(3) **Atoms with Two or More Equivalent Electrons**—For two equivalent electrons (same n and l values) the values of atleast one the remaining quantum numbers (m_l or m_s) must differ to satisfy Pauli's exclusion principle. Hence certain terms which were possible for two non-equivalent electrons are now not allowed. For instance, two non-equivalent p-electrons, such as $2p$ and $3p$, give rise to the terms ^1S, ^1P, ^1D, ^3S, ^3P, ^3D ; but if the two electrons are equivalent, say $2p^2$, then the terms ^3D, ^3S and ^1P do not exist and we have only the terms ^1S, ^1D and ^3P. Let us now see how to obtain terms from a configuration involving

equivalent electrons. Before we do so we must mention two important facts :

(*i*) *A closed sub-shell, such as* s^2, p^6, d^{10}, ... *always forms a* $^1S_0$ *term only*. The closed sub-shell consists of maximum number, $2(2l+1)$, of equivalent electrons in antiparallel pairs so that

$$\Sigma\, m_l = 0^*$$

and

$$\Sigma\, m_s = 0^*.$$

This means that

$$M_L = 0,\ M_S = 0$$

and so

$$L = 0 \text{ (S-State)}$$
$$S = 0,\ 2S+1 = 1 \text{ (singlet)}$$

and

$$J = 0.$$

That is, the only possible term is $^1S_0$. Hence we conclude that *when a subshell is completely filled, the only allowed state is one in which the total spin angular momentum, total orbital angular momentum and total angular momentum are all zero.* This also means that the subshell has no net magnetic dipole moment.

(*ii*) *The terms of a configuration* $(nl)^q$ *are the same as the terms of the configuration* $(nl)^{r-q}$, *where r is the maximum number of electrons, that is* $2(2l+1)$. For example the terms of p^5 are the same as those of p^1, the terms of p^4 are the same as those of p^2, the terms of d^8 are the same as those of d^2, and so on.

This simplification is based on the fact that a completed sub-shell like p^6 gives only a $^1S_0$ term (zero angular momenta). This means that the vector addition of the angular momenta of the terms of p^2 (say) to the corresponding quantities for p^4 must give zero. From this it follows that the quantum numbers S and L must be the same for p^2 and p^4 *i.e.* the terms of p^2 are the same as those of p^4.

We now calculate the spectral terms arising from two equivalent *p*-electrons (p^2). Let us imagine the atom to be placed in a very strong magnetic field where all the internal couplings are broken down. The individual $\vec{l}$ and $\vec{s}$ vectors then precess independently round the magnetic field with quantised components $m_l\, h/2\pi$ and $m_s\, h/2\pi$ respectively. The value of l for a *p*-electron is 1 and hence the values of m_l are 1, 0, -1 while those of m_s are $+\frac{1}{2}$ and $-\frac{1}{2}$. Now, all possible combinations of m_l and m_s for a single *p*-electron are :

$m_l =$	1	0	-1	1	0	-1
$m_s =$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$
	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)

Thus there are six possible states (*a*), ... (*f*) in which a single *p*-electron can exist in an atom. The possible states for two (equivalent) electrons can be obtained by taking all possible combinations of the above six states taken two at a time, with no two alike (because by Pauli's principle, both m_l and m_s cannot be same for the two electrons). There will be 15 such combinations $\left({}^6C_2 = \frac{6\,!}{2\,!(6-2)\,!} = 15\right)$. They are

ab, ac, ad, ae, af ;
bc, bd, be, bf ;
cd, ce, cf ;
de, df ;
ef .

For each of these 15 combinations of very strong field quantum numbers we add the two values of m_l to obtain the strong field values of M_L, and the two values of m_s to form M_S [$\Sigma\, m_l = M_L$ and $\Sigma\, m_s = M_S$]. This leads to the following tabulation :

	ab	*ac*	*ad*	*ae*	*af*	*bc*	*bd*	*be*	*bf*	*cd*	*ce*	*cf*	*de*	*df*	*ef*
M_L	1	0	2	1	0	−1	1	0	−1	0	−1	−2	1	0	−1
M_S	1	1	0	0	0	1	0	0	0	0	0	0	−1	−1	−1

The highest value of M_L is 2 which indicates a *D* term ($L=2$). Since this value of M_L occurs only with $M_S=0$, the term is ^1D ($S=0$). Apart from $M_L=2$; $M_L=1, 0, -1, -2$ also belong to this term, each having $M_S=0$. Thus out of the above 15 combinations, the following form ^1D term.

	ad	*ae*	*af*	*bf*	*cf*	
M_L =	2	1	0	−1	−2	^1D.
M_S =	0	0	0	0	0	

Of the remaining M_L and M_S values, the highest M_L is 1 and the highest M_S is 1. These values must belong to a ^3P term ($L=1$, $S=1$), because only for such a term can the highest values of M_L and M_S be 1. But $L=1$ corresponds to $M_L = 1, 0, -1$; and $S=1$ corresponds to $M_S = 1, 0, -1$. Hence all the following nine configurations belong to the ^3P term :

	ab	*ac*	*bc*	*bd*	*cd*	*ce*	*de*	*df*	*ef*	
M_L =	1	0	−1	1	0	−1	1	0	−1	^3P.
M_S =	1	1	1	0	0	0	−1	−1	−1	