nachr. 1916, p. 142, Phys. Zs. 17, p. 507. 1916.
A. SOMMERFELD, Phys. Zs. 17, p. 491. 1916.
A. RUBINOWICZ, Phys. Zs. 19, p. 441 en 465. 1918.

[2]) N. BOHR, Phil. Mag 27, p. 506. 1914.

$$\nu = \psi(i) - \varphi(k) \left\{ \begin{array}{l} i = 1 . 2 . 3 \ldots \\ k = 2 . 3 . 4 \ldots \end{array} \right. \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

I have extensively set this forth in my treatise "Le Phénomène de ZEEMAN et les séries spectrales" [1]), and will henceforth refer to this.

There I have demonstrated among others that for every "complex" of spectrum lines, i.e. all the spectrum lines whose frequencies satisfy equation (3) when the functions ψ and φ are given, and i and k each pass through the series of the whole positive values, a definite type of anomalous ZEEMAN-effect holds, provided the influence of the PASCHEN-BACK-effect be taken into account. Hence we may briefly say that every type of anomalous ZEEMAN-effect is determined by the form of the functions ψ and φ. When these functions have once been determined, the difference of these functions for positive whole values of the argument always yields a spectrum line with a definite type of ZEEMAN-effect.

As has been shown more at length in my cited paper [2]), these functions may be indicated as:

Single	p			s			d			f		
Double	P		P'	S		S'	D		D'	F		F'
Triple	Π	Π'	Π''	Σ	Σ'	Σ''	Δ	Δ'	Δ''	Φ	Φ'	Φ''

Accordingly the symbol $\Pi\Sigma$ is the brief way of writing:

$$\nu = \Pi(i) - \Sigma(k) \left\{ \begin{array}{l} i = 1 . 2 . 3 \ldots \\ k = 2 . 3 . 4 \ldots \end{array} \right.$$

For the ZEEMAN-effects belonging to every complex I refer to (l.c.).

The above question may, therefore, now also be worded as follows: Is each of the above-mentioned functions ("sequences") separately changed by a magnetic field, and is, therefore, the ZEEMAN-effect that is observed the result of the change of the two sequences together?

Or could we ask when speaking of Π-paths, Σ-paths etc., by which we therefore express that an electron that jumps from an Σ-path to a Π-path gives rise to a spectrum line belonging to the complex $\Pi\Sigma$:

Is every Π-path, Σ-path, etc. in a magnetic field each in itself

1) T. VAN LOHUIZEN, Arch. Musée Teyler (III) 2, p. 165. 1914.

2) Henceforth to be indicated as (l. c.).

split up into different paths, each with a somewhat different energy value, so that when jumping from and to these transformed paths the electrons would emit a vibration with a somewhat changed frequency?

If this question should be answered in the affirmative, it would follow from this that given the modes of splitting up of each of the paths (Π, Σ etc.), the observed types of ZEEMAN-effect might be found from this by simple subtraction, in other words, that the anomalous ZEEMAN-effect would follow the so-called "Kombinationsprinzip".

To answer the questions put I have done exactly the reverse. I have namely tried to determine whether in the material of observation of the anomalous ZEEMAN-effect indications were to be found of the validity or non-validity of the "Kombinationsprinzip".

In what follows I will communicate some of the results obtained by me.

As material has served what I had collected in (l.c.). In order to be able to treat a number of complexes as large as possible with a number of sequences as small as possible I have confined myself for my first investigation to the triple complexes, and added to this some single complexes with strange asymptote.

These are collected in the following table:

initial path / final path	Σ	Δ	Δ''	d
Π	$\Pi\Sigma$	$\Pi\Delta$	$\Pi\Delta''$	Πd
Π'	$\Pi'\Sigma$	$\Pi'\Delta$	$\Pi'\Delta''$	$\Pi'' d$
Π''	$\Pi''\Sigma$	$\Pi''\Delta$	$\Pi''\Delta''$	$\Pi'' d$

For the types of ZEEMAN-effect that these complexes present, see (l.c.).

From this material some general conclusions may first of all be made.

When the electron jumps from an initial path to a Π-path, the ZEEMAN-effect is more complicated than when from the same initial path it jumps to a Π'-path, and this in its turns is again more complicated than when from the same initial path it jumps to a Π''-path.

It is therefore natural to assume that in a magnetic field the

Π-path will split up into more paths than the Π'-path, and this again into more than the Π''-path.

For the double series the same thing applies to the P-path and the P'-path.

When only the $\perp$ polarized components are considered, the same rules hold for them, in this case "more" should however be replaced by "more or equal".

The number of components polarized // is for Π' greater than Π'', and for P equal to P'.

Another general conclusion can be drawn. When the electron jumps from Σ (and also from s and S) paths the components polarized $\perp$ and // are always different.

Jumps from the other initial paths ($\Delta, \Delta', \Delta''$, and d) often yield coinciding $\perp$ and // polarized components. This is e.g. the case for jumps

from Δ paths to Π, Π', and Π'' paths
" Δ " " Π' "
" Δ'' " " Π' and Π'' "
" d " " Π' "

This peculiar behaviour of the Σ (resp. s and S) paths raises the question whether this may possibly be in connection with SOMMERFELD's[1]) view:

"Infolgedessen drängt sich folgende geometrische Deutung auf: die p- und d-Terme entsprechen ebenen Bahnen in der Symmetrieebene des Atoms, ähnlich den KEPPLER-Ellipsen; der s-Term hat seinen Grund darin, dass die beim Wasserstoff bestehende Punktsymmetrie durch die Atomstruktur von *Li* und *He* aufgehoben ist und dass daher noch andere Bahnen als die in der Symmetrieebene möglich werden".

The Σ (resp. s and S) paths might therefore be imagined $\perp$ to the equator, and possibly this situation outside the equator might be the reason that in its jump to a path in the equator plane the electron does not give coinciding components, whereas it might be imagined that in jumps between paths lying in the equator plane, the chance to coinciding components is much greater.

From a private conversation which I had shortly ago with Professor BOHR on this subject it appeared to me that he had grounds to suppose the Σ (resp. s and S) paths to be also equatorial.

It should further be remarked that the complexes which are the

[1]) A. SOMMERFELD, Zur Quantentheorie der Spektrallinien, München. Ber. 4 Nov. 1916, p. 153.

subject of this investigation, occur exclusively for chemically bivalent elements. For univalent and trivalent elements there occur no Greek complexes.

After these more general remarks I will now set forth in what way I have carried out the inquiry as to the possible validity of the "Kombinationsprinzip".

On a closer examination of the different types of the abnormal ZEEMAN-effect for the complexes mentioned it strikes us that for most of them the distances of the components from the original line are multiples of half the distance of two components from the normal LORENTZ-triplet.

When we call ε the change of energy which a path must undergo for an electron jumping from that path to an unchanged path to emit light corresponding with one of the components polarized $\perp$ of the normal LORENTZ-triplet, while jumping from the unmodified path it emits light of a frequency of vibration equal to that of the middle component polarized //, then

$$dv = \frac{\varepsilon}{h}$$

will indicate the difference in frequency between the two beforementioned components.

Accordingly this ε must be proportional to the $\mathfrak{H}$.

I have now introduced the hypothesis that through the magnetic field each of the initial- and final paths splits up into two or more paths, which present energy-differences with the original path of $\pm n \, . \, \frac{\varepsilon}{2} \, (n = 0.\,1.\,2.\,3)$.

Then I have examined what values of n must be assigned to each of the initial and final paths to enable us to explain the observed components.

This yielded the following results:

The Π path splits up into 7 paths with energy differences $0, \pm\frac{\varepsilon}{2}, \pm\varepsilon, \pm\frac{3\varepsilon}{2}$

„ Π' „ „ „ „ 4 „ „ „ $\pm\frac{\varepsilon}{2}, \pm\varepsilon$

„ Π'' „ „ „ „ 2 „ „ „ $\pm\varepsilon$

„ Σ „ „ „ „ 2 „ „ „ $\pm\varepsilon$

„ Δ „ „ „ „ 3 „ „ „ $0, \pm\varepsilon$

„ Δ'' „ „ „ „ 4 „ „ „ $\pm\frac{\varepsilon}{2}, \pm\varepsilon$

„ d „ „ „ „ 3 „ „ „ $0 \quad \pm\varepsilon$

Then we get the following types for the ZEEMAN-effect for the different complexes.

$\Pi\,\Sigma$

$$\left(\frac{5\varepsilon}{2}\right) \quad \overline{2\varepsilon} \quad \overline{\frac{3\varepsilon}{2}} \quad \overline{\varepsilon} \quad \underline{\frac{\varepsilon}{2}} \quad \underline{0} \quad \underline{\frac{-\varepsilon}{2}} \quad \overline{-\varepsilon} \quad \overline{\frac{-3\varepsilon}{2}} \quad \overline{-2\varepsilon} \quad \left(-\frac{5\varepsilon}{2}\right)$$

$$\frac{3\varepsilon}{2}-(-\varepsilon) \quad \varepsilon-(-\varepsilon) \quad \frac{\varepsilon}{2}-(-\varepsilon) \quad 0-(-\varepsilon) \quad \frac{3\varepsilon}{2}-\varepsilon \quad \varepsilon-\varepsilon \quad \frac{\varepsilon}{2}-\varepsilon \quad 0-\varepsilon \quad \frac{-\varepsilon}{2}-\varepsilon \quad -\varepsilon-\varepsilon \quad \frac{-3\varepsilon}{2}-\varepsilon$$

$$\frac{-\varepsilon}{2}-(-\varepsilon) \quad -\varepsilon-(-\varepsilon) \quad \frac{-3\varepsilon}{2}-(-\varepsilon)$$

$\Pi'\,\Sigma$

$$\overline{2\varepsilon} \quad \overline{\frac{3\varepsilon}{2}} \quad \underline{\frac{\varepsilon}{2}} \quad (0) \quad \underline{\frac{-\varepsilon}{2}} \quad \overline{\frac{-3\varepsilon}{2}} \quad \overline{-2\varepsilon}$$

$$\varepsilon-(-\varepsilon) \quad \frac{\varepsilon}{2}-(-\varepsilon) \quad \frac{-\varepsilon}{2}-(-\varepsilon) \quad \varepsilon-\varepsilon \quad \frac{\varepsilon}{2}-\varepsilon \quad \frac{-\varepsilon}{2}-\varepsilon \quad -\varepsilon-\varepsilon$$

$$-\varepsilon-(-\varepsilon)$$

$\Pi''\,\Sigma$

$$\overline{2\varepsilon} \quad \underline{0} \quad \overline{-2\varepsilon}$$

$$\varepsilon-(-\varepsilon) \quad \varepsilon-\varepsilon \quad -\varepsilon-\varepsilon$$

$$-\varepsilon-(-\varepsilon)$$

$\Pi\,\Delta$

$$\left(\frac{5\varepsilon}{2}\right) \quad (2\varepsilon) \quad \overline{\frac{3\varepsilon}{2}} \quad \overline{\varepsilon} \quad \overline{\underline{\frac{\varepsilon}{2}}} \quad \underline{0} \quad \overline{\underline{\frac{-\varepsilon}{2}}} \quad \overline{-\varepsilon} \quad \overline{\frac{-3\varepsilon}{2}} \quad (-2\varepsilon) \quad \left(\frac{-5\varepsilon}{2}\right)$$

$$\frac{3\varepsilon}{2}-(-\varepsilon) \quad \varepsilon-(-\varepsilon) \quad \frac{3\varepsilon}{2}-0 \quad \varepsilon-0 \quad \frac{3\varepsilon}{2}-\varepsilon \quad \varepsilon-\varepsilon \quad \frac{\varepsilon}{2}-\varepsilon \quad 0-\varepsilon \quad \frac{-\varepsilon}{2}-\varepsilon \quad -\varepsilon-\varepsilon \quad \frac{-3\varepsilon}{2}-\varepsilon$$

$$\frac{\varepsilon}{2}-(-\varepsilon) \quad 0-(-\varepsilon) \quad \frac{\varepsilon}{2}-0 \quad 0-0 \quad \frac{-\varepsilon}{2}-0 \quad -\varepsilon-0 \quad \frac{-3\varepsilon}{2}-0$$

$$\frac{-\varepsilon}{2}-(-\varepsilon) \quad -\varepsilon-(-\varepsilon) \quad \frac{-3\varepsilon}{2}-(-\varepsilon)$$

$\Pi'\,\Delta$

$$(2\varepsilon) \quad \overline{\frac{3\varepsilon}{2}} \quad \underline{\varepsilon} \quad \overline{\underline{\frac{\varepsilon}{2}}} \quad \overline{0} \quad \overline{\underline{\frac{-\varepsilon}{2}}} \quad \underline{-\varepsilon} \quad \overline{\frac{-3\varepsilon}{2}} \quad (-2\varepsilon)$$

$$\varepsilon-(-\varepsilon) \quad \frac{\varepsilon}{2}-(-\varepsilon) \quad \varepsilon-0 \quad \frac{\varepsilon}{2}-0 \quad \varepsilon-\varepsilon \quad \frac{\varepsilon}{2}-\varepsilon \quad -\varepsilon-0 \quad \frac{-\varepsilon}{2}-\varepsilon \quad -\varepsilon-\varepsilon$$

$$\frac{-\varepsilon}{2}-(-\varepsilon) \quad -\varepsilon-(-\varepsilon) \quad \frac{-\varepsilon}{2}-0$$

$\Pi''\,\Delta$

$$\overline{2\varepsilon} \quad \overline{\underline{\varepsilon}} \quad \overline{\underline{0}} \quad \overline{\underline{-\varepsilon}} \quad \overline{-2\varepsilon}$$

$$\varepsilon-(-\varepsilon) \quad \varepsilon-0 \quad \varepsilon-\varepsilon \quad -\varepsilon-0 \quad -\varepsilon-\varepsilon$$

$$-\varepsilon-(-\varepsilon)$$

$\Pi\,\Delta''$

$$\overline{\tfrac{5\varepsilon}{2}} \quad (2\varepsilon) \quad \overline{\tfrac{3\varepsilon}{2}} \quad \underline{\varepsilon} \quad \overline{\tfrac{\varepsilon}{2}} \quad \underline{0} \quad \overline{\tfrac{-\varepsilon}{2}} \quad \underline{-\varepsilon} \quad \overline{\tfrac{-3\varepsilon}{2}} \quad (-2\varepsilon)$$

$$\tfrac{3\varepsilon}{2}-(-\varepsilon) \quad \tfrac{3\varepsilon}{2}-\left(\tfrac{-\varepsilon}{2}\right) \quad \varepsilon-\left(\tfrac{-\varepsilon}{2}\right) \quad \tfrac{3\varepsilon}{2}-\tfrac{\varepsilon}{2} \quad \tfrac{3\varepsilon}{2}-\varepsilon \quad \varepsilon-\varepsilon \quad \tfrac{\varepsilon}{2}-\varepsilon \quad 0-\varepsilon \quad \tfrac{-\varepsilon}{2}-\varepsilon \quad -\varepsilon-\varepsilon \quad \tfrac{-3}{2}$$

$$\varepsilon-(-\varepsilon) \quad \tfrac{\varepsilon}{2}-(-\varepsilon) \quad \tfrac{\varepsilon}{2}-\left(\tfrac{-\varepsilon}{2}\right) \quad \varepsilon-\tfrac{\varepsilon}{2} \quad \tfrac{\varepsilon}{2}-\tfrac{\varepsilon}{2} \quad 0-\tfrac{\varepsilon}{2} \quad \tfrac{-\varepsilon}{2}-\tfrac{\varepsilon}{2} \quad -\varepsilon-\tfrac{\varepsilon}{2} \quad \tfrac{-3\varepsilon}{2}-\tfrac{\varepsilon}{2}$$

$$0-(-\varepsilon) \quad 0-\left(\tfrac{-\varepsilon}{2}\right) \quad \tfrac{-\varepsilon}{2}-\left(\tfrac{-\varepsilon}{2}\right) \quad -\varepsilon-\left(\tfrac{-\varepsilon}{2}\right) \quad \tfrac{-3\varepsilon}{2}-\left(\tfrac{-\varepsilon}{2}\right)$$

$$\tfrac{-\varepsilon}{2}-(-\varepsilon) \quad -\varepsilon(-\varepsilon) \quad \tfrac{-3\varepsilon}{2}-(-\varepsilon)$$

$\Pi'\,\Delta''$

$$\overset{?}{2\varepsilon} \quad \overline{\tfrac{3\varepsilon}{2}} \quad \underline{\varepsilon} \quad \overline{\tfrac{\varepsilon}{2}} \quad \underline{0} \quad \overline{\tfrac{-\varepsilon}{2}} \quad \underline{-\varepsilon} \quad \overline{\tfrac{-3\varepsilon}{2}} \quad \overset{?}{-2\varepsilon}$$

$$\varepsilon-(-\varepsilon) \quad \varepsilon-\left(\tfrac{-\varepsilon}{2}\right) \quad \tfrac{\varepsilon}{2}-\left(\tfrac{-\varepsilon}{2}\right) \quad \varepsilon-\tfrac{\varepsilon}{2} \quad \varepsilon-\varepsilon \quad \tfrac{\varepsilon}{2}-\varepsilon \quad \tfrac{-\varepsilon}{2}-\tfrac{\varepsilon}{2} \quad \tfrac{-\varepsilon}{2}-\varepsilon \quad -\varepsilon-\varepsilon$$

$$\tfrac{\varepsilon}{2}-(-\varepsilon) \quad \tfrac{-\varepsilon}{2}-(-\varepsilon) \quad \tfrac{\varepsilon}{2}-\tfrac{\varepsilon}{2} \quad -\varepsilon-\left(\tfrac{-\varepsilon}{2}\right) \quad -\varepsilon-\tfrac{\varepsilon}{2}$$

$$\tfrac{-\varepsilon}{2}-\left(\tfrac{-\varepsilon}{2}\right)$$

$$-\varepsilon-(-\varepsilon)$$

$\Pi''\,\Delta''$

$$(2\varepsilon) \quad \left(\tfrac{3\varepsilon}{2}\right) \quad \overline{\underline{\tfrac{\varepsilon}{2}}} \quad \underline{0} \quad \overline{\underline{\tfrac{-\varepsilon}{2}}} \quad \left(\tfrac{-3\varepsilon}{2}\right) \quad (-2\varepsilon)$$

$$\varepsilon-(-\varepsilon) \quad \varepsilon-\left(\tfrac{-\varepsilon}{2}\right) \quad \varepsilon-\tfrac{\varepsilon}{2} \quad \varepsilon-\varepsilon \quad -\varepsilon-\left(\tfrac{-\varepsilon}{2}\right) \quad -\varepsilon-\tfrac{\varepsilon}{2} \quad -\varepsilon-\varepsilon$$

$$-\varepsilon-(-\varepsilon)$$

$\Pi\,d$

$$\left(\tfrac{5\varepsilon}{2}\right) \quad \overline{2\varepsilon} \quad \overline{\tfrac{3\varepsilon}{2}} \quad \overset{?}{\varepsilon} \quad \overline{\underline{\tfrac{\varepsilon}{2}}} \quad (0) \quad \overline{\underline{\tfrac{-\varepsilon}{2}}} \quad \overset{?}{-\varepsilon} \quad \overline{\tfrac{-3\varepsilon}{2}} \quad \overline{-2\varepsilon} \quad (-$$

$$\tfrac{3\varepsilon}{2}-(-\varepsilon) \quad \varepsilon\ \ (-\varepsilon) \quad \tfrac{3\varepsilon}{2}-0 \quad \varepsilon-0 \quad \tfrac{3\varepsilon}{2}-\varepsilon \quad \varepsilon-\varepsilon \quad \tfrac{\varepsilon}{2}-\varepsilon \quad 0-\varepsilon \quad \tfrac{-\varepsilon}{2}-\varepsilon \quad -\varepsilon-\varepsilon \quad \tfrac{-3}{2}$$

$$\tfrac{\varepsilon}{2}-(-\varepsilon) \quad 0-(-\varepsilon) \quad \tfrac{\varepsilon}{2}-0 \quad 0-0 \quad 0-\tfrac{\varepsilon}{2} \quad -\varepsilon-0 \quad \tfrac{-3\varepsilon}{2}-0$$

$$\tfrac{-\varepsilon}{2}-(-\varepsilon) \quad -\varepsilon-(-\varepsilon) \quad \tfrac{-3\varepsilon}{2}-(\ \ \varepsilon)$$

$\Pi' d$

(2ε)	$\overline{\frac{3\varepsilon}{2}}$	$\overline{\varepsilon}$	$\underline{\overline{\frac{\varepsilon}{2}}}$	$\underline{0}$	$\underline{\overline{\frac{-\varepsilon}{2}}}$	$\overline{-\varepsilon}$	$\overline{\frac{-3\varepsilon}{2}}$	(-2ε)
$\varepsilon-(-\varepsilon)$	$\frac{\varepsilon}{2}-(-\varepsilon)$	$\varepsilon-0$	$\frac{\varepsilon}{2}-0$	$\varepsilon-\varepsilon$	$\frac{\varepsilon}{2}-\varepsilon$	$-\varepsilon-0$	$\frac{-\varepsilon}{2}-\varepsilon$	$-\varepsilon-\varepsilon$
			$\frac{-\varepsilon}{2}-(-\varepsilon)$	$-\varepsilon-(-\varepsilon)$	$\frac{-\varepsilon}{2}-0$			

$\Pi'' d$

(2ε)	$\overline{\varepsilon}$	$\underline{0}$	$\overline{-\varepsilon}$	(-2ε)
$\varepsilon-(-\varepsilon)$	$\varepsilon-0$	$\varepsilon-\varepsilon$	$-\varepsilon-0$	$-\varepsilon-\varepsilon$
		$-\varepsilon-(-\varepsilon)$		

Under every component it is indicated from what jump or jumps it is supposed to have arisen. A $-\frac{\text{above}}{\text{under}}$ the component expresses that it is polarized $\frac{\perp}{//}$. When both signs occur, the two components coincide or the polarization is incomplete. Between ( ) are placed the so-called superfluous components, which have not been found in the observation. The adjoined notes of interrogation will be discussed further on.

First a few words about the superfluous components. By far the greater part are extreme outer components. As the outer components that have been observed, are mostly very faint, it is possible that the theoretically found components are so faint that they could not be observed up to now. These components originate namely by jumps from and to the most greatly deformed paths, and according to SOMMERFELD these are less probable than the less deformed ones, so that the number of jumps of the electron from these greatly deformed paths is relatively much smaller, hence the produced component much fainter.

This explanation, is however, not applicable to the question whether the middle components of $\Pi' \Sigma$ and Πd are superfluous.

It would, however, also be possible that the "Kombinationsprinzip" was dependent on a restrictive condition. Prof. BOHR was namely of opinion, as appeared to me from a conversation on this question, that in its jumping the electron should also be bound to the condition that the angular momentum in initial and final path may not differ more than $1 \times \frac{h}{2\pi}$. I have not succeeded as yet in introducing this condition as restriction of the "Kombinationsprinzip". That there must somehow exist a restrictive condition, does not seem doubtful to me.

That however in some cases the non-appearance of a middle component can yet be ascribed to the observation, may appear from the following example:

In my paper (loc. cit.) the ZEEMAN-effect for $\Pi'\Delta''$ is given as an octet without middle component, here as a nonet with middle component.

My first statement was among other things based on the observations by MILLER [1]), who has not found a middle component, whereas WENDT [2]) does find the middle component for the same lines: "bei dem zweiten Begleiter ist die mittlere Komponente ubersehen". (p. 559).

From this it may, therefore, appear that it is by no means impossible that some of the observed types of ZEEMAN-effect are incomplete, and that possibly some of the "superfluous" components found by me will after all appear to be present on closer observation.

The outer components of $\Pi'\Delta''$ are marked with a note of interrogation. These components have been found both by WENDT (loc. cit.) and MILLER (loc. cit.), the distances to the middle component are, however, somewhat smaller than agrees with 2ε. The state of polarisation could not be determined by MILLER on account of the slight intensity; WENDT finds $\perp$.

The other notes of interrogation are found beside Πd. WENDT finds for this ten components, whereas MILLER has observed twelve. The latter observer remarks here, however (loc. cit. p. 117):

"Die durch Klammern zusammengefassten Linienpaare liefen in eine Linie zusammen, wenn beide Arten von Schwingungen zugelassen waren".

When this is taken into account, the notes of interrogation may be omitted, and $\overline{\underline{\varepsilon}}$ and $\overline{\underline{-\varepsilon}}$ may be substituted for them.

The 0-component has, however, not yet been accounted for.

Another factor that remains to be explained, is the state of polarisation of the components.

Though here for the anomalous ZEEMAN-effects, just as for the normal triplet, the outmost components appear always to be polarized $\perp$, I must confess that I have not yed succeeded as yet in

[1]) W. MILLER, Zeeman effekt an Mg. Ca. u. s. w. Ann. d. Physik, 24, p. 105, 1907.

[2]) G. WENDT, Untersuchungen an Quecksilberlinien. Ann. d. Physik, 37, p. 535. 1912.

finding a simple rule for the state of polarisation of the components.

As regards the intensity, the supposition has already been expressed above that according as the electrons jump from or to strongly eccentric paths, the intensity of the produced components would be slighter. It is to be regretted that the material of observation does not allow us to test this supposition in every detail, because the values found by different observers are often contradictory.

MILLER (loc. cit. p. 112) gives, indeed, e.g. for the intensities of:

$\Pi\,\Delta$	1	2	2	6	2	2	1
$\Pi'\,\Delta$	1	1	4	4	4	1	1
$\Pi''\Delta$	<1	4		8	4		<1

and from this appears a rapid decrease of intensity towards the outer components, (with which my "superfluous" components, which are still weaker, are in good agreement). Also the fact that the middle components are stronger, is in good harmony with this that each of the components can be produced by some different jumps.

This investigation can, however, not yet be universally carried through on account of the above-mentioned mutual contradictions. The causes of these differences of intensity have been investigated by ZEEMAN [1], but it can seldom be inferred from the publications of the different observers what circumstances have given rise to their differences in intensity, and which are the reliable intensities. A research as discussed above will not be possible until this has been settled with certainty. From the results of such an investigation important conclusions might be drawn as to the correctness or incorrectnes of the hypotheses given by me in this paper.

From what has been found so far I think I am justified in concluding that there are indications to be found in the material of observation for the validity of the "Kombinationsprinzip", also for the anomalous ZEEMAN-effect. It is, however, not excluded that a restrictive condition in the sense as given by BOHR (see above) causes the principle not to be always clearly manifested.

At any rate I think I have shown that the "sequences" vary separately in the magnetic field, and that the observed ZEEMAN-effect is the result of the variations of the two sequences together.

In connection with this I am also of opinion that BOHR's equation:

$$\nu = \frac{W_1 - W_2}{h}$$

keeps its validity in the magnetic field.

The Hague, May 7 1919.

[1] P. ZEEMAN, Proc. Amsterdam, Oct. 1912 and Researches in Magneto-Optics p 94 et seq, Macmillan 1913