The Pauli exclusion Principle

<u>statement</u> : No two electrons in an atom exist in the same quantum state. The four quantum numbers n, l, m_l, m_s determine the state of an electron completely. Hence the principle may be stated as No two electrons in an isolated atom may have the same four quantum numbers.

<u>Explanation</u> :

The principle implies that each electron in an atom must have a different set of quantum numbers, n, l, m_l and m_s. If two electrons have all their quantum numbers identical, then one of those two electrons would be excluded from entering into the constitution of the atom. Hence the name "<u>exclusion principle</u>".

<u>Application</u> :

This principle enables us to calculate the number of electrons that can occupy a given subshell.

<u>consider K - shell</u> .

$n = 1$, $l = 0$ and $m_l = 0$ and $s = 1/2$, m_s can either be $+1/2$ or $-1/2$. Hence K - shell will have 2 electrons. (ie) electron 1 with quantum numbers $n = 1$, $l = 0$ $m_l = 0$ and $m_s = 1/2$ and electron 2 with quantum numbers $n = 1$, $l = 0$ $m_l = 0$ and $m_s = -1/2$.

If there were a third electron, its quantum numbers will be identical with those of the first or second which is against Pauli's exclusion principle. The K-shell is therefore completed or closed with two electrons.

2) For L-shell

* $n = 2$, $l = 0$ or 1

* For $n = 2$, $l = 0$, m_l must be zero and $m_s = +1/2$ or $-1/2$. Hence there can be two electrons in the subshell.

* For $n = 2$, $l = 1$, m_l must have three values ie $-1, 0, +1$ therefore for each value of m_l, m_s can have ~~those~~ either $1/2$ or $-1/2$. Hence there will be six possible values for the quantum numbers characterizing the electron ~~where~~. Therefore, the maximum number of electrons in this sub-shell is 6.

The L-shell has two subshells [$n = 2$, $l = 0$) and $n = 2$, $l = 1$) is therefore, completed when it contains $2 + 6 = 8$ electrons.

(3) For M-shell

$n = 3$, $l = 0, 1, 2$ [as l takes values $= 0 \ldots n-1$]

* $n = 3$, $l = 0$, $m_l = 0$; $\therefore m_s = +1/2$ or $-1/2$ } – 2 values

$n = 3$, $l = 1$, $m_l = -1, 0, +1$ [as m_l takes values $= -l$ to $+l$]

$\therefore m_l = -1$, $m_s = +1/2$ or $-1/2$
$m_l = 0$, $m_s = 1/2$ or $-1/2$
$m_l = 1$, $m_s = 1/2$ & $-1/2$
} 6 values for m_s.

$n = 3$, $l = 2$ $m_l = -2, -1, 0, 1, 2$ [as m_l takes values from $-l$ to l]

$\therefore m_l = -2$ $m_s = +1/2$ & $-1/2$
$m_l = -1$ $m_s = +1/2$ & $-1/2$
$m_l = 0$ $m_s = +1/2$ & $-1/2$
$m_l = 1$ $m_s = 1/2$ & $-1/2$
$m_l = 2$ $m_s = 1/2$ & $-1/2$

} 10 values for m_s.

$\therefore$ for M shell - $2 + 6 + 10 = 18$ electrons.

** For N = shell.

$n = 4$; $l = 0, 1, 2, 3$ [$l = n-1$ values]

$m_l = 1/2$ & $-1/2$ (2 electrons) [$l = 0$]

For $l = 1$, m_l takes 3 values [ie $-1, 0, +1$]

$\therefore m_l = -1$ $2e^-$ ($1/2$ & $-1/2$)
$m_l = 0$ $2e^-$ ($+1/2$ & $-1/2$)
$m_l = +1$ $2e^-$ ($+1/2$ & $-1/2$)

} 6 electrons.

For $l = 2$

m_l takes $-2, -1, 0, 1, 2$ (5 values)

$m_l = -2$ 2 electrons
$m_l = -1$ 2 electrons
$m_l = 0$ 2 electrons
$m_l = 1$ 2 electrons
$m_l = 2$ 2 electrons

} - 10 electrons

|||ly

For $l = 3$ m_l takes $-3, -2, -1, 0, 1, 2, 3$

takes 7 values.

∴ when $m_l = -3$ $\frac{1}{2}$ & $-\frac{1}{2}$ $2e^-$

$m_l = -2$ " $2e^-$

$m_l = -1$ " $2e^-$

$m_l = 0$ " $2e^-$ } $14e^-$

$m_l = 1$ " $2e^-$

$m_l = 2$ " $2e^-$

$m_l = 3$ " $2e^-$

∴ N shell has

$2 + 6 + 10 + 14 = 32$ electrons.

(i) Similarly in the n^{th} shell there are n sub shells corresponding to the values $0, 1, 2, 3 \ldots (n-1)$ of l. The maximum number of electrons in a sub shel is given by with the given value of l is $2(2l+1)$.

orbital quantum number (l)	0,	1,	2,	3,	4 ...	
Possible no. of electron states	2,	6,	10,	14,	18 ...	
subshell symbol.	s	p	d	f	g ...	

(ii) The number of electrons that can be accommodated in a shell with principal quantum number n = sum of electrons in the constituent n sub-shells.

$$= \sum_{l=0}^{l=n-1} 2(2l+1) = 2 \sum_{l=0}^{l=n-1} (2l+1)$$

$$= 2[1 + 3 + 5 + 7 \ldots [2(n-1)+1]] = 2n^2$$

The following table shows the distribution of electrons according to this scheme.

shell symbol	K	L	M	N	O
quantum number (n)	1	2	3	4	5
no of electrons ($2n^2$)	2	8	18	32	50

The distribution of electrons in the various states (shells and sub shells) according to the exclusion principle is given in the following table.

n	l	m_l	m_s	Number of e^-s in sub shells. with spectroscopic notation		Total number of electrons in shel $=2n^2$
1	0	0	$1/2, -1/2$	2	$1s^2$	2
2	0, 1	0	$1/2, -1/2$	2	$2s^2$	8
2	1	-1, 0, +1	$1/2, -1/2$	6	$2p^6$	
3	0	0	$1/2, -1/2$	2	$3s^2$	18
3	1	-1, 0, +1	$1/2, -1/2$	6	$3p^6$	
3	2	-2, -1, 0, +1 +2	$1/2, -1/2$	10	$3d^{10}$	
4	0	0	$1/2, -1/2$	2	$4s^2$	32
4	1	-1, 0, +1	$1/2, -1/2$	6	$4p^6$	
4	2	-2, -1, 0, +1 + 2	$1/2, -1/2$	10	$4d^{10}$	
4	3	-3, -2, -1 0, 1, 2, 3	$1/2, -1/2$	14	$4f^{14}$	

The periodic classification of elements.

The periodic table:

The periodic table is an
The periodic table that
arrangement of different elements chemical
exist in nature, based on their
properties and atomic numbers.
properties and atomic numbers.

Elements with similar properties
form the groups shown columns in the
table. Thus group 1 consists of hydrogen
plus the alkali metals, all of which are
extremely active chemically and all of
which have valence of +1. group VII consists
of the halogens that have valence of −1.
group VIII consists of the inert gases
which are chemically inactive.

The horizontal rows are called periods
As we go from left to right in the same
period, the chemical and physical properties
of the elements vary gradually as the
atomic number increases. Since the atomic
number gives also the number of electrons
in the atom. it follows that the atoms
of successive elements in the periodic
table are formed by the addition of one
more electron at each step.

we have already seen the arrangement
of electrons in an atom by applying Pauli's
exclusion principle. The notion of electron
shells and sub shells fits perfectly into the
pattern of the periodic table. The Total
orbital and spin angular momenta of the
of the electron in a closed subshell are
zero. The electrons in a closed shell

are all very tightly bound, since the positive nuclear charge is large relative to the negative charge of the inner shielding electrons. Since an atom containing only closed shells has no dipole moment, it does not attract other electrons and its electrons cannot be readily detached. We expect such atoms to be passive chemically like the inert gases and the inert gases all turn out to have closed shell electron configurations.

Those atoms which have a single electron in their outermost shell, tend to lose this electron. Hydrogen and the alkali metals are in this category and accordingly have valences of +1. Atoms whose outer shell lack a single electron for being closed, tend to acquire such an electron, which accounts for the chemical behaviour of the halogens. It is clear that the chemical and physical properties of an atom are determined by the number and arrangement of the electron in the outermost-shell and not by the total number of electrons in the atom. In this manner the similarities of the members of various groups of the periodic table may be accounted for.

examples.

The electronic configuration of an atom is the distribution of electrons in various subshells around the nucleus of the atom.

small letters used to represent the values of l as.

$l = 0, 1, 2, 3, 4, 5 \ldots$

subshells → s, p, d, f, g, h ... etc.

$n = 1, 2, 3, 4 \ldots$

Shell - K, L, M, N etc

<u>Hydrogen</u> (Atomic number (Z) = 1)

$n = 1$, ∴ $l = 0$, $m_l = 0$ & $m_s = +1/2$ or $-1/2$

symbolic representation is $1s^1$. $[n l^{\text{no. of } e^-}]$

This belongs to K shell it requires one more electron to be completed. Hence atomic hydrogen is very active chemically.

<u>Helium</u> (Z = 2)

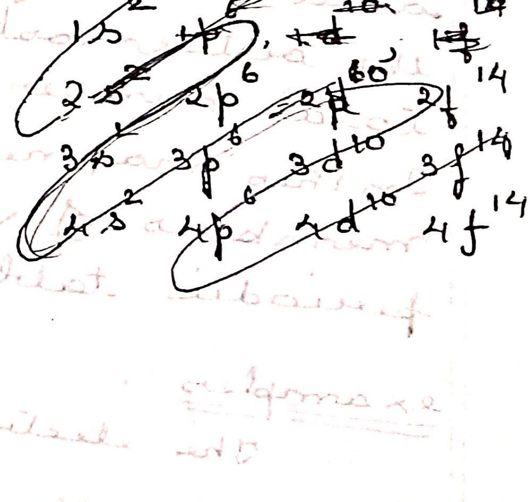
$n = 1$, $l = 0$, $m_l = 0$ & $m_s = +1/2$ & $-1/2$

$1s^2$ – symbolic representation. This belongs to K shell and it is completed or closed ie it has stable configuration.

<u>Lithium</u> (Z = 3)

$n = 1$, $l = 0$

$1s^2 2s^1$



<u>Beryllium</u> (Z = 4)

$1s^2 2s^2$

<u>Boron</u> (Z = 5)

$1s^2 2s^2 2p^1$

<u>carbon</u> (Z = 6) $1s^2 2s^2 2p^2$

Nitrogen ~~carbon~~ (Z = 7) – $1s^2\ 2s^2\ 2p^3$

oxygen (Z = 8) – $1s^2\ 2s^2\ 2p^4$

Fluorine (Z = 9) – $1s^2\ 2s^2\ 2p^5$

Neon (Z = 10) – $1s^2, 2s^2, 3p^6$

sodium (Z = 11) – $1s^2, 2s^2, 3p^6, 3s^1$

Magnesium (Z = 12) – $1s^2, 2s^2, 3p^6 . 3s^2$

Aluminium (Z = 13) – $1s^2, 2s^2, 3p^6, 3s^2, 3p^1$