10.8. Paschen-Back Effect of a Principal-series Doublet.—As an example of the Paschen-Back effect, consider first the calculation of terms and term separations involved in a principal-series doublet $^2S_{\frac{1}{2}}$–$^2P_{\frac{1}{2},\frac{3}{2}}$. The fine-structure separations due to the interaction of l^* and s^* in field-free space are given in Col. 2, Table 10.2 (see Fig. 8.9). In the next three columns the weak-field energies are calculated (see Fig. 10.8). In the last five columns the strong-field energies are calculated, using Eq. (10.34).

The values tabulated are shown schematically in Fig. 10.12. At the left the undisturbed fine-structure levels and the observed transitions are shown. The weak-field Zeeman levels are next shown with the observed Zeeman patterns below. In the strong field the Paschen-Back levels are shown with, and without, the small l^*s^* coupling correction

$m_l m_s$. The allowed transitions and the calculated pattern are shown below.

In deriving the above equations for the Zeeman and Paschen-Back effects, the atomic system was assumed to be in one of two ideal situations. In the first case the field was assumed so weak that j^*, the resultant of l^* and s^*, was invariant as regards magnitude and inclination to the field axis. In the second case the field was assumed so strong that l^* and s^* precess independently around H. The question of intermediate

TABLE 10.2.—WEAK- AND STRONG-FIELD ENERGIES FOR A PRINCIPAL-SERIES DOUBLET

No field		Weak field (Zeeman effect)			Strong field (Paschen-Back effect)				
Term	Γ	m	g	mg	m_l	m_s	$m = m_l + m_s$	$m_l + 2m_s$	$m_l m_s$
$^2P_{\frac{3}{2}}$	$+a/2$	$+\frac{3}{2}$	$\frac{4}{3}$	$+2$	$+1$	$+\frac{1}{2}$	$+\frac{3}{2}$	$+2$	$+a/2$
		$+\frac{1}{2}$		$+\frac{2}{3}$	0	$+\frac{1}{2}$	$+\frac{1}{2}$	$+1$	0
		$-\frac{1}{2}$		$-\frac{2}{3}$	-1	$+\frac{1}{2}$	$-\frac{1}{2}$	0	$-a/2$
		$-\frac{3}{2}$		-2	$+1$	$-\frac{1}{2}$	$+\frac{1}{2}$	0	$-a/2$
$^2P_{\frac{1}{2}}$	$-a$	$+\frac{1}{2}$	$\frac{2}{3}$	$+\frac{1}{3}$	0	$-\frac{1}{2}$	$-\frac{1}{2}$	-1	0
		$-\frac{1}{2}$		$-\frac{1}{3}$	-1	$-\frac{1}{2}$	$-\frac{3}{2}$	-2	$+a/2$
$^2S_{\frac{1}{2}}$	0	$+\frac{1}{2}$	2	$+1$	0	$+\frac{1}{2}$	$+\frac{1}{2}$	$+1$	0
		$-\frac{1}{2}$		-1	0	$-\frac{1}{2}$	$-\frac{1}{2}$	-1	0

fields, therefore, arises, and one asks, how does each weak-field level go over to a corresponding strong-field level? Darwin's treatment of this problem, which will not be given here, answers this question in a very simple manner.[1] According to the classical law of the conservation of angular momentum, the sum of the projections on H of the various angular-momentum vectors must remain the same for all field strengths. Since in weak field this sum is given by m and in strong field by $m_l + m_s$ we may write, as part of the correlation rule, $m = m_l + m_s$. This alone is not sufficient to correlate all weak- and strong-field levels, since in most instances there will be more than one level with the same m value. The more specific rule, in keeping with the quantum mechanics, may be stated as follows: *Levels with the same m never cross.*

An ingenious method for obtaining the same correlation has been given by Breit.[2] An array of weak- and strong-field quantum numbers

written down as follows (see Fig. 10.13). Values of m_l are written down in their regular order in a horizontal row and values of m_s in a vertical column. The array is next filled in with all possible sums of

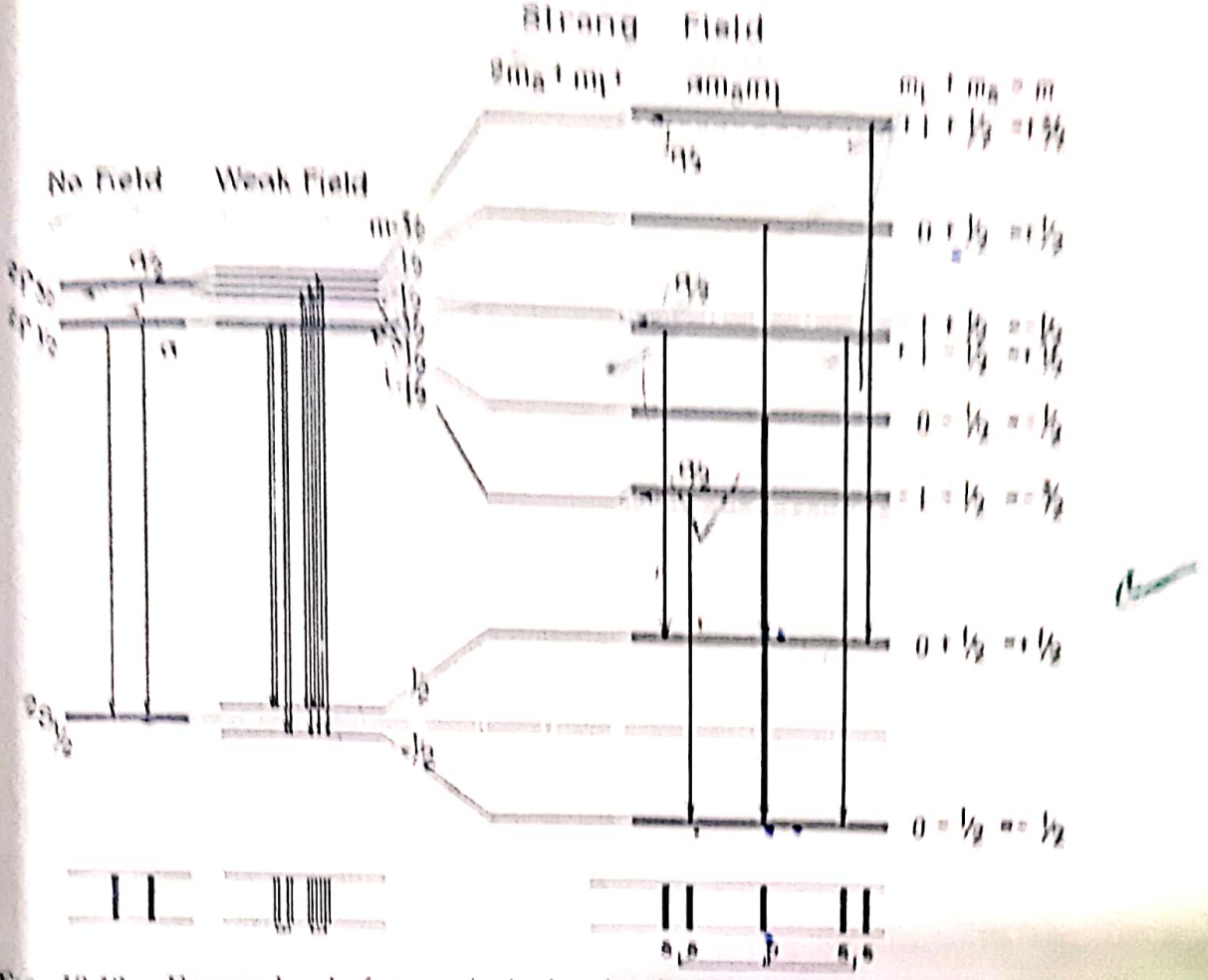

FIG. 10.12. Energy levels for a principal-series doublet starting with no field at the left and ending with a strong field (Paschen-Back effect) at the right. Allowed transitions are shown below.

m_l and m_s. These sums are the weak-field quantum numbers, divided into two parts by the dotted lines. Each weak-field level m is to be correlated with the strong-field level given by the value of m_l directly above, and the value of m_s directly to the right of the m value. The $^2P_{\frac{3}{2}}$ $m = \frac{3}{2}$ state, for example, goes to the state $m_l = 1$, and $m_s = \frac{1}{2}$.

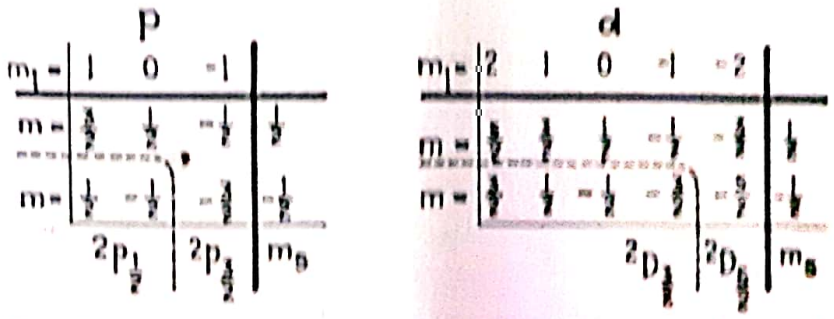

FIG. 10.13. Correlation of weak- and strong-field quantum numbers and energy levels. (*After Breit.*)

It is obvious that there are two ways of drawing the L-shaped dotted line. Of the two ways only the one shown will give the correct correlation for doublets from a single electron.