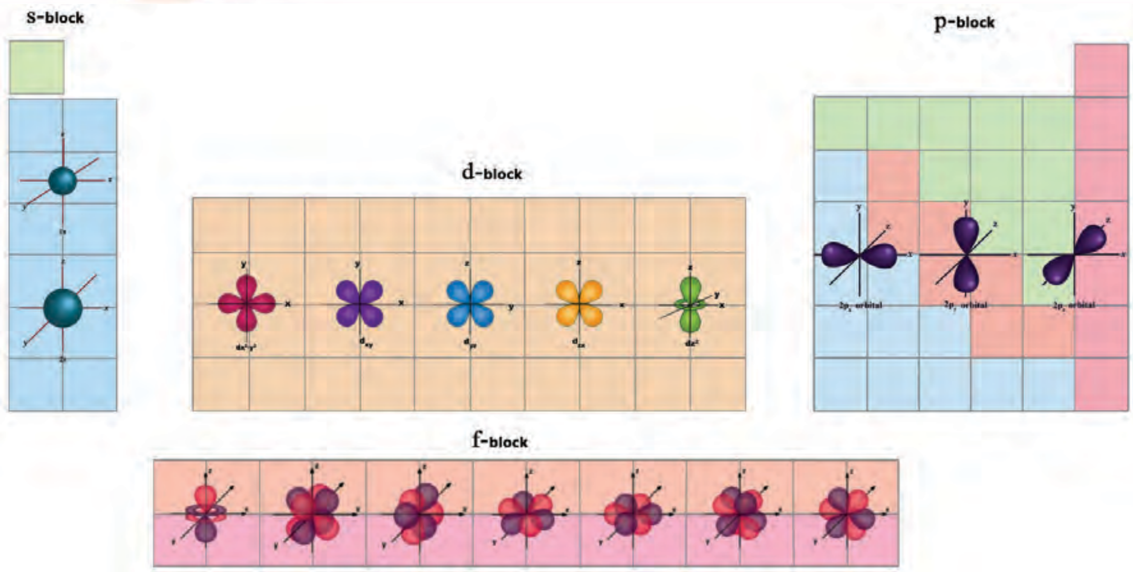
3 PERIODIC TABLE AND ELECTRON CONFIGURATION



All substances in the universe are composed of atoms of different elements. You have already learnt that the table in which elements are arranged on the basis of their chemical properties is known as the periodic table. You know how to write and illustrate the electron configuration of the atoms of various elements. The orbit electron configuration of magnesium atom is given (Fig. 3.1).

- Write down the electron configuration of magnesium.

  ....

- Electrons are arranged in three orbits (shells) in this element, aren't they? Which of these orbits has the least energy?

  ....

- Which orbit is the farthest from the nucleus?

  ....

- Which orbit has the maximum energy?

  ....

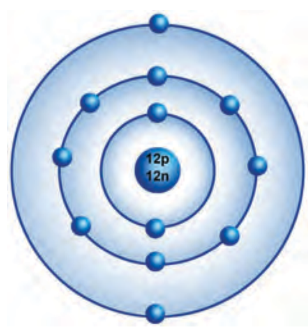


Figure 3.1

You have learnt that according to Bohr model of atom, orbits have definite energy and hence they are known as stationary energy levels.

But, later studies showed that Bohr model of atom has certain limitations. Louis de Broglie discovered the wave nature of matter. This wave nature is highly significant for microscopic particles. In other words, the scientific community has recognised the particle nature as well as the wave nature of electrons. According to Heisenberg's Uncertainty Principle, it is impossible to determine simultaneously the exact position and the exact velocity of a fast moving subatomic particle like electron. That is, on the basis of wave - particle dual nature and uncertainty principle an electron cannot be considered merely as a particle moving along an orbit. This is considered as one of the limitations of Bohr atom model.

An atom model that is in line with the dual nature of matter and the uncertainty principle was developed on the basis of quantum mechanics. According to quantum mechanical model of atom, there are regions around the nucleus where there is maximum probability of finding the electrons.

The regions around the nucleus where there is maximum probability of finding the electrons are called orbitals. The numbers which are used to describe the characteristics of orbitals and electrons based on quantum mechanical model of atom are called quantum numbers.

1. Principal quantum number (n)

Principal quantum number (n) is used to represent the shells or principal energy levels. The possible values for this quantum number are n = 1, 2, 3, 4, ...

n = 1 denotes K shell whereas n = 2 denotes L shell.

Have a look at the table given below.

Principal quantum number (n)	1	2	3	4
Shell	K	L	M	N

Table 3.1

2. Azimuthal quantum number (l)

Azimuthal quantum number (l) defines the three dimensional shape of the orbital. The orbitals having definite three dimensional shape and oriented towards different directions are clubbed together and considered as subshells. Azimuthal quantum number is also used to represent the subshells of each shell. The subshells are denoted using the symbols s, p, d and f. The number of subshells in a particular shell is equal to the values of n. The value of l ranges from zero to (n-1). In other words, the value of l can be determined from the value of n.

When n = 1, l = 0

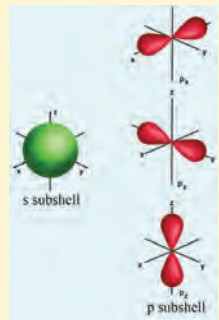
When n = 2, l = 0,1

l = 0 denotes s subshell, and l =1 denotes p subshell.

Look at Table 3.2.

Subshells

The subshells are represented using the symbols s, p, d, f etc. which are derived from the words describing certain properties of atomic structures of elements. s-sharp, p-principal, d-diffuse, f-fundamental. The s subshell has only one orbital, which is spherical in shape. The p subshell has three orbitals, each having dumbbell shape. The d subshell has five orbitals and the f subshell has seven orbitals with more complex shapes.



Principal quantum number (n)	1	2		3			4			
Shell	K	L		M			N			
l	0	0	1	0	1	2	0	1	2	3
Sub shell	s	s	p	s	p	d	s	p	d	f

Table 3.2

3. Magnetic quantum number (m)

Magnetic quantum number is denoted using the symbol 'm'. The quantum number that represents the difference in the orientation of orbitals is called magnetic quantum number. For a particular value of l, there are ($2l$ + 1) values for m. When the value of l is zero (l = 0), m can have only one value, that is (2 x 0 + 1 = 1). This shows that s orbital (l = 0) has only one orientation.

Which subshell is denoted by $l = 1$?

Here, m can have 3 values , that is $(2 \times 1 + 1) = 3$. It means that there are three different orientations for p orbitals.

How many values will be there for m when $l = 2$?

There will be 5 values for m, $(2 \times 2 + 1) = 5$

If so, how many d orbitals are there? ....

You can find the number of f orbitals in the same manner.

The total number of orbitals with respect to each shell is given in Table 3.3.

Principal quantum number (n)	1 K shell	2 L shell		3 M shell			4 N shell			
Subshell	s	s	p	s	p	d	s	p	d	f
Number of orbitals	1	1	3	1	3	5	1	3	5	7
Total number of orbitals	1	4		9			16			

Table 3.3

It is clear that the total number of orbitals in each shell is n^2.

You have already learnt that the maximum number of electrons that can be accommodated in each shell is $2n^2$.

If so, let us find out the maximum number of electrons that can be accommodated in each orbital.

The maximum number of electrons that can be accommodated in

$$\text{K shell} = \frac{\text{Total number of electrons}}{\text{Total number of orbitals in K shell}} = \frac{2}{1} = 2$$

Find out the maximum number of electrons that can be accommodated in L, M and N shells in the same way and record the values in your science diary.

Now it is clear that the maximum number of electrons that can be accommodated in each orbital = $2n^2/n^2 = 2$

Complete the Table 3.4 based on this.

Principal quantum number (n)	1 K shell	2 L shell		3 M shell			4 N shell			
Maximum number of electrons that can be accommodated in each shell ($2n^2$)	2	8		18			32			
l	0	0	1	0	1	2	0	1	2	3
Subshell	s	s	p	s	p	d	s	p	d	f
Number of orbitals	1	1	3	1	3	5	1	3	5	7
Maximum number of electrons that can be accommodated in each subshell	1×2 = 2	.....	3×2 = 6	.....	.....	5 × 2 = 10	.....	....	....	7 × 2 = 14

Table 3.4

The maximum number of orbitals that can be accommodated in each shell = n^2

The maximum number of electrons can be accommodated in each shell = $2n^2$

The maximum number of electrons that can be accommodated in each orbital = 2

The maximum number of electrons that can be accommodated in each subshell = $2(2l+1)$

The maximum number of electrons that can be accommodated in each subshell = s – 2, p – 6 , d – 10, f – 14

Filling of electrons in subshells

You know that each shell has subshells.

Which subshell is common to all shells ? ....

How can the s subshell in each shell be represented?

Let us represent the subshells along with the serial number (value of n) of the corresponding shell.

The s subshell of K shell (n=1) can be represented as 1s.

If so, how can the subshells of the shells L, M , and N be represented?

Similarly, it is possible to represent the other subshells such as p, d, and f.

Complete the Table 3.5.

Principal quantum number (n)	1 K shell	2 L shell		3 M shell			4 N shell			
Subshell	s	s	p	s	p	d	s	p	d	f
The method of representing the subshell	1s	.....	2p	.....	.....	3d	.....	....	....	4f

Table 3.5

Now, you know the maximum number of electrons that can be accommodated in each subshell.

Complete the Table 3.6 based on this.

Principal quantum number (n)	1 K shell	2 L shell		3 M shell			4 N shell			
Subshell	1s	....	2p	....	3p	....	4s	....	....	....
The maximum number of electrons that can be accommodated in each subshell	2	....	6	....	....	10	....	....	....	14
The maximum number of electrons that can be accommodated in each shell	2	8		18			32			

Table 3.6

You have learnt that the shells do not have the same energy.

How does the energy of shells vary with the increase in distance from the nucleus? ....

The energy of shells increases in the order K< L< M< N.

The energy of subshells increases in the following order.

$$s < p < d < f$$

In each shell, there is a gradual increase in the energy of a particular subshell.

Example: 1s < 2s < 3s < 4s < 5s ....

The energies of other subshells also vary in this manner.

When electrons are added to a shell in an atom, they will be distributed in various subshells. Electrons are being filled gradually in the subshells in the increasing order of energy. This type of arrangement is known as subshell electron configuration.

When the electrons in an atom are distributed in subshells, they are being filled gradually in the increasing order of energies of the subshells. This is called subshell electron configuration.

Now it is evident that the ascending order of energy of subshells should be known, in order to write the subshell electron configuration. The order of energy can be found from the principal quantum number (n) and azimuthal quantum number (l) values representing each subshell.

The energy of subshells increases in the ascending order of ($n+l$) values.

On the basis of ($n+l$) values , let us examine which subshell has greater energy, 1s or 2s.

$1s \rightarrow n = 1, l = 0 \quad (n+l) = 1 + 0 = 1$

$2s \rightarrow n = 2, l = 0 \quad (n+l) = 2 + 0 = 2$

2s subshell has more energy than 1s subshell.

In this manner, we can find out that 2p subshell has more energy than 2s subshell.

Write down the ($n+l$) values of 2p and 3s subshells. ....

Now, it is clear that the ($n+l$) values of both 2p and 3s subshells are the same. In such cases, it is considered as the subshell with higher n value has more energy. This means that 3s subshell has more energy than 2p subshell. 3s represents the s subshell of the third shell (M) and 2p represents the p subshell of the second shell (L). It can be seen that on the basis of the distance from the nucleus, the 3s subshell has more energy than 2p subshell.

Examine which subshell has more energy, 3d or 4s.

3d $\quad n = 3, l = 2, \quad n + l = 5$

4s $\quad n = 4, l = 0, \quad n + l = 4$

That is, 4s subshell has lesser energy than 3d subshell. Hence filling of electrons takes place in 3d subshell only after 4s subshell gets filled.

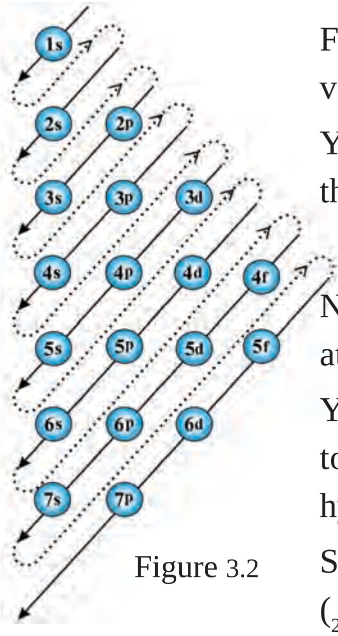


Figure 3.2

Figure 3.2 will help you to find the ascending order of energy of various subshells as mentioned above.

You can write the subshells in the ascending order of energy with the help of this figure.

1s < 2s < 2p < 3s < ..... < ..... < ..... < ....

Now, let us see how to write the subshell electron configuration of atoms of various elements.

You know that the only electron of the hydrogen atom gets added to its 1s subshell. Thus, the subshell electron configuration of hydrogen atom can be written as $1s^1$.

Similarly, what will be the electron configuration of Helium atom ($_2$He)? ....

It is clear that, in Helium atom the 1s subshell gets occupied by the maximum number of electrons that can be accommodated in it.

In the case of the subshell electron configuration of Lithium ($_3$Li), the electrons get filled in 1s and 2s subshells in the ascending order of energy. $_3$Li ....

How to read the subshell electron configuration.

$1s^1$ ‘One s one’

$1s^2\,2s^1$ ‘One s two’ ‘ Two s one’

Complete Table 3.7 by writing the subshell electron configuration of the elements given below.

Element	Number of electrons	Subshell electron configuration
$_4$Be	4	$1s^2\,2s^2$
$_5$B	5	$1s^2\ 2s^2\ 2p^1$
$_6$C	6	....
$_7$N	7	....
$_8$O	8	....
$_9$F	9	....
$_{10}$Ne	10	$1s^2\ 2s^2\ 2p^6$

Table 3.7

Complete Table 3.7 and verify it using Kalzium software.

It is evident that the p subshell of neon atom is occupied by the maximum number of electrons that it can accomodate.

Therefore in sodium the last electron is added to the 3s subshell.
The subshell electron configuration of sodium is ....

Write down the subshell electron configuration of elements from $_{12}Mg$ upto $_{18}Ar$ in your science diary.

With the help of Figure 3.2, write down the electron configuration of potassium ($_{19}K$).

In which subshell does the last electron gets filled in potassium?

When 3p subshell is completely filled, the next electron is added to the 4s subshell.

Which subshell has more energy, 3d or 4s?

Write the shell wise electron configuration of potassium. ....

M shell of potassium can accomodate more than eight electrons. However, after the first 8 electrons get added to M shell, the next electron goes to the N shell. The reason is now clear to you.

Write down the electron configuration of calcium ($_{20}Ca$) in the same manner.

Shell wise electron configuration ....

Subshell wise electron configuration ....

?

- Compare the energies of 1s and 2s subshells.
- Which subshell has more energy, 3d or 4s?

You have learnt that scandium ($_{21}Sc$) is a transition element. To which shell does the last electron get added in the case of transition elements?

....

Now, write the shell wise electron configuration of scandium.

....

The subshell electron configuration of scandium is in the order $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$.

This is written as $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$ in the order of the shell.

That means, as per the order of energy, in transition elements, the 4s subshell is completely filled first followed by the gradual filling up of 3d subshell.

Write the electron configuration of the elements that follow, namely $_{22}Ti$ and $_{23}V$.

$_{22}Ti$ ...., $_{23}V$ ....

Record the subshell electron configuration of more transition elements in your science diary.

Let us get familiarised with another method of representing subshell electron configuration.

While writing the electron configuration of an element, the symbol of the noble gas preceding that element is shown within square bracket followed by the electron configuration of the remaining subshell.

For example, let us see how the electron configuration of sodium is written in this manner.

The electron configuration of sodium is $1s^2\ 2s^2\ 2p^6\ 3s^1$.

Which noble gas precedes this element? What is its atomic number?

....

Hence the electron configuration of sodium can be written including the symbol of neon as [Ne] $3s^1$.

So, how will you write the electron configuration of potassium in the same manner? ....

Similarly write the subshell electron configuration of other elements also.

This method is commonly used for writing the subshell electron configuration of elements with higher atomic numbers.

The peculiarity of the subshell electron configuration of chromium (Cr) and copper (Cu)

Write the subshell electron configuration of chromium $_{24}Cr$. ....

But the stable subshell electron configuration of chromium is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$.

Let us examine the reason for this anomalous electron configuration.

What is the maximum number of electrons that can be accommodated in a d subshell?

It can be represented as d^{10}.

How can we represent a half filled d orbital?

....

The completely filled configuration (d^{10}) and the half filled configuration (d^5) are more stable than other configurations.

In other words, among the electron configuration from d^1 to d^{10}, d^5 and d^{10} are more stable. Hence for atoms where the configuration should be $d^4\ s^2$ and $d^9\ s^2$, the filling of electrons takes place such that the configuration becomes $d^5\ s^1$ and $d^{10}\ s^1$ respectively to attain stability.

Isn't it clear why there is a change in the electron configuration of chromium?

Write down the subshell electron configuration of $_{29}Cu$.

What change is to be made in the electron configuration of copper in order to attain stability as mentioned above? Note it down.

....

In the subshell electron configuration of chromium and copper, the configuration with half filled d subshell or completely filled d subshell show greater stability.

How to find the block from subshell electron configuration

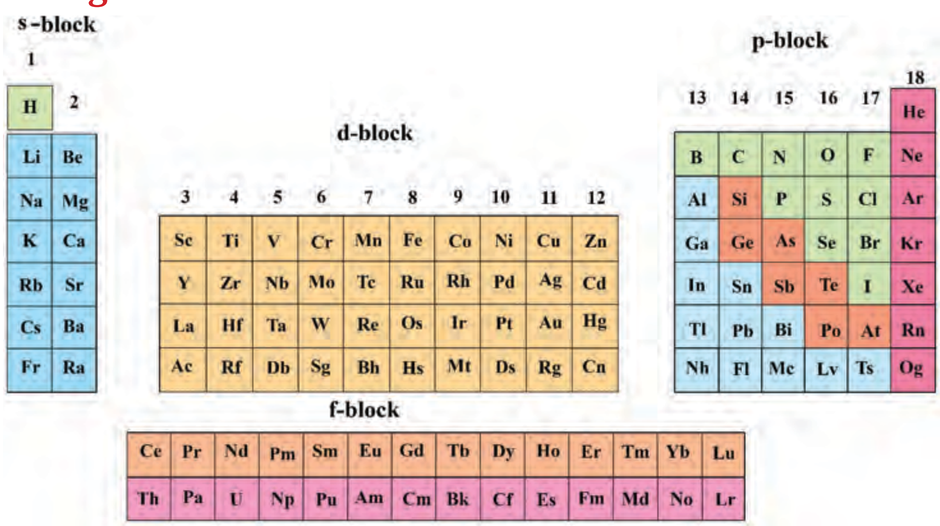


Figure 3.3

With the help of periodic table, complete Table 3.8 by finding the blocks to which the given elements belong.

Element	Subshell electron configuration	The subshell to which the last electron was added	Block
$_{4}Be$	....	....	s
$_{11}Na$	....	....	....
$_{8}O$	....	....	p
$_{17}Cl$	....	....	....
$_{21}Sc$	....	....	d
$_{26}Fe$	....	....	....

Table 3.8

By analysing the table, can you find the relation between the subshell to which the last electron was added and the block to which the element belongs?

The subshell to which the last electron is added will be the same as the block to which the electron belongs.

The groups which are included in s block - 1, 2
The groups which are included in p block - 13 to 18
The groups which are included in d block - 3 to 12
f block elements are placed at the bottom of the periodic table in two separate rows.

How to find the period number from subshell electron configuration

You know how to find the period number from shell wise electron configuration.

Write down the shell wise electron configuration of magnesium ($_{12}Mg$). ....

To which period does magnesium belong?....................................

It is possible to find the period number from subshell electron configuration. Complete the Table 3.9 with the help of periodic table.

Element	Subshell electron configuration	The highest shell number	Period number
$_{6}C$	....	2	....
$_{11}Na$	....	3	....
$_{21}Sc$	....	4	....

Table 3.9

The period number of an element is the highest shell number in its subshell electron configuration

How to find the group number from subshell electron configuration

Complete Table 3.10 and verify it using Kalzium software.

The group number of s block elements

It is possible to find the group number of elements on the basis of subshell electron configuration. Complete Table 3.10 with the help of periodic table.

Element	Subshell electron configuration	Block	Number of electrons in the outermost subshell	Group number
$_{3}Li$	....	....	....	1
$_{11}Na$	....	....	....	....
$_{12}Mg$	....	....	....	2
$_{20}Ca$	....	....	....	....

Table 3.10

Group number of s block elements is the number of electrons in the outermost s subshell.

The group number of p block elements

Which are the groups included in p block? ....

The group number of p block elements is the number obtained by adding the digit 10 (which represents 10 groups of transition elements) to the number of outermost electrons.

Element	Subshell electron configuration	The total number of electrons in the outermost s and p subshells	Group number
$_{5}B$	$1s^2\ 2s^2\ 2p^1$	3	13
$_{14}Si$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$	4	14
$_{7}N$	$1s^2\ 2s^2\ 2p^3$	5	15
$_{8}O$	$1s^2\ 2s^2\ 2p^4$	6	16
$_{17}Cl$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$	7	17
$_{18}Ar$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	8	18

Table 3.11

The group number of p block elements is the number obtained by adding the digit 10 (which represents 10 groups of transition elements) to the number of outermost electrons.

Complete Table 3.12 and verify it using Kalzium software.

Group number of d block elements

Where are the d block elements placed in periodic table? From which period does d block elements begin?

A few d block elements are given in table 3.12. Find the group number of these elements with the help of the periodic table and complete the table.

Element	Subshell electron configuration	Group number	Total number of electrons in 3d and 4s subshells
$_{21}Sc$	....	3	1+2 = 3
$_{24}Cr$	....	....	5 + 1 = 6
$_{26}Fe$	....	....	6 + 2 = 8
$_{29}Cu$	....	....	10 + 1 = 11
$_{30}Zn$	....	....	10 + 2 = 12

Table 3.12

The group number of d block elements will be same as the sum of the number of electrons in the outermost s subshell and the number of electrons in the d subshell preceding it.

Periodic trend in periodic table

Ionisation enthalpy

You have learnt about ionisation enthalpy (ionisation energy) in Standard IX.

Ionisation enthalpy of an element is the minimum amount of energy required to remove the most loosely bound electron from the outermost shell of an isolated gaseous atom of the element.

Using periodic table, let us examine how ionisation enthalpy varies on moving down a group.

What happens to the number of shells on moving down a group? (Increases / decreases)

What happens to the attractive force of nucleus on the outermost electrons as the number of shells increases? (Increases / decreases)

How does the nuclear charge vary on moving down a group? (Increases / decreases)

What happens to the attractive force of nucleus on the outermost electrons with an increase in the nuclear charge? (Increases / decreases)

Though the nuclear charge increases down a group, its influence is overcome by the increase in the number of shells.

If so, on moving down a group, does the possibility of donating the outermost electrons increase or decrease? ....

Ionisation enthalpy decreases on moving down a group.

Let us have a look at how ionisation enthalpy varies along a period.

Is there any change in the number of shells on moving from left to right in a period? ....

Does the nuclear charge increase? ....

Though nuclear charge increases on moving from left to right in a period, there is no change in the number of shells.

How does the attractive force of nucleus on the outermost electrons vary? (Increases / decreases)

If so, how does the ionisation enthalpy change?

....

On moving from left to right in a period, there is no change in the number of shells. But, nuclear charge increases gradually. The attractive force of the nucleus on the outermost electrons increases. Hence, ionisation enthalpy increases.

Where can you locate the elements with comparatively low ionisation enthalpy in the periodic table? ....

Caesium and Francium are the elements having the least ionisation enthalpy.

The elements having ns^1 and ns^2 as the valence shell electron configurations are considered to be s block elements. The elements of group 1 and that of group 2 have configuration ns^1 and ns^2 respectively. Hydrogen ($1s^1$) and helium ($1s^2$) are s block elements.

Where are the elements having generally higher ionisation enthalpy placed in the periodic table? ....

Now it is clear that ionisation enthalpy of s block elements is relatively lower than that of the elements of other blocks.

Which family of elements has the highest ionisation enthalpy? ....

Characteristics of s block elements

You know that alkali metals and alkaline earth metals belong to s block.

In these elements, electrons of which subshell take part in chemical reactions?

When s block elements take part in chemical reactions, the electrons of outermost s subshell are .... (donated / accepted / shared)

Find out the oxidation states of s block elements in the compounds given below.

- NaCl ....
- MgO ....

Determine the oxidation states of more s block elements from their compounds and record it in your science diary.

The elements of group 1 and group 2 exhibit +1 and +2 oxidation states respectively.

Radium (Ra)

Radium is the alkaline earth metal having the highest atomic mass. This radioactive element was discovered by Marie curie and her husband Pierre Curie in 1898. Radium does not exist free in nature This is mostly found in the minerals of uranium.

The most stable isotope of radium is Ra-226. As the alpha radiations emitted by radium produce scintillations on zinc sulphide, it was used as luminescent paint in watch, clock etc. In early days isotopes of radium were used for the treatment of cancer. Since contact with radium may cause cancer, genetic changes and other serious health issues, its industrial use is restricted . However the mixture of radium and beryllium is used as a source of neutrons in the fields of scientific research and petroleum exploration.

s block elements generally exist in solid state. But Caesium ($_{55}Cs$) is a metal having very low melting point (28.40°C). Hence it exists in liquid state on warm days. The elements Francium ($_{87}Fr$) and Radium ($_{88}Ra$) are radioactive in nature.

Characteristics of p block elements

Notice the given portion of the periodic table.

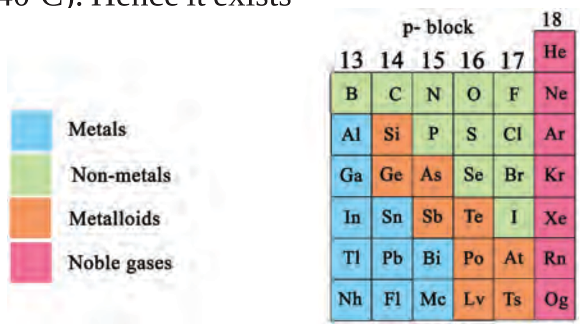


Figure 3.4

- Which are the groups that include p block elements?
- p block elements include metals, non metals and metalloids. These elements exist in solid, liquid and gaseous states. Find examples and note them down in your science diary.

Let us see what is the peculiarity in the oxidation state of p block elements as compared to s block elements.

Find the oxidation state of p block elements in the following compounds.

HF $\quad$ Al_2O_3 $\quad$ SO_2

p block elements exhibit both positive (+) and negative (–) oxidation states.

Gallium is an element having a very low melting point (29.77°C). On warm days, it exist in the liquid state.

s block and p block elements are main group elements.

Is the ionisation enthalpy lower for s block elements or p block elements? Explain.

Characteristics of d block elements

d block elements are known as transition elements.

Using periodic table, analyse the peculiarities of d block elements given in the box.

- They are placed in groups 3 to 12.
- The electrons are being gradually filled up in the penultimate shell.
- All the d block elements are metals.

Let us examine some other characteristics of d block elements.

You have learnt that elements of the same group show similarities in properties. d block elements also show similarities in properties in their corresponding groups. Have a look at the Table 3.13 in which subshell electron configuration of d block elements of 4th period is given.

Group number	3	4	5	6	7	8	9	10	11	12
Electron configuration	Sc $3d^1\ 4s^2$	Ti $3d^2\ 4s^2$	V $3d^3\ 4s^2$	Cr $3d^5\ 4s^1$	Mn $3d^5 4s^2$	Fe $3d^6 4s^2$	Co $3d^7 4s^2$	Ni $3d^8 4s^2$	Cu $3d^{10}\ 4s^1$	Zn $3d^{10}\ 4s^2$

Table 3.13

What is the outermost subshell electron configuration of these elements (excluding Cr , Cu)? ....

Similarly the outermost subshell electron configuration of the elements of 5th period will be generally $5s^2$.

The electron configuration of the outermost subshell of d block elements (transition elements) along a period is generally the same (ns^{1-2}). Therefore, they show similarities in properties not only within the groups but also along the periods. You have already learnt about this similarity along a period in shell wise electron configuration.

General outermost electron configuration

s block - ns^{1-2}

p block - $ns^2\,np^{1-6}$

d block - $(n - 1)d^{1-10}\ ns^{1-2}$

Oxidation states of d block elements

Ferrous chloride and ferric chloride are two chlorides of iron.

Ferrous chloride $FeCl_2$

Ferric chloride $FeCl_3$

The oxidation state of Fe in $FeCl_2$ is ....

The oxidation state of Fe in $FeCl_3$ is ....

(Hint: The oxidation state of Cl = –1)

It is clear that Fe shows variable oxidation states.

What is the reason for this?

The subshell electron configuration of $_{26}Fe$ is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$.

How does it change into Fe^{2+}? ....

Can you write the subshell electron configuration of Fe^{2+} ? ....

How does Fe get + 3 oxidation state in $FeCl_3$?

....

From which subshells are the electrons lost?

There is only a slight difference between the energies of the outermost s (4s) subshell and the penultimate d (3d) subshell. Hence, from which subshell is the third electron lost along with the two 4s electrons? ....

You can write the subshell electron configuration of Fe^{3+} on the basis of this, can't you ? ....

The atomic number of manganese (Mn) is 25. Different compounds of manganese are given in Table 3.14. Determine the oxidation state of Mn and complete the table.

Compound	Oxidation state of **Mn**	Subshell electron configuration of **Mn** ion
$MnCl_2$	+2	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$
MnO_2	....	....
Mn_2O_3	....	....
Mn_2O_7	....	....

Table 3.14

Now it is clear that d block elements show variable oxidation states. What is the reason for it?

The elements Zinc, Cadmium and Mercury which belong to the 12th group do not show all the general characteristics of transition elements. Hence, they are known as pseudo transition elements.

In transition elements there is only a slight energy difference between the outermost s subshell and the penultimate d subshell. As a result, under favourable conditions, electrons from the d subshell also take part in chemical reactions. That is why transition elements show variable oxidation states.

Coloured compounds

Among the compounds in your science lab, identify the coloured ones and list them. Aren't they generally compounds of transition elements?

For example: Copper sulphate ($CuSO_4 . 5H_2O$), potassium permanganate ($KMnO_4$), potassium dichromate ($K_2Cr_2O_7$).

The presence of ions of transition elements (eg:- Cu^{2+} , Co^{2+}) or the ions which contain transition elements (eg:- MnO_4^- , $Cr_2O_7^{2-}$) are generally responsible for the colour of the compounds.

But the compounds of zinc ($_{30}Zn$) are colourless.

The compounds of transition elements are generally coloured.

Record the characteristics of d block elements in your science diary.

Characteristics of f block elements

Where are the f block elements located in the periodic table?...

In which subshell does the filling up of electrons take place in them?

In these elements, filling up of electrons takes place in the anti penultimate shell. They are known as inner transition elements.

The metal of the 21st century- Titanium (Ti)

Titanium gets its name from the name of the Greek God Titan. It was discovered by the scientist William Gregor in 1791. Although it is strong, it has light weight, low density and high melting point (1668°C). This metal can be easily alloyed. It shows superconductivity at very low temperatures. This metal does not undergo corrosion when it comes into contact with sea water, acids , chlorine etc. Since it is non-toxic and non-allergic, it is used in medical field to make various implants. Titanium plays a significant role in the manufacture of aircraft, spacecraft, missiles, ships, sports equipments, and energy storage cells. Titanium dioxide is a key component in the manufacture of paint. It is also used in MRI scanning machine and water purification.

How are the f block elements of the 6th period known?

....

What about the elements of the 7th period?

....

Let us have a look at the characteristics and uses of f block elements.

They show variable oxidations states.

Actinoids are radioactive elements. These include man-made elements as well.

Certain isotopes of elements like Uranium (U), Thorium (Th) and Plutonium (Pu) are used as fuel in nuclear reactors.

Neodymium (Nd) is used for making strong magnets.

Some elements are used as catalyst in the petroleum industry. For example:- Cerium (Ce), Lanthanum (La).

Rare earth elements

Rare earth elements consist of 17 elements including 15 elements of Lanthanoids along with scandium and yttrium. In reality, they are not so rare in nature as the name indicates. Since they lie scattered on the earth's surface, it is difficult to find them in large quantities in a particular region. Hence, the process of extracting the metal from its ore is often a challenging task. Rare earth elements have diverse applications in the field of technology. They are used in computers, LCD screens, mobile phones, renewable energy sources, batteries, etc. Monazite, one of the main ores of rare earth metals, is commonly found in the coastal regions of southern Kerala.

Let us assess

1. The element X having 3 shells belongs to group 17.
   a) Write the subshell electron configuration of this element.
   b) To which block does this element belong?
   c) What is its period number?
   d) Write the molecular formula of the compound formed when X reacts with an atom of element Y which belongs to the third period and has one electron in its p subshell.

2. A few subshells are given.

   3p, 4d, 3f, 2d, 2p

   a) Among these, which subshells are not possible?
   b) Explain the reason.

3. The position of two elements A and B in the periodic table are given. (Symbols are not real)

   A - 4th period and 2nd group
   B - 2nd period and 16th group

   a) Write the subshell electron configuration of A and B.
   b) Write the values of n and l of electrons in the outermost subshell of A.
   c) How many orbitals are there in the subshell of B having the outermost electron? Find it on the basis of magnetic quantum number 'm'.
   d) Write the molecular formula of the compound formed by the combination of A and B.
   e) What type of chemical bond is present in this compound?

4. The subshell electron configuration of a few elements are written on the basis of noble gas.

   (i) [Ne] $3s^2\ 3p^6$ (ii) [He] $2s^1$
   (iii) [Ar] $3d^2\ 4s^2$ (iv) [Kr] $5s^2$

   a) Write the complete subshell electron configuration.
   b) Find the symbols of these elements with the help of periodic table.

5. The last electron of an atom is added to the 3d subshell. There are 7 electrons in this subshell. Answer the following questions regarding this atom.

   a) What is its atomic number?

   b) Write its complete electron configuration.

   c) To which block does it belong?

   d) Find its period number.

   e) What is its group number?

6. Find the oxidation state of s block elements in the following compounds..

   a) Na_2O b) KBr c) CaO d) $MgCl_2$

7. Which subshell is represented by each pair of the quantum number values given below?

   a) n = 1, $l = 0$ b) n = 2, $l = 1$

8. A few subshells are given. Find the values of n and l.

   a) 2s b) 4p c) 3d d) 5f

9. The subshell electron configuration of certain elements are given. Write the short form of each using the symbol of corresponding inert gas.

   a) $1s^2 2s^2 2p^4$ b) $1s^2 2s^2 2p^6 3s^2 3p^5$

   c) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$

10. Iron (Fe) takes part in chemical reactions and becomes Fe^{3+} ion. (Atomic number of Fe = 26).

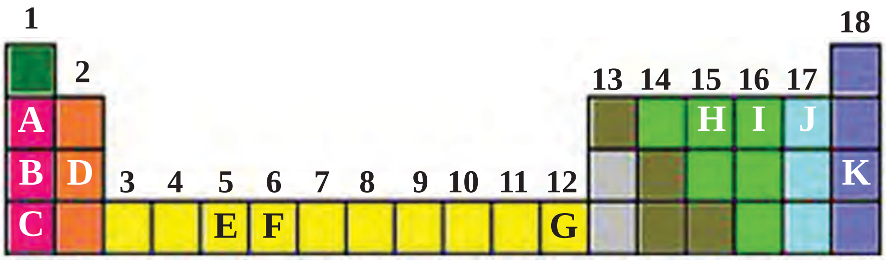
    a) Write the electron configuration of this ion.

    b) Write the chemical formula of the compound formed when this ion combines with sulphate ion (SO_4^{2-}) .

    c) Which is the other oxidation state of this element? Write the electron configuration of the ion thus formed.

    d) Iron shows variable oxidation states. Why?

11. A portion of the periodic table is given. Answer the following questions (Symbols are not real).



a) Which element has the lowest ionisation enthalpy?

b) Identify the alkaline earth metal.

c) Which are the d block elements?

d) Which element has the completely filled d subshell?

e) Identify the element having the electron configuration $3d^3 4s^2$?

f) Identify the noble gas.

g) Which element has only 3 electrons in the outermost p subshell?

Extended activities

1. Write down the subshell electron configuration of elements having atomic number 1 to 30.
2. Prepare a a slide show on the shapes of various orbitals with the help of presentation software.
3. Prepare a short note on various fields in which f block elements are used.