

CHEMISTRY

Standard x

Part 1



Government of Kerala
Department of General Education

State Council of Educational Research and Training (SCERT) Kerala

2019

THE NATIONAL ANTHEM

Jana-gana-mana adhinayaka jaya he
Bharatha-bhagya-vidhata,
Punjab-Sindh-Gujarat-Maratha
Dravida-Utkala-Banga
Vindhya-Himachala-Yamuna-Ganga
Uchchala-Jaladhi-taranga
Tava subha name jage,
Tava subha asisa mage,
Gahe tava jaya gatha.
Jana-gana-mangala-dayaka jaya he
Bharatha-bhagya-vidhata,
Jaya he, jaya he, jaya he,
Jaya jaya jaya jaya he!

PLEDGE

India is my country. All Indians are my brothers and sisters.

I love my country, and I am proud of its rich and varied heritage. I shall always strive to be worthy of it.

I shall give my parents, teachers and all elders respect, and treat everyone with courtesy.

To my country and my people, I pledge my devotion. In their well-being and prosperity alone lies my happiness.

State Council of Educational Research and Training (SCERT)

Poojappura, Thiruvananthapuram 695012, Kerala

Website : www.scertkerala.gov.in, e-mail : scertkerala@gmail.com

Phone : 0471 - 2341883, Fax : 0471 - 2341869

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Dear children,

Scientific activity, while enabling social progress, must also uphold eco-friendly values. This should happen at deeper levels of any science enquiry and activity. The text has tried to incorporate such ideologies to the possible extent and to discuss emerging areas like Green Chemistry.

The text provides opportunities for student's active participation in the classrooms. We have tried to organise these activities giving due emphasis to the level of your competence through investigative learning.

The initial units focus on explaining peculiarities of elements related to their electronic configuration, identifying the relationship between mass of substances and their number of molecules and also identifying the significance of mole concept in chemistry. Following this, discussions on the rate of reactions and equilibrium and chemical reactivity of metals and their stages of production are made. Some basic concepts in Organic Chemistry are discussed in this textbook.

The educational portal 'Samagra' and the QR Code incorporated textbook make the classroom learning process effortless and stimulating. National Skills Qualification Framework (NSQF), Disaster management techniques relevant to contemporary issues and the ICT possibilities are considered in this textbook.

It is the duty of each one of you to assimilate ideas in this text, carry out the activities effectively and attain your goal. Hope that your journey be fruitful in this through active interactions and appropriate activities.

Wishing you the best...

Dr J. Prasad
Director, SCERT

CONSTITUTION OF INDIA

Part IV A

FUNDAMENTAL DUTIES OF CITIZENS

ARTICLE 51 A

Fundamental Duties- It shall be the duty of every citizen of India:

- (a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;
- (b) to cherish and follow the noble ideals which inspired our national struggle for freedom;
- (c) to uphold and protect the sovereignty, unity and integrity of India;
- (d) to defend the country and render national service when called upon to do so;
- (e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;
- (f) to value and preserve the rich heritage of our composite culture;
- (g) to protect and improve the natural environment including forests, lakes, rivers, wild life and to have compassion for living creatures;
- (h) to develop the scientific temper, humanism and the spirit of inquiry and reform;
- (i) to safeguard public property and to abjure violence;
- (j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievements;
- (k) who is a parent or guardian to provide opportunities for education to his child or, as the case may be, ward between age of six and fourteen years.



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THE SYMBOLS USED IN THE TEXTBOOK



Additional Information
(Need not be assessed)



ICT Possibilities for Concept Clarity



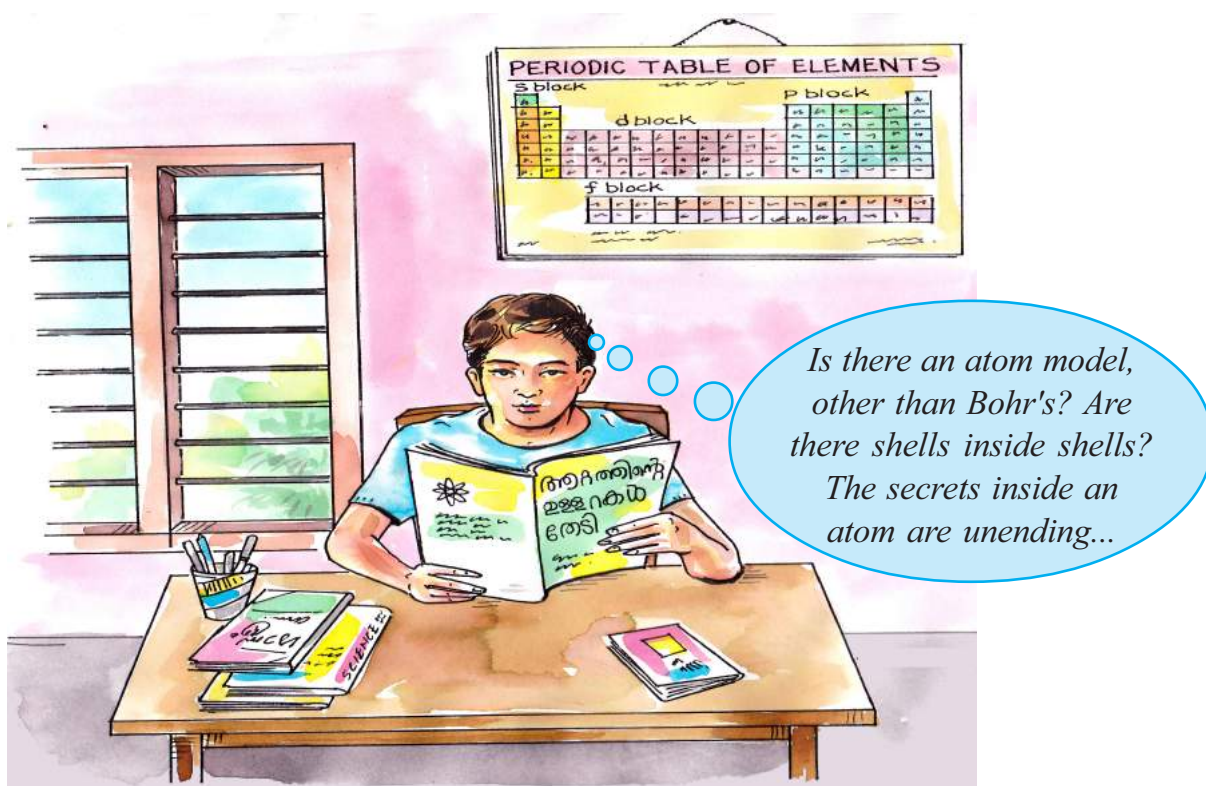
Let Us Assess



Extended Activities

1

Periodic Table and Electronic Configuration



You may have the same curiosity as that of the child when you have read about the structure of the atom. The scientific community has developed the concepts about an atom through many experiments and assumptions. You know that the periodic table, in which there is a comprehensive classification of elements, is based on atomic structure.

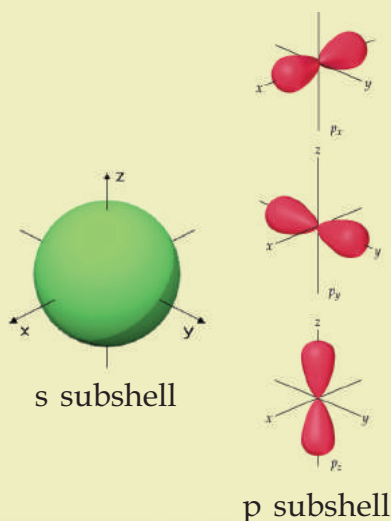
What is the basis of classification of elements in the periodic table?



Subshells

The names s, p, d, f are given to subshells based on words indicating certain properties related to the atomic spectra of elements. s → sharp, p → principal, d → diffuse, f → fundamental.

According to modern theories of atomic structure, electrons revolve in a three dimensional region around the nucleus. Each main energy level has sublevels or subshells. In these subshells, there are regions where there is a high probability of finding electrons. These are known as orbitals. The maximum number of electrons that can be accommodated in an orbital is 2. The **s** subshell has only one orbital with a spherical shape. The **p** subshell has 3 orbitals which are dumb-bell shaped, the **d** subshell has 5 orbitals and the **f** subshell has 7 orbitals. The shapes of these orbitals are more complex.



If you know the atomic number of an element, you can determine its position and nature from the periodic table.

Eg: Atomic number of sodium is 11.

Electronic configuration - 2, 8, 1

Group number -

Period number -

- Is this group 1 element a metal or a non-metal?

The classification in this table is done in such a way that we can analyse and predict the properties of elements. In the periodic table, the basis of the periodic function of elements is their atomic structure. Let's see how the latest knowledge about an atom and periodic table are related.

You have learnt about various atom models. According to Bohr model, in an atom electrons are arranged in various shells around the nucleus and they are filled in the increasing order of energy.

As the distance from the nucleus increases, the energy of the electrons in the shells increases and the attractive force between the nucleus and the electrons decreases.

The electronic configuration of lithium (${}_3\text{Li}$) is 2, 1.

Like this, write the electronic configuration of sodium and argon and complete Table 1.1.

Element	Shells		
	K	L	M
${}_{11}\text{Na}$			
${}_{18}\text{Ar}$			

Table 1.1

- How many electrons are present in the M shell, the outermost shell of argon?

- What is the maximum number of electrons that can be accommodated in the M shell?

Potassium ($_{19}\text{K}$), the element next to argon has one electron more than that of argon. The electronic configuration of potassium is 2, 8, 8, 1. Why does the last electron of potassium go to the 4th shell instead of occupying the third shell, even though the third shell has the capacity to accommodate ten more electrons?

You have seen the anxiety expressed by the child given in the introductory picture? You have also learned that the studies related to the atomic structure are progressing continuously. Bohr model is a simple explanation of the atomic structure. Studies related to the nature and position of the electrons in an atom revealed the limitations of the Bohr model and new assumptions were postulated. Accordingly electrons in each energy level are arranged in its sub energy levels. Each sub energy level in a shell is called a subshell. They are named as s, p, d, f respectively. Each main energy level except 'K' has more than one subshell. The number of subshells in each energy level is equal to its shell number.



Using the KALZIUM software of IT @ school Edubuntu, check the accuracy of the entries in Table 1.1.

The 'K' shell, which is the first shell, has 1 subshell. The next 'L' shell has 2, and so on.

- What will be the number of subshells in the 'M' shell and 'N' shell?

M =, N =

See the subshells present in each shell shown in Table 1.2.

Shell number	1	2	3	4
Subshells	s	s, p	s, p, d	s, p, d, f

Table 1.2

Which subshell is common to all shells?

How can you identify the shell in which each subshell belongs to?

Let's give the serial number of the shell to the symbol of the subshell. For example, '1s' to indicate the 's' subshell of the first shell and '2s' for the 's' subshell of the second shell and so on.

Complete the Table 1.3.

Shell number	1	2		3			4			
Subshell	s	s	p	s	p	d	s	p	d	f
Representation of subshells	1s	-	-	-	3p	-	-	-	4d	-

Table 1.3

The number of electrons in subshells

Haven't you found out from the table which all subshells are present in each shell?

You know the maximum number of electrons that can be accommodated in each shell. Then, how many electrons can be accommodated in each subshell?

On the basis of your discussion points, complete the Table 1.4 given below.

Shell number	1	2		3			4			
Maximum number of electrons that can be accommodated in each shell	2	8		18			32			
Subshell	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f
Maximum number of electrons that can be accommodated in each subshell	2	2	-	-	-	-	-	-	-	-

Table 1.4

What is the maximum number of electrons that can be accommodated in the 's' subshell?

Among the 8 electrons in the second shell, 2 will be in the 's' subshell. What may be the maximum number of electrons to be filled in the 'p' subshell? Find out by completing the table.

You have seen the maximum number of electrons that can be accommodated in the 's' and 'p' shells. Fill the columns regarding the third shell and find out the maximum number of electrons that can be accommodated in the 'd' subshell?

Likewise, find out by filling the table, how the 32 electrons in the fourth shell are distributed in s, p, d, f subshells?

The maximum number of electrons that can be accommodated in each sub shell is given in Table 1.5.

Subshell	s	p	d	f
Maximum number of electrons that can be accommodated	2	6	10	14

Table 1.5

Filling of electrons in the subshell

The electrons are filled in shells in the increasing order of their energy. For example the electronic configuration of carbon (${}_6\text{C}$) is 2, 4.

The first two electrons are filled in the 'K' shell, which has the lowest energy and the remaining four electrons are filled in the 'L' shell which has higher energy. Likewise, when the electrons in an atom are distributed in subshells, they are filled in the increasing order of the energies of subshells. This is called subshell electronic configuration. Then what will be the subshell wise electronic configuration of the carbon atom?

Let's familiarise on how to write the subshell wise electronic configuration of elements.

The number of electrons in an atom is equal to its atomic number (Z). The atomic number of hydrogen is 1 (${}_1\text{H}$).

- How many electrons are present? - - - - -
- In which shell is the electron filled? - - - - -
- In which subshell? - - - - -

The subshell electronic configuration of hydrogen can be represented as $1s^1$.



(Read it as one s one)

How many electrons are present in helium (${}_2\text{He}$)?

Complete the subshell electronic configuration.

1s^{.....}

Let's see the way of writing the electronic configuration of the next element lithium (${}_3\text{Li}$). Of the total 3 electrons, if 2 electrons are filled in 1s, then the remaining electron should enter the 2s subshell as it comes next, in the order of the increasing energy.

How many electrons are filled in 2s?

1s² 2s^{.....}

Read the electronic configuration of lithium as one s two, two s one (1s², 2s¹).

Complete the electronic configuration of beryllium.

• Be[Z=4] - 1s^{.....} 2s^{.....}

The next element is boron, isn't it? After filling 1s & 2s the next higher energy level is 2p. Write the electronic configuration of boron.

• B[Z=5] - 1s² 2s² 2p^{.....}

• Write the electronic configuration of carbon.

C[Z=6] - 1s^{.....} 2s^{.....} 2p^{.....}



When we write the subshell wise electronic configuration, the number on the left side of the subshell denotes the shell number and the number on the top right side denotes the number of electrons.

Write down the subshell electronic configuration of the elements given below and complete the Table 1.6.

Element	No. of electrons	Subshell electronic configuration
${}_7\text{N}$	7	1s ² 2s ² 2p ³
${}_9\text{F}$	9	1s ^{.....} 2s ^{.....} 2p ^{.....}
${}_{11}\text{Na}$	-	1s ^{.....} 2s ^{.....} 2p ^{.....} 3s ^{.....}
${}_{13}\text{Al}$	-	1s ^{.....} 2s ^{.....} 2p ^{.....} 3s ^{.....} 3p ^{.....}
${}_{17}\text{Cl}$	-	-
${}_{18}\text{Ar}$	-	-

Table 1.6

Let's take the case of potassium ($_{19}\text{K}$) having atomic number 19. Remember the speciality of the configuration of this element mentioned earlier.

- How was the shell wise electronic configuration of potassium written?

See Figure 1.1 which shows the relationship between the subshells and their energies.

- Compare the energies of 1s and 2s subshells. Which one has lower energy?
- Among the 3s & 3p subshells which has higher energy? What about 3d and 4s?

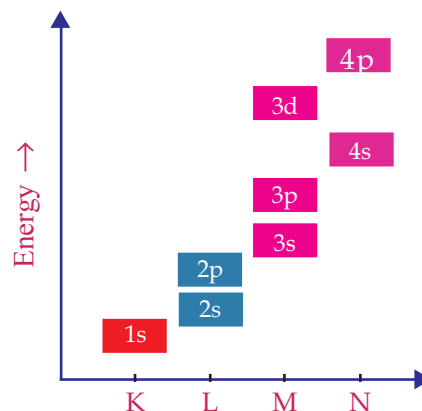


Figure 1.1

It can be seen that the energy of 4s is less than that of 3d.

- Write down the subshells in the increasing order of their energies.
 $1s < 2s < 2p < 3s < \dots < \dots < \dots < \dots$
- Write the subshell wise electronic configuration of potassium.

From the above, we can understand that as the energy of 4s is less than 3d, the last one electron in potassium entered the N shell after the M shell is occupied with 8 electrons.

Figure 1.2 helps you to find out the increasing order of energy of various subshells. Note the direction of the arrow. Try to write the subshell electronic configuration of the elements having atomic number upto 30 with the help of the Figure.

- The electronic configuration of scandium ($_{21}\text{Sc}$) is 2, 8, 9, 2. How can we write its subshell electronic configuration?

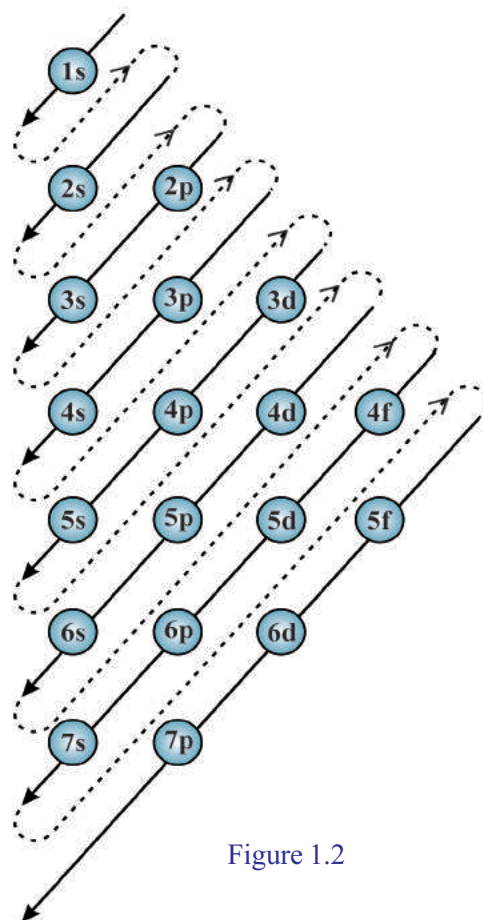


Figure 1.2

Electrons are filled in the subshells of scandium in the order $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$.

But this is written as $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$, ie., in the order of the shells.

Based on the increasing order of energy, once the 4s is filled, the next electron should go to 3d. This is how Sc gets the electronic configuration 2, 8, 9, 2.

- Write the electronic configuration of $_{22}\text{Ti}$, $_{23}\text{V}$, the two elements after Sc.

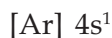
Let us familiarise another method of representing subshell electronic configuration.

While writing the subshell electronic configuration of elements with higher atomic numbers, the symbol of the noble gas preceding that element may be shown within square brackets followed by the electronic configuration of the remaining subshells.

The electronic configuration of potassium is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$.

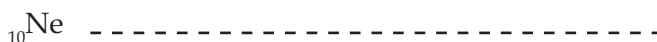
The preceding noble gas argon has the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6$.

Hence we may write the configuration of potassium using the symbol of argon as given below.



Which is the noble gas preceding sodium ($_{11}\text{Na}$)?

Write its subshell electronic configuration.



Subshell electronic configuration of sodium.



Using the symbol of neon, write down the subshell electronic configuration of sodium.

Find out the preceding noble gas with the help of the periodic table and complete Table 1.7.

Elements	Subshell electronic configuration
$_{21}\text{Sc}$	$[\text{Ar}] 3d^1 4s^2$
$_{20}\text{Ca}$	
$_{12}\text{Mg}$	
$_{27}\text{Co}$	
$_{30}\text{Zn}$	

Table 1.7



Using the KALZIUM software of IT @ School Edubuntu check the accuracy of the activity in Table 1.7.

Peculiarity of the electronic configuration of chromium (Cr) and copper (Cu)

- Write the subshell electronic configuration of $_{24}\text{Cr}$.
-
- The stable electronic configuration of Cr is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$.

Analyse and find out the reason for this from the box given below.

The d sub shell can accommodate a maximum of 10 electrons. The completely filled configuration (d^{10}) or the half filled configuration (d^5) of this subshell is more stable than the others. Based on this, atoms with $d^4 s^2$, $d^9 s^2$ configurations will have some changes in the filling of electrons to attain stability. Likewise, for f sub shell, f^7 and f^{14} arrangements are more stable.

On the basis of this, identify the correct electronic configuration of $_{29}\text{Cu}$ from those given below:

- $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 4s^2$ ☐
- $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ ☐

For the subshell electronic configurations of chromium and copper, the configurations with half filled d subshell or completely filled d subshell show greater stability.

- If the subshell wise electronic configuration of an atom is $1s^2 2s^2 2p^6 3s^2$, find answers to the following:
- How many shells are present in this atom?
 - Which are the subshells of each shell?
 - Which is the subshell to which the last electron was added?
 - What is the total number of electrons in the atom?
 - What is its atomic number?
 - How can the subshell electronic configuration be written in short form?



Use the KALZIUM software of IT @ School Edubuntu for further clarification.

Subshell electronic configuration and blocks

Based on the subshell electronic configuration, elements are classified into four blocks s, p, d and f in the modern periodic table.

The periodic table, with the blocks labelled, is given in Figure 1.3. Analyse it and complete Table 1.8.

s-block												p-block													
1														13		14		15		16		17		18	
H	2	d-block												B	C	N	O	F	He						
Li	Be													Al	Si	P	S	Cl	Ar						
Na	Mg	3	4	5	6	7	8	9	10	11	12	Ga	Ge	As	Se	Br	Kr								
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	In	Sn	Sb	Te	I	Xe								
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	Tl	Pb	Bi	Po	At	Rn								
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Nh	Fl	Mc	Lv	Ts	Og								
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	f-block													
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu										
		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr										

Figure 1.3

Element	Atomic Number	Subshell electronic configuration	The subshell to which the last electron is added	Block
${}^3\text{Li}$				
${}^{12}\text{Mg}$				
${}^7\text{N}$				
${}^{21}\text{Sc}$				

Table 1.8

- Which is the subshell of lithium to which the last electron was added?

- What about the subshell to which the last electron of nitrogen was added?

- What is the relation between the subshell to which the last electron was added and the block to which the element belongs to?

- Write the subshell electronic configurations of the following elements and find the blocks to which they belong.

a. ${}^4\text{Be}$ -----

b. ${}^{26}\text{Fe}$ -----

c. ${}^{18}\text{Ar}$ -----



Using the KALZIUM software of IT @ School Edubuntu check the accuracy of the activity in Table 1.8.



The block to which the element belongs will be the same as the subshell to which the last electron is added. In the periodic table, elements in groups 1 & 2 belong to s block, those in groups 13 to 18 belong to the p block and those in groups 3 to 12 belong to the d block. The elements in the f block are placed at the bottom of the periodic table in two separate rows.

The period and the group can be found out on the basis of subshell electronic configuration.

You know how to find the period number of an element on the basis of its shell wise electronic configuration. Let us see how to find the period from subshell electronic configuration. Complete Table 1.9.

Element	Subshell electronic configuration	No. of the outer most shell	Period number
${}_4\text{Be}$	$1s^2 2s^2$	2	2
${}_6\text{C}$	$1s^2 2s^2 2p^2$	2	2
${}_{11}\text{Na}$	$1s^2 2s^2 2p^6 3s^1$	3	-
${}_{19}\text{K}$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$	-	-

Table 1.9

The period number is same as the shell number of the outer most shell in the subshell electronic configuration.

The group number of s block elements

The group number of elements can be found on the basis of subshell electronic configuration. Some elements are given in Table 1.10.

With the help of the periodic table (Figure 1.4) complete the table.

Element	Subshell electronic configuration	No. of electrons present in the last subshell	Group number
Li	$1s^2 2s^1$	1	1
Na	$1s^2 2s^2 2p^6 3s^1$	-	1
Mg	$1s^2 2s^2 2p^6 3s^2$	-	2
Ca	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$	-	-

Table 1.10

It is clear that the elements in groups 1 and 2 belong to s block.

- What is the relation between number of electrons present in the last s subshell and their group number?

For s block elements the number of electrons in the outermost s subshell will be the group number.



Periodic Table

Hints		Atomic number Symbol Name in English (Name in Latin/Greek)	
Gases			
Liquids			
Artificial Elements			
¹ H Hydrogen 1	⁴ Be Beryllium 2,2	¹¹ Na Sodium (Natrium) 2,8,1	¹² Mg Magnesium 2,8,2
³ Li Lithium 2,1	²⁰ Ca Calcium 2,8,8,2	¹⁹ K Potassium (Kalium) 2,8,8,1	³⁸ Sr Strontium 2,8,18,6,2
⁵ B Boron 2,3	²¹ Sc Scandium 2,8,9,2	³⁹ Y Yttrium 2,8,18,9,2	⁵⁷ La Lanthanum 2,8,18,32,18,2
⁶ C Carbon 2,4	²² Ti Titanium 2,8,10,2	⁴⁰ Zr Zirconium 2,8,18,10,2	⁵⁸ Ce Cerium 2,8,18,19,5,2
⁷ N Nitrogen 2,5	²³ V Vanadium 2,8,11,2	⁴¹ Nb Niobium 2,8,18,12,1	⁵⁹ Pr Praseodymium 2,8,18,21,8,2
⁸ O Oxygen 2,6	²⁴ Cr Chromium 2,8,13,1	⁴² Mo Molybdenum 2,8,18,13,1	⁶⁰ Nd Neodymium 2,8,18,22,8,2
⁹ F Fluorine 2,7	²⁵ Mn Manganese 2,8,13,2	⁴³ Tc Technetium 2,8,18,14,1	⁶¹ Pm Promethium 2,8,18,23,8,2
¹⁰ Ne Neon 2,8	²⁶ Fe Iron (Ferrum) 2,8,14,2	⁴⁴ Ru Ruthenium 2,8,18,15,1	⁶² Sm Samarium 2,8,18,23,8,2
¹³ Al Aluminium 2,8,3	²⁷ Co Cobalt 2,8,15,2	⁴⁵ Rh Rhodium 2,8,18,16,1	⁶³ Eu Europium 2,8,18,25,8,2
¹⁴ Si Silicon 2,8,4	²⁸ Ni Nickel 2,8,16,2	⁴⁶ Pd Palladium 2,8,18,18	⁶⁴ Gd Gadolinium 2,8,18,25,9,2
¹⁵ P Phosphorus 2,8,5	²⁹ Cu Copper (Cuprum) 2,8,18,1	⁴⁷ Ag Silver (Argentum) 2,8,18,18,1	⁶⁵ Tb Terbium 2,8,18,27,8,2
¹⁶ S Sulphur 2,8,6	³⁰ Zn Zinc 2,8,18,2	⁴⁸ Cd Cadmium 2,8,18,18,2	⁶⁶ Dy Dysprosium 2,8,18,28,8,2
¹⁷ Cl Chlorine 2,8,7	³¹ Ga Gallium 2,8,18,3	⁴⁹ In Indium 2,8,18,18,3	⁶⁷ Ho Holmium 2,8,18,29,8,2
³⁴ Se Selenium 2,8,18,6	³² Ge Germanium 2,8,18,4	⁵⁰ Sn Tin (Stannum) 2,8,18,18,4	⁶⁸ Er Erbium 2,8,18,30,8,2
⁵² Te Tellurium 2,8,18,18,6	³³ As Arsenic 2,8,18,5	⁵¹ Sb Antimony (Stibium) 2,8,18,18,5	⁶⁹ Tm Thulium 2,8,18,31,8,2
⁵³ I Iodine 2,8,18,18,7	³⁴ Se Selenium 2,8,18,6	⁵² Te Tellurium 2,8,18,18,6	⁷⁰ Yb Ytterbium 2,8,18,32,8,2
⁸⁴ Po Polonium 2,8,18,32,18,6	³⁵ Br Bromine 2,8,18,7	⁸³ Bi Bismuth 2,8,18,32,18,5	⁷¹ Lu Lutetium 2,8,18,32,9,2
⁸⁵ At Astatine 2,8,18,32,18,7	³⁶ Kr Krypton 2,8,18,8	⁸⁴ Po Polonium 2,8,18,32,18,6	⁷² Hf Hafnium 2,8,18,32,10,2
¹¹⁶ Lv Livermorium 2,8,18,32,18,6	³⁷ Rb Rubidium 2,8,18,8,1	⁸⁵ At Astatine 2,8,18,32,18,7	¹⁰⁴ Rf Rutherfordium 2,8,18,32,10,2
¹¹⁷ Ts Tennessine 2,8,18,32,18,7	³⁸ Sr Strontium 2,8,18,6,2	⁸⁶ Rn Radon 2,8,18,32,18,8	¹⁰⁵ Db Dubnium 2,8,18,32,11,2
¹¹⁸ Og Oganesson 2,8,18,32,18,8	³⁹ Y Yttrium 2,8,18,9,2	⁸⁷ Fr Francium 2,8,18,32,18,8,1	¹⁰⁶ Sg Seaborgium 2,8,18,32,12,2
	⁴⁰ Zr Zirconium 2,8,18,10,2	⁸⁸ Ra Radium 2,8,18,32,18,8,2	¹⁰⁷ Bh Bohrium 2,8,18,32,13,2
	⁴¹ Nb Niobium 2,8,18,12,1	⁸⁹ Ac Actinium 2,8,18,32,18,9,2	¹⁰⁸ Hs Hassium 2,8,18,32,14,2
	⁴² Mo Molybdenum 2,8,18,13,1	⁹⁰ Th Thorium 2,8,18,32,18,10,2	¹⁰⁹ Mt Meitnerium 2,8,18,32,15,2
	⁴³ Tc Technetium 2,8,18,14,1	⁹¹ Pa Protactinium 2,8,18,32,20,9,2	¹¹⁰ Ds Darmstadtium 2,8,18,32,16,1
	⁴⁴ Ru Ruthenium 2,8,18,15,1	⁹² U Uranium 2,8,18,32,21,9,2	¹¹¹ Rg Roentgenium 2,8,18,32,17,1
	⁴⁵ Rh Rhodium 2,8,18,16,1	⁹³ Np Neptunium 2,8,18,32,22,9,2	¹¹² Cn Copernicium 2,8,18,32,18,2
	⁴⁶ Pd Palladium 2,8,18,18	⁹⁴ Pu Plutonium 2,8,18,32,24,8,2	¹¹³ Nh Nihonium 2,8,18,32,18,3
	⁴⁷ Ag Silver (Argentum) 2,8,18,18,1	⁹⁵ Am Americium 2,8,18,32,25,8,2	¹¹⁴ Fl Flerovium 2,8,18,32,18,4
	⁴⁸ Cd Cadmium 2,8,18,18,2	⁹⁶ Cm Curium 2,8,18,32,25,9,2	¹¹⁵ Mc Moscovium 2,8,18,32,18,5
	⁴⁹ In Indium 2,8,18,18,3	⁹⁷ Bk Berkelium 2,8,18,32,27,8,2	¹¹⁶ Lv Livermorium 2,8,18,32,18,6
	⁵⁰ Sn Tin (Stannum) 2,8,18,18,4	⁹⁸ Cf Californium 2,8,18,32,28,8,2	¹¹⁷ Ts Tennessine 2,8,18,32,18,7
	⁵¹ Sb Antimony (Stibium) 2,8,18,18,5	⁹⁹ Es Einsteinium 2,8,18,32,29,8,2	¹¹⁸ Og Oganesson 2,8,18,32,18,8
	⁵² Te Tellurium 2,8,18,18,6	¹⁰⁰ Fm Fermium 2,8,18,32,30,8,2	
	⁵³ I Iodine 2,8,18,18,7	¹⁰¹ Md Mendelevium 2,8,18,32,31,8,2	
	⁵⁴ Xe Xenon 2,8,18,18,8	¹⁰² No Nobelium 2,8,18,32,32,8,2	
	⁵⁵ Cs Caesium 2,8,18,18,8,1	¹⁰³ Lr Lawrencium 2,8,18,32,32,9,2	
	⁵⁶ Ba Barium 2,8,18,18,8,2		
	⁵⁷ La Lanthanum 2,8,18,32,18,8,2		
	⁵⁸ Ce Cerium 2,8,18,19,5,2		
	⁵⁹ Pr Praseodymium 2,8,18,21,8,2		
	⁶⁰ Nd Neodymium 2,8,18,22,8,2		
	⁶¹ Pm Promethium 2,8,18,23,8,2		
	⁶² Sm Samarium 2,8,18,23,8,2		
	⁶³ Eu Europium 2,8,18,25,8,2		
	⁶⁴ Gd Gadolinium 2,8,18,25,9,2		
	⁶⁵ Tb Terbium 2,8,18,27,8,2		
	⁶⁶ Dy Dysprosium 2,8,18,28,8,2		
	⁶⁷ Ho Holmium 2,8,18,29,8,2		
	⁶⁸ Er Erbium 2,8,18,30,8,2		
	⁶⁹ Tm Thulium 2,8,18,31,8,2		
	⁷⁰ Yb Ytterbium 2,8,18,32,8,2		
	⁷¹ Lu Lutetium 2,8,18,32,9,2		
	⁷² Hf Hafnium 2,8,18,32,10,2		
	⁷³ Ta Tantalum 2,8,18,32,11,2		
	⁷⁴ W Tungsten (Wolfram) 2,8,18,32,12,2		
	⁷⁵ Re Rhenium 2,8,18,32,13,2		
	⁷⁶ Os Osmium 2,8,18,32,14,2		
	⁷⁷ Ir Iridium 2,8,18,32,15,2		
	⁷⁸ Pt Platinum 2,8,18,32,17,1		
	⁷⁹ Au Gold (Aurum) 2,8,18,32,18,1		
	⁸⁰ Hg Mercury (Hydrargyrum) 2,8,18,32,18,2		
	⁸¹ Tl Thallium 2,8,18,32,18,3		
	⁸² Pb Lead (Plumbum) 2,8,18,32,18,4		
	⁸³ Bi Bismuth 2,8,18,32,18,5		
	⁸⁴ Po Polonium 2,8,18,32,18,6		
	⁸⁵ At Astatine 2,8,18,32,18,7		
	⁸⁶ Rn Radon 2,8,18,32,18,8		
	⁸⁷ Fr Francium 2,8,18,32,18,8,1		
	⁸⁸ Ra Radium 2,8,18,32,18,8,2		
	⁸⁹ Ac Actinium 2,8,18,32,18,9,2		
	⁹⁰ Th Thorium 2,8,18,32,18,10,2		
	⁹¹ Pa Protactinium 2,8,18,32,20,9,2		
	⁹² U Uranium 2,8,18,32,21,9,2		
	⁹³ Np Neptunium 2,8,18,32,22,9,2		
	⁹⁴ Pu Plutonium 2,8,18,32,24,8,2		
	⁹⁵ Am Americium 2,8,18,32,25,8,2		
	⁹⁶ Cm Curium 2,8,18,32,25,9,2		
	⁹⁷ Bk Berkelium 2,8,18,32,27,8,2		
	⁹⁸ Cf Californium 2,8,18,32,28,8,2		
	⁹⁹ Es Einsteinium 2,8,18,32,29,8,2		
	¹⁰⁰ Fm Fermium 2,8,18,32,30,8,2		
	¹⁰¹ Md Mendelevium 2,8,18,32,31,8,2		
	¹⁰² No Nobelium 2,8,18,32,32,8,2		
	¹⁰³ Lr Lawrencium 2,8,18,32,32,9,2		

Figure 1.4

As per IUPAC recommendations Lanthanum ($_{57}\text{La}$) in a Lanthanoid and Actinium ($_{89}\text{Ac}$) in an Actinoid

Some common characteristics of 's' block elements

You have learned that the s block elements contain alkali metals and alkaline earth metals. Their oxides and hydroxides are basic in nature.

- When the s block elements react, do they donate or accept electrons?

- Which type of chemical bond is usually formed?

Ionic bond/Covalent bond

We can understand that s block elements usually form ionic compounds.

- How many electrons are donated by the first group elements in chemical reactions?

- What about the second group elements?

- Suppose that 1st and 2nd group elements are represented by the symbols X and Y.

Complete the table given below.

Group	Valency	Oxidation state	Symbol of ions	Chemical formula of oxides
1 st group [X]	1	+1	-	X ₂ O
2 nd group [Y]	2	-	Y ²⁺	-

Table 1.11

Upon completing the table, it can be seen that 's' block elements show definite valency and oxidation state.

's' block elements are present at the extreme left side of the periodic table. Relating to their position, what other characteristics can be listed out?

- More metallic character
- Less ionisation energy
- Less electronegativity
-
-

List out the characteristics of s block elements and prepare a note.

p block elements

- Which are the groups included in the p block.

Look at the portion of the second period of p block elements in the periodic table.

Group Number	13	14	15	16	17	18
Element	B	C	N	O	F	Ne
Outermost subshell configuration	5 $2s^2 2p^1$	6 $2s^2 2p^2$	7 $2s^2 2p^3$	8 $2s^2 2p^4$	9 $2s^2 2p^5$	10 $2s^2 2p^6$

Table 1.12

- In which subshell did the filling of the last electron take place?

1 to 6 electrons are seen in the p subshell.

p block starts in the periodic table after 12 groups. Can you find out the group number by adding 12 to the number of p electrons? Analyse with respect to the given table.

Element	No. of p electrons	Group Number
${}_5\text{B}$	1	$1+12 = 13$
${}_7\text{N}$	-	$\dots + 12 = \dots$
${}_{10}\text{Ne}$	-	$\dots + \dots = \dots$

Table 1.13

The outermost subshell wise electronic configuration of an element Y (Symbol is not real) is $3s^2 3p^4$.

- To which period and group does this element belong to?

- Write down the outermost subshell electronic configuration of the element coming just below it in the same group.

These can be written due to the similarity in the electronic configuration of these elements.

Characteristics of p block elements

See the portion of the periodic table which contains the p block elements.

						18
						He
	13	14	15	16	17	
	B	C	N	O	F	Ne
	Al	Si	P	S	Cl	Ar
	Ga	Ge	As	Se	Br	Kr
	In	Sn	Sb	Te	I	Xe
	Tl	Pb	Bi	Po	At	Rn
	Nh	Fl	Mc	Lv	Ts	Og

	Metals
	Non - metals
	Metalloids
	Noble gases

Figure 1.5

As evident from the figure, elements representing different classes are included in this picture.

Elements in the solid, liquid and gaseous states at room temperature are also included in this block.

Find out examples of elements in such different states with the help of the periodic table (Fig. 1.4).

- p block elements usually show higher ionisation energy than the s block elements. Which element has the highest ionisation energy in each period? Think on the basis of electronic configuration.

- The element having the highest electronegativity is in the p block.

Find its name and position.

Analyze the general characteristics of the p block elements and prepare a note on this.

Complete the Table 1.14, (X, Y) are not real symbols.

Element	Outermost electronic configuration	Complete subshell electronic configuration	Atomic number Z	Period	Group	Block
X	$3s^2$					
Y	$3s^23p^5$					

Table 1.14

- Which element has a valency 1?
- Which element shows metallic character?
- Which element has the highest ionisation energy?
- Write the chemical formula of the compound formed by the combination of X and Y and label the oxidation states.

d block elements

- Where is the position of d block elements in the periodic table?

- From which period onwards does the d block begin?

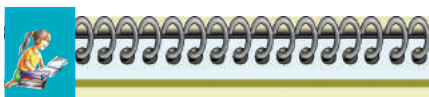
The d block elements in the fourth period are given in the table below. The electronic configuration of the last two subshells, 3d and 4s are given in the table.

Group	3	4	5	6	7	8	9	10	11	12
Element	21 Sc $3d^14s^2$	22 Ti $3d^24s^2$	23 V $3d^34s^2$	24 Cr $3d^54s^1$	25 Mn $3d^54s^2$	26 Fe $3d^64s^2$	27 Co $3d^74s^2$	28 Ni $3d^84s^2$	29 Cu $3d^{10}4s^1$	30 Zn $3d^{10}4s^2$

Table 1.15

Is there any relationship between group number and the total number of electrons present in the 3d and 4s sub shells? Examine.

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



The elements Zn, Cd, Hg which belong to the 12th group do not show the common characteristics of transition elements. Hence they are known as pseudo transition elements.

Characteristics of d block elements

d block elements are those in which the last electron is filled in the **d** subshell of the penultimate shell. They are also known as **transition elements**.

Put a tick mark '✓' against the statements given below which are applicable to d block elements.

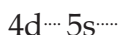
- ☐ These are metals.
- ☐ The last electron is filled in the penultimate shell.
- ☐ In the case of these elements in the 4th period, the last electron is filled in 4s.
- ☐ These are found in groups 3 to 12 of the periodic table.

You have already learned that representative elements which belongs to **s** and **p** groups show similarity in their respective groups. This is because the elements of the same group have the same number of electrons in the outermost shells.

Analyse the electronic configuration of the 3d and 4s subshells of the d block elements in the 4th period which are given in Table 1.15.

What is the speciality in the number of electrons present in the outermost 4s subshell? Do transition elements show similarity in periods? Likewise, it can be inferred that there will be similarity in the outermost electronic configuration in succeeding periods

as well. Write the subshell electronic configuration of the element which comes just below scandium.



The outermost subshell electronic configuration of the transition elements are generally the same in a group and also along a period. Therefore they show similarities in properties not only in groups but also in periods.

Oxidation state of d block elements

You know that valency is the number of electrons lost or gained or shared by atoms during chemical bond formation. The concept of oxidation state is also known to you.

Look at the names and chemical formulae of two different chlorides of iron (Fe) given below.

- Ferrous chloride - FeCl_2
- Ferric chloride - FeCl_3

The oxidation state of chlorine is (-1).

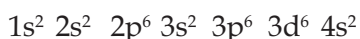
Find the oxidation state of Fe in these compounds and then complete Table 1.16.

Compound	Oxidation state of Fe	Symbol of Fe ions
FeCl_2		
FeCl_3		

Table 1.16

When d block elements undergo chemical reactions, along with the electrons in the outermost subshell, the electrons in the penultimate d subshell also take part. In the d block elements, electrons are not lost in the same order as they are filled up, that is electrons are lost from the outermost s subshell first.

Look at the sub shell electronic configuration of $_{26}\text{Fe}$.



- How does Fe change to Fe^{2+} ?

- Write down the subshell electronic configuration of Fe^{2+} .

In FeCl_3 , iron loses 3 electrons to form Fe^{3+} ion.

There is only a small difference of energy between the outermost s subshell and the penultimate d subshell of transition elements.

- If so, which will be the subshell from which iron loses the third electron?

- Write the electronic configuration of Fe^{3+} on the basis of this.

Manganese (Mn) is the element with atomic number 25.

Subshell electronic configuration.

MnCl_2 , MnO_2 , Mn_2O_3 and Mn_2O_7 are different compounds of manganese. Complete the Table 1.17 by writing the oxidation state of manganese in each of these and also the subshell electronic configuration of each.

Compound	Oxidation state of Mn	Subshell electronic configuration of Mn ions
MnCl_2	-	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$
MnO_2	+4	-
Mn_2O_3	-	-
Mn_2O_7	-	-

Table 1.17

When s and p block elements take part in chemical reactions, the electrons in the outermost shell are involved. But in the case of transition elements the difference in energy between the outermost s subshell and the penultimate d subshell is very small. Hence under suitable conditions the electrons in d subshell also take part in chemical reactions. Hence transition elements show variable oxidation states.

Coloured compounds

See some compounds of the transition elements given below.

- Copper sulphate
- Cobalt nitrate
- Potassium permanganate
- Ferrous sulphate
-

Examine these compounds available in the science lab and find out their colours. Find more coloured compounds and extend the list.

Most of the coloured salts are compounds of transition elements. The colour is due to the presence of transition metal ions present in these compounds.

- Compounds of transition elements are used for giving colour to glasses and in oil paintings. Find out more information through reference.

Characteristics of f block elements

The f block elements are the elements coming after lanthanum and actinium and are placed in two rows at the bottom of the periodic table.

The last electrons in these elements are filled up in the antepenultimate shell. The elements in the first row are called Lanthanoids and those in the second row are called Actinoids. These elements belong to the 6th and 7th periods respectively. On examining the subshell electronic configuration you can find that the last electrons are filled up in the f subshell. Some characteristics and uses of f block elements are given below.



The catalytic property of transition elements

Catalysts are substances which influence the speed of a chemical reaction without themselves undergoing any permanent chemical change. Generally transition elements and their compounds are widely used as catalysts. Vanadium pentoxide (V_2O_5) in contact process, spongy Iron in Haber process, and Nickel (Ni) in hydrogenation of vegetable oils to obtain vanaspathi are some examples. One reason for the catalytic activity of the d block elements is that they are capable of showing different oxidation states and hence can act as oxidizing agents or reducing agents at the same time.



The mineral wealth of Kerala

The distribution of minerals is not uniform throughout the earth. Our state Kerala, is blessed with abundant deposits of certain minerals. The beach sands of Kerala are rich sources of minerals like monazite, ilmenite, zircon, rutile, etc. Ilmenite is the raw material for the production of titanium dioxide (TiO_2) which is widely used in daily life. The mineral monazite is the source of thorium (Th) which is considered to be useful in breeder reactors. Monazite is also the raw material for the production of the metal neodymium (Nd).



Neodymium is widely used for the production of powerful and light weight magnets. Monazite is also the mineral of cerium (Ce) metal used for making flint stones. We should judiciously utilize this valuable mineral wealth.

- Like the d block elements most of these show variable oxidation states.
- Most of the actinoids are radioactive and are artificial elements.
- Uranium (U), Thorium (Th), Plutonium (Pu) etc. are used as fuels in nuclear reactors.
- Many of them are used as catalysts in the petroleum industry.

Note the part of the periodic table given below (Table 1.18). The symbols given in the column are not real.

1	Group																18
	2											13	14	15	16	17	
														E	F	G	H
		3	4	5	6	7	8	9	10	11	12						
A	B			C	D												

Table 1.18

- List out the elements of the s block.
-
- Which element shows +2 oxidation state?
 - Which element contains 5 electrons in the outermost shell?
 - Which is the element that has 5 p electrons in the outermost shell?
 - Which are the elements in which the last electron enters the d subshell?
 - Which element has the highest ionisation energy?
 - Which is the highly reactive non metal?
 - Which element shows – 2 oxidation state?

- The outermost electron configuration of an element in this is $2s^2 2p^6$.
 - Which is the element?
 - Write down the complete subshell electronic configuration.
 - Write any two characteristics of this element.
- Write the chemical formula of the compound formed between A and G.

Frame maximum number of questions, the answer of which is an element in the table.

In this chapter, we have familiarised the possibility of using the periodic table for analysing and comparing the characteristics of elements while studying chemistry. You can make use of the periodic table for further learning of the nature of substances.



Let's assess

- Based on the hints given, find out the atomic number and write down the subshell electronic configuration of elements (Symbols used are not real).
 - A – period 3 group 17
 - B – period 4 group 6
- When the last electron of an atom was filled in the 3d subshell, the subshell electronic configuration was $3d^8$. Answer the questions related to this atom.
 - Complete subshell electronic configuration
 - Atomic number
 - Block
 - Period number
 - Group number
- Pick out the wrong subshell electronic configurations from those given below.

a) $1s^2 2s^2 2p^7$	b) $1s^2 2s^2 2p^2$
c) $1s^2 2s^2 2p^5 3s^1$	d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^1$
e) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$	

4. The element X in group 17 has 3 shells. If so,
 - a) Write the subshell electronic configuration of the element.
 - b) Write the period number.
 - c) What will be the chemical formula of the compound formed, if the element X reacts with Y of the third period which contains one electron in the p sub shell?
5. The element Cu with atomic number 29 undergoes chemical reaction to form an ion with oxidation number +2.
 - a) Write down the subshell electronic configuration of this ion?
 - b) Can this element show variable valency? Why?
 - c) Write down the chemical formula of one compound formed when this element reacts with chlorine ($_{17}\text{Cl}$).
6. Certain subshells are given below.

2s, 2d, 3f, 3d, 5s, 3p

 - a) Which are the subshells that are not possible?
 - b) Give reason.



Extended Activity

1. Prepare a comprehensive table which indicates the name, symbol, electron configuration, subshell configuration of elements having atomic number 1 to 36.

Atomic Number	Element	Symbol	Electronic configuration	Subshell electronic configuration

2. Some information related to the elements of the p block in the 17th group of the periodic table are given in the table below. Complete the table and analyse the following questions.

Element	Symbol	State at STP	Chemical reactivity with Hydrogen	Common oxidation State	Chemical formula of hydrides
Fluorine	.....	.....	Vigourous reaction	-1	HF
.....	Cl	.....	Vigourous reaction	-1	.....
Bromine	.....	Liquid	Slow reaction	–	.....
Iodine	.....	.....	Very slow reaction	–	.....

- What is the family name of elements belonging to the 17th group?
- What is their common valency?
- Which element has the highest electronegativity?
- Which element has the highest ionisation energy?
- List out the name and chemical formula of the compounds formed by these elements with s block elements.

2

Gas Laws and Mole Concept



Compared to solids and liquids, gases have a lot of characteristic features. Many elements and compounds are seen in gaseous state. We are handling so many gases in daily lives, industries and laboratories.

Certain statements regarding gases are given.

- Each gas contains numerous minute molecules.
- When compared to the total volume of a gas, the real volume of molecules is very less.
- The molecules of a gas are in a state of rapid random motion in all directions.

- As a result of the random motion of the gas molecules, they collide with each other and also collide with the walls of the container in which it is kept. This collision with the walls account for the pressure of a gas.
- As the collision of molecules are perfectly elastic in nature, there is no loss of energy.
- There is no attraction between the gas molecules and with the walls of the container.

On the basis of the above statements, complete Table 2.1 given below:

Energy of gas molecules	Very high
Distance between the molecules	.....
Freedom of movement of molecules	.....
Attractive force between molecules	.....

Table 2.1

On examining these statements, you may get an idea of the volume of gases, pressure and energy of gas molecules.

Volume of a gas

The space occupied by a substance is known as its volume.

Even if a litre of liquid is transferred into a container of any size there is no difference in its volume. If a gas which is kept in a cylinder having a volume of 1 litre, is completely transferred to another 5 litre cylinder then what will be the volume of the gas?

Volume of a gas is the volume of the container which it occupies

Pull the piston of a syringe backwards. Press the piston after closing the nozzle of the syringe. What will happen to the volume of air inside the syringe?

Explain it on the basis of the distance between the molecules of gas and their freedom of movement.



Figure 2.1

Pressure of a Gas

The molecules of gas kept inside a closed container are shown in the figure.

- What is the speciality of the movement of the molecules?

- What assumption can be made regarding the possibility of collision between gas molecules?

Consider any surface inside the container. A force is experienced on this surface as a result of the collision of the gas molecules on the surface. If we know the force exerted on the surface and its surface area, we can calculate the force experienced per unit area.

$$\text{Force on unit area} = \frac{\text{Total force exerted on the surface}}{\text{Surface area}}$$

Force exerted per unit area is called pressure.

Temperature

Molecules in gases are moving rapidly, aren't they?

- Which is the energy gained due to the movement of the molecules? Potential energy / Kinetic energy
- When a gas is heated, temperature is increased. What happens to the movement of molecules if the temperature of the gas is increased?
- As a result, what happens to the energy of the molecules?

Temperature is the average kinetic energy of molecules in a substance.

On the basis of the acquired information, write a short note on the given properties of a gas.

- Volume
- Pressure
- Temperature

Volume and pressure

Look at Figure A and Figure B.

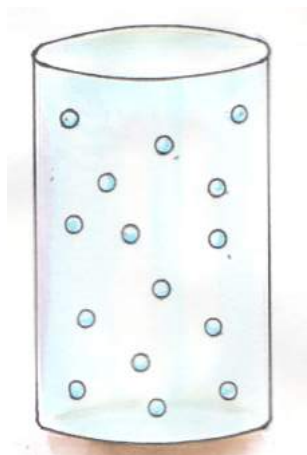


Figure 2.2 (A)

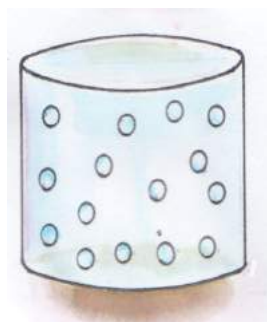


Figure 2.2 (B)

A definite mass of a gas kept in a closed cylinder is shown in figure A. Suppose the gas is transferred to the other cylinder without changing the temperature, as shown in Figure B. Is there any change in the number of molecules? What happens to the pressure when the volume is decreased?

Let's do another experiment.

Pull the piston of a 10 mL syringe backwards. Press the piston by keeping its nozzle closed.

What change can you observe in the volume of the gas inside the syringe?

What about decreasing the pressure?

What relation do you arrive at between pressure and volume of the gas?

It is Robert Boyle, the British Physicist and Chemist (1627-1691), who established the relationship between volume and pressure of a gas through experiments. This relation is known as **Boyle's Law**.

At a constant temperature, volume of a definite mass of gas is inversely proportional to its pressure. If P is the pressure and V the volume, then $P \times V$ is a constant.

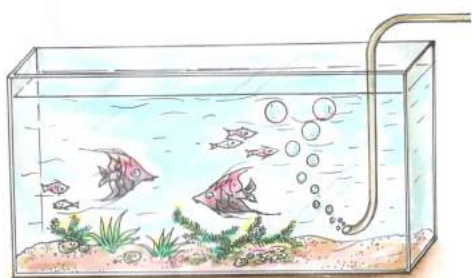


Figure 2.3

The size of the air bubbles rising from the bottom of an aquarium increases. Can you explain the reason?

Volume and temperature

Let's do an experiment.

Take a dry bottle (an injection bottle) having a rubber stopper. Fix an empty refill through the rubber stopper. Fill a drop of ink into the lower end of the refill tube, then close the bottle. Dip this arrangement in luke warm water.

What do you observe?

What is the reason for the rising of the ink upwards?

What did you observe on cooling the bottle after taking it out? Why?

From this, what can you infer about the relation between the volume and temperature of a gas?

The observations of an experiment to prove the relation between the volume and temperature of a definite mass of gas are given below (Pressure is kept constant).

Volume V	Temperature T (In Kelvin scale)	$\frac{V}{T}$
546mL	273 K	$\frac{546}{273} = 2$
600mL	300 K	$\frac{600}{300} = 2$
640mL	320 K	$\frac{640}{320} = 2$
660mL	330 K	.....

Table 2.2

In which unit is the temperature stated?

What happens to the volume when the temperature is increased?

It is the French scientist Jacques Charles (1746-1823) who proved the relationship between the volume and temperature of a gas. This law is known as **Charles' law**.

At constant pressure, the volume of a definite mass of a gas is directly proportional to the temperature in Kelvin Scale. If V is

volume and T the temperature, Then $\frac{V}{T}$ will be a constant.

If an inflated balloon is kept in sunlight, it will burst. What may be the reason for this?

Volume and Number of Molecules

A cylinder, fitted with a frictionless piston, is filled with a gas at 1 atm pressure and 300K temperature.

What happens to the volume of the gas when its pressure is decreased or temperature is increased?

Volume increases/decreases

If the temperature and pressure are kept constant how can we increase the volume? Fill the cylinder with a little more gas. Does the number of molecules increase or decrease now?

What is the relation between the volume and number of molecules?

It is the Italian scientist Amedeo Avagadro (1776-1856) who discovered the relation between volume and number of molecules of a gas. This relationship is known as **Avagadro's Law**.

At constant temperature and pressure, the volume of a gas is directly proportional to the number of molecules.

How is the number of minute particles calculated?

According to Avagadro's law when the temperature and pressure remain constant on which factor does the volume of a gas depend?

You know that the size of a molecule is very small. If so, how can we determine the number of molecules in a substance accurately?

How many people and how much time are needed for counting the same type of coins in a bank or the like? For example: Imagine, how much time is needed for counting the coins (Suppose the size and the mass are same) worth ten lakhs?

If the mass of a coin is 5 g, then what will be the mass of thousand coins?

If the mass of coins in a bag is 50,000 g, then how many coins will be there?

Like this we can calculate the number of coins on the basis of mass. Can't we? Is there any relation between the mass and the number, if the particles are of the same mass.

If the particles having the same size and mass, even though they are in crores, we can determine their accurate number on the basis of mass.

Relative Atomic Mass

Look at the atomic mass of certain elements.

Element	Hydrogen	Helium	Sodium
Atomic mass	1	4	23

Table 2.3

The numbers given above are not the real mass of the atoms. What may be the method of stating the mass of atoms? What do you understand from the statement that the atomic mass of Helium is 4?

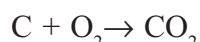
It is possible to find out the accurate mass of minute particles through the modern techniques. For example, the mass of a Hydrogen atom is 1.67×10^{-24} g. But in practice, it is stated in terms of relative mass.

In this method, the mass of an atom is compared to the mass of another atom and expressed as a number which shows how many times it is heavier than the other atom. The atomic mass of elements are expressed by considering 1/12 mass of an atom of carbon-12 as one unit.

When average atomic masses of elements are calculated taking into account the different isotopes of elements, the atomic masses of elements may have fractional values. However for practical purposes and calculations, most of these values are taken as whole numbers.

Number of atoms

See the chemical equation given for the reaction of burning of carbon in oxygen to form carbon dioxide.



How many oxygen atoms combine with one carbon atom?

How many oxygen atom combine with 1000 carbon atoms?

Likewise new substances are formed by the combination of crores of atoms. If so, how can we calculate the accurate number of atoms?

Haven't you understood that if the particles are of the same mass, it is possible to find out the number of particles. On the basis of the mass of carbon and oxygen, the numbers of atoms are scientifically found out and are given in the table.

Element	The mass taken	No. of atoms
C	12g	6.022×10^{23} carbon atoms
O	16g	6.022×10^{23} oxygen atoms

Table 2.4

How many atoms are present in 12g carbon?

A carbon atom combines with two oxygen atoms. If so, how many oxygen atoms are needed for combining with 6.022×10^{23} carbon atoms?

What will be the mass of these atoms?

Likewise, based on the mass, the number of particles taking part in a chemical reaction can be calculated.

Gram Atomic Mass

The atomic mass of carbon is 12 and that of oxygen is 16.

Each element is taken with mass in grams equal to their atomic masses. The number of atoms (6.022×10^{23}) present in them are found to be equal.

12 gram carbon is known as 1 Gram Atomic Mass of carbon (1 GAM). Likewise 16 grams of oxygen is called as 1 Gram Atomic Mass (1 GAM) of oxygen.

The mass of an element in grams equal to its atomic mass is called 1 Gram Atomic Mass (1 GAM) of the element. This may also be shortened as 1 Gram Atom.

Element	Atomic mass	Mass in grams	GAM	No. of atoms
Carbon	12	12g	1GAM	6.022×10^{23}
Oxygen	16	16g	1GAM	6.022×10^{23}
Nitrogen	14	...	1GAM	.....
Chlorium	35.5	...	...	6.022×10^{23}

Table 2.5

One GAM carbon is 12 g carbon, isn't it? We can also see that the number of atoms present in it is 6.022×10^{23} . When we take one GAM of any other element, the number of atoms will be equal.

One gram atomic mass of any element contains 6.022×10^{23} atoms. This number is known as Avagadro number. This is indicated as N_A .

1 GAM sodium means 23 g sodium. This contains 6.022×10^{23} atoms. If so, how many GAM will be there in 46 g sodium? What about the number of atoms in it?

$$46 \text{ g sodium} = \frac{46}{23} = 2 \text{ GAM}$$

$$\text{No. of Gram Atomic mass} = \frac{\text{Given mass in grams}}{\text{GAM of the element}}$$

It contains $2 \times 6.022 \times 10^{23}$ atoms.

If so, how many GAM is present in 69 g sodium? How many atoms are present in it?

How many GAMs are present in each the samples given below?

Calculate the number of atoms present in each of the sample?
(Atomic mass N = 14 O = 16)

1. 42 g Nitrogen
2. 80 g Oxygen

One mole atom

We know that 1 gram hydrogen means 1 GAM hydrogen and it contains 6.022×10^{23} atoms. This is known as one mole of hydrogen atoms.

12g C = 1GAM Carbon = 6.022×10^{23} carbon atoms = 1 mole carbon atom

14g N = 1 GAM Nitrogen = 6.022×10^{23} nitrogen atoms = 1 mole nitrogen atom

1 mole of atom means 6.022×10^{23} atoms

Molecular Mass and Gram Molecules Mass

In the free state, elements and compounds exist as molecules. Complete the table given below by finding out the chemical formula and molecular mass.

(Atomic Mass : H=1, O=16, N=14)

Element / Compound	Chemical formula	Molecular mass
Hydrogen	H ₂	1+1 = 2
Oxygen	O ₂	.....
Nitrogen	N ₂	.....
Water	H ₂ O	1+1 +16 = 18
Ammonia	NH ₃	.....

Table 2.6

Calculate the molecular mass of glucose (C₆H₁₂O₆) and sulphuric acid (H₂SO₄) (Atomic mass C = 12, H = 1, O = 16, S = 32).

The amount of an element in grams equal to its atomic mass is called Gram Atomic Mass, isn't it? Likewise, the mass in grams equal to the molecular mass of the substance is called Gram Molecular Mass (GMM) of that substance.

Number of Molecules

What is the relation between the mass of elements and compounds and the number of molecules present in them? Analyse the table given below and complete it.

Element/ Compound	Molecular Mass	Mass in grams	GMM	No. of molecules
Hydrogen H ₂	2	2g	1GMM	6.022×10^{23} H ₂ molecules
Oxygen O ₂	32	32g	1GMM	6.022×10^{23} O ₂ molecules
Nitrogen N ₂	28	28g	.....	.....
Water H ₂ O	18	18g	1GMM	6.022×10^{23} H ₂ O molecules
Ammonia NH ₃	17	17g	.....	.....

Table 2.7

What is the molecular mass of oxygen?

How many GMM is present in 32g oxygen?

How many molecules are present in it?

How many GMM is present in 28 gm nitrogen?

How molecules are present in it?

How many GMM is present in 18 gm water?

How many H₂O molecules are present in it?

What do you mean by 1 GMM?

What is the relationship between one gram molecular mass and the number of molecules present in it?

- The amount of a substance in grams equal to its molecular mass is called Gram Molecular Mass.
- One gram molecular mass of any substance contains Avagadro number of molecules.

One GMM oxygen is 32g Oxygen, isn't it? This contains 6.022×10^{23} oxygen molecules. How many GMM are there in 64g oxygen? How many molecules are present in it?

$$64 \text{ g O}_2 = \frac{64}{32} = 2 \text{ GMM}$$

This contains $2 \times 6.022 \times 10^{23}$ molecules.

Calculate the number of GMM present in 96g oxygen?

$$\text{No. of Gram Molecular Mass} = \frac{\text{Given mass in grams}}{\text{Grams Molecular Mass (GMM)}}$$

How many GMM are present in each of the given samples?

Calculate the number of molecules present in each sample?

- 360 g glucose (Molecular mass = 180)
- 90 g water (Molecular mass = 18)

One mole molecules

Haven't you familiarised the word mole? Mole is the unit used to denote the amount of substance which contains 6.022×10^{23} particles.

How many molecules of water are present in one mole of water?

What is its mass?

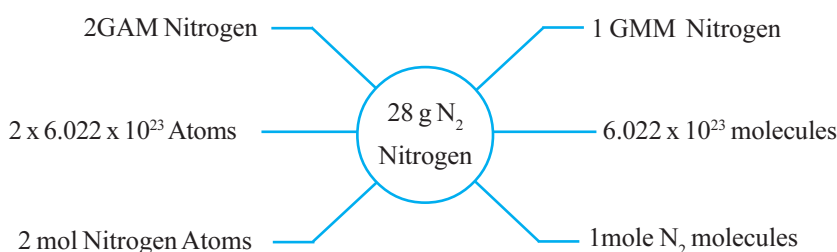
How many GMM is present in it?

6.022×10^{23} molecules are called one mole molecule.

1 GMM = 1 Mole = 6.022×10^{23} molecules.



N_2 is a diatomic molecule. The molecular mass of nitrogen is 28. Look at the word diagram given below.



Relationship between volume of a gas and moles

We know properties of gases are different from solids and liquids. In gases, molecules are very distant apart. Compared to the size of the molecules the distance between them is much greater.

In the case of gases, at a given pressure and temperature, the volume of a gas depends upon the number of molecules, and not on the type and size of the molecules. So, whatever gas may it be,

at the same conditions of pressure and temperature, if the number of molecules are the same, their volume also the same, isn't it?

One mole of any gas under the same conditions of temperature and pressure will contain the same number of molecules and hence their volume will also be the same. This is called **molar volume** of the gas.

But what about if there are changes in temperature and pressure? While analysing the gas laws, we understand that if there are changes in pressure and temperature, the volume is also changed. Scientists experimentally proved that the volume of 6.022×10^{23} molecules (1 mol) of any gas at 273K and 1 atm pressure occupies 22.4 litres.

273 K temperature and 1 atm pressure are known as standard temperature and pressure or STP.

That is, at STP one mole of any gas will occupy a volume of 22.4 L. This is called molar volume at STP.

Gas	Volume
• One mole hydrogen at STP (H_2)	22.4 L
• One mole nitrogen at STP (N_2)	22.4 L
• One mole CO_2 at STP	22.4 L
•	
•	

22.4 L of a gas at STP = 1 mole

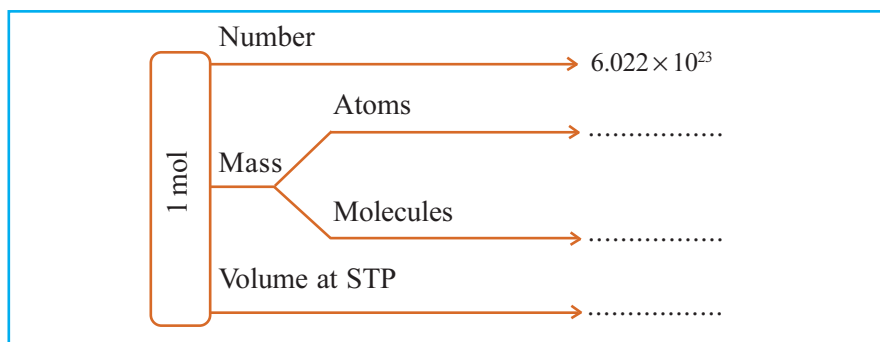
$$44.8 \text{ L of a gas at STP} = \frac{44.8}{22.4} = 2 \text{ mole}$$

$$224 \text{ L of a gas at STP} = \dots\dots\dots$$

Number of moles of gases at STP

$$= \frac{\text{Volume in litres at STP}}{22.4 \text{ L}}$$

Complete the flow chart given below, related to one mole of substance.



Let us assess

- Examine the data given in the table (Temperature and number of molecules of the gas are kept constant).

Pressure (P)	Volume (V)
1 atm	8 L
2 atm	4 L
4 atm	2 L

- Calculate $P \times V$.
 - Which is the gas law related to this?
- Analyse the situations given below and explain the gas law associated with it.
 - A balloon is being inflated.
 - When an inflated balloon is immersed in water, its size decreases.
 - Certain data regarding various gases kept under the same conditions of temperature and pressure are given below.

Gas	Volume (L)	No. of molecules
Nitrogen	10 L	x
Oxygen	5 L	
Ammonia	10 L	---
Carbon di oxide	---	2x

- Complete the table.
- Which gas law is applicable here?

4. a) Calculate the mass of 112 L CO_2 gas kept at STP (molecular mass = 44).
b) How many molecules of CO_2 are present in it?
5. a) Calculate the volume of 170g of ammonia at STP? (Molecular mass - 17)
6. Find out the number of moles of molecules present in the samples given below.
(GMM - $\text{N}_2 = 28\text{g}$, $\text{H}_2\text{O} = 18\text{g}$)
a) 56g N_2 b) 90g H_2O
7. The Molecular mass of ammonia is 17.
a) How much is the GMM of ammonia?
b) Find out the number of moles of molecules present in 170g of ammonia.
c) Calculate the number of ammonia molecules present in the above sample of ammonia?
8. The molecular mass of oxygen is 32.
a) What is the GMM of O_2 ?
b) How many moles of molecules are there in 64 g of oxygen? How many molecules are there in it?
c) Calculate the number of oxygen atoms present in 64g of oxygen?



Extended Activities

- How many grams of carbon and oxygen are required to get the same number of atoms as in one gram of Helium?
- Examine the samples given.

a. 20 g He	b. 44.8 L of NH_3 at STP
c. 67.2 L N_2 at STP	d. 1 mol of H_2SO_4
e. 180 g of water	

 - i) Arrange the samples in the increasing order of the number of molecules in each.
 - ii) What will be the ascending order of the number of atoms?
 - iii) What will be the mass of samples b, c, and d?
- In 90 gram of water
 - a) How many molecules are present in it?
 - b) What will be the total number of atoms?
 - c) What will be the total number of electrons in this sample?

3

Reactivity series and Electrochemistry



Haven't you noticed the picture? Certain instances of using electricity and a few sources of electricity are shown in the picture, aren't they? We use different kinds of batteries to work electronic equipments. Here chemical energy is converted into electrical energy and vice versa. You may have noticed different metals used in a cell. What may be its reason? You have already observed the rusting of iron and the formation of verdigris on copper. Are all metals like this? While some metals engage in chemical reactions vigorously, certain others react sluggishly in the same reaction. Let us find out the difference in reactivity of metals and try to examine how they can be utilised in different cells.

Reaction of metals with water

Take three beakers having the same quantity of water. Take pieces of sodium, magnesium and copper of same size and drop each one to each beaker. Observe the reactions.

- Which metal reacts vigorously?
- Which gas is formed as a result of this reaction?
- Write down its chemical equation.

Drop magnesium and copper metal in hot water and observe the differences in their reactions. Record observation of these two experiments in the table given below.



See the video clip based on 'Sodium Muthalaya Lohangal-jalavumayulla rasapravarthanam' given in the page 'Lohangal' of 'Chemistry for Class X' in the 'School Resources' of Edubuntu of IT @ School

Metal	In cold water	In hot water
Sodium		
Magnesium		
Copper		

Table 3.1

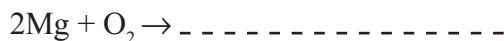
Based on your observation, arrange these metals in the decreasing order of their reactivity.

Reactions of Metals with Air

Freshly cut surfaces of metals will have a shiny appearance, won't they? This property is known as metallic luster. Cut a piece of sodium using a knife. Observe the freshly cut portion. Don't you see that its shining fades after sometime?

This is due to the conversion of sodium into its compounds by reacting with oxygen, moisture and carbon dioxide in the atmosphere.

Haven't you noticed a fresh magnesium ribbon losing its luster when kept exposed in the air for some days? This is also due to its reaction with atmospheric air.



It can be seen that the lustre of Aluminum vessels diminishes as time passes by. In the case of copper vessels, it takes months for the loss of its lustre by the formation of verdigris. Does the shining of gold fade even after a long time?

Doesn't this indicate that metals react with air at different rates?

- Which metal among magnesium, copper, gold, sodium and aluminium, loses its lustre at a faster rate?

- List the above metals in the decreasing order of their reactivity with air and thereby losing luster.

Reaction of Metals with Acids

Usually metals react with dilute HCl and produce hydrogen. The way in which the metals like Mg, Pb, Zn, Fe and Cu engage in chemical reaction with dilute HCl are given in the picture below. Arrange these metals in the decreasing order of their rate of chemical reaction.

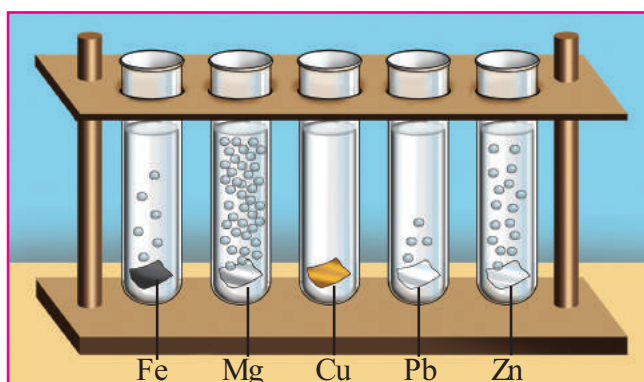


Figure 3.1



It is understood from these experiments that metals differ in their reactivity.

The series obtained by arranging some of the metals in the decreasing order of their reactivity is given in Table 3.2. This is known as the **reactivity series**. Note that hydrogen is also included in this series for the sake of comparison of chemical reactivity.



Potassium	K	↑ ↓	React with dil HCl and displace hydrogen
Sodium	Na		
Calcium	Ca		
Magnesium	Mg		
Aluminium	Al		
Zinc	Zn		
Iron	Fe		
Nickel	Ni		
Tin	Sn		
Lead	Pb		
Hydrogen	H	↓	Do not displace hydrogen from dil. HCl
Copper	Cu		
Silver	Ag		
Gold	Au		

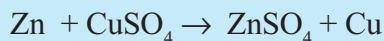
Table 3.2

Reactivity series and displacement reactions

Prepare some CuSO_4 solution in a beaker and dip a Zn rod in it. Observe the changes after sometime.

- What happened to the Zn rod?
- What is the reason for this?
- What is the reason for the change in intensity of the colour of CuSO_4 solution?

The blue colour of CuSO_4 solution is due to the presence of Cu^{2+} ions. When the Zn rod is dipped in CuSO_4 solution, the Cu^{2+} ions in the solution get deposited at the Zn rod as Cu atoms. The chemical reaction taking place here is given below.



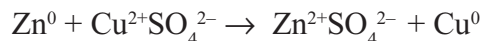
- Which is the metal that gets displaced here?

- Which is more reactive Zn or Cu?

- On the basis of the position of Zn and Cu in the reactivity series, can you explain why Cu had been displaced?

Isn't it due to the higher reactivity of zinc (Zn) when compared to copper (Cu)?

Let us rewrite the above equation showing the nature of the ions, as below.



The change that happened to Zn : $\text{Zn}^0 \rightarrow \text{Zn}^{2+} + 2\text{e}^-$

- Is this reaction oxidation or reduction? Why?

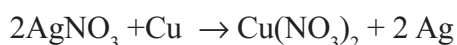
The change that happened to Cu^{2+} :

----- + ----- $\rightarrow$ -----

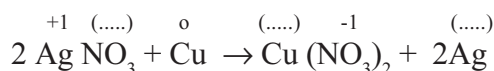
- What is the name of this reaction? Why?

Zn is oxidised and Cu^{2+} is reduced, i.e. oxidation and reduction take place simultaneously. Isn't this a redox process?

A copper plate is immersed in AgNO_3 solution, gets a layer of Ag deposited on its surface. Examine the equation for the chemical reaction taking place here.



Explain this process on the basis of reactivity series.



Complete this chemical equation by assigning oxidation numbers. Which ion is responsible for the change in colour of AgNO_3 solution to blue after sometime?

Which metal was oxidised in this case? Which metal was reduced?

Write equations showing oxidation and reduction.

Oxidation :

Reduction :

Metals having high reactivity displace the metals having less reactivity from their salt solution. Such chemical reactions are known as displacement reactions. Metals with higher reactivity get oxidised and those with lesser reactivity get reduced. Displacement reactions are redox reactions.



Observe the pictures given below. Based on the reactivity series, predict which among these undergo a displacement reaction. Complete the table.

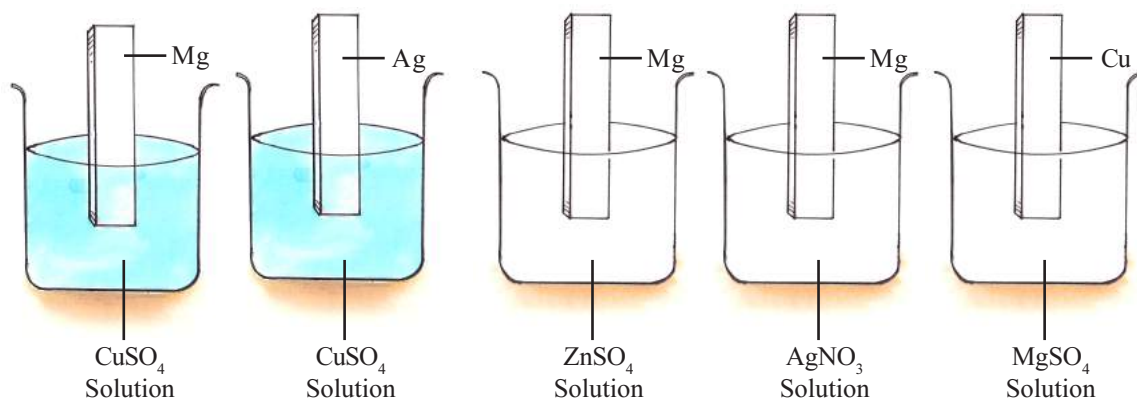


Figure 3.2

Metal	Solution	Displacement reaction
Mg	CuSO_4	Takes place
Ag	CuSO_4	.....
Mg	ZnSO_4	.....
Mg	AgNO_3	.....
Cu	MgSO_4	.....

Table 3.3

Galvanic cell

You have learned that metals differ in their reactivity. Galvanic cell is an arrangement in which the difference in reactivity of metals is used to produce electricity. Arrange the apparatus as shown in the picture. Take two beakers, one containing 100mL ZnSO_4 solution and the second containing the same amount of CuSO_4 solution with the same concentration.

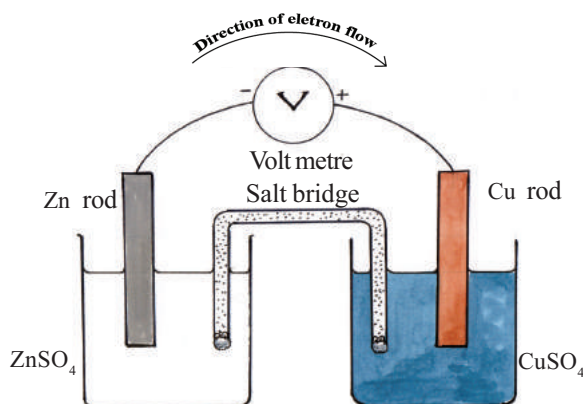


Figure 3.3

Dip Zn rod in ZnSO_4 solution and Cu rod in CuSO_4 solution. Connect the negative terminal of voltmeter to the Zn rod and the positive terminal to the Cu rod. Connect the two solutions in the beakers using a salt bridge (A long filter paper which is moistened with KCl solution can be used instead of salt bridge). Now watch the change in the reading of the voltmeter. Can't we produce electricity using such arrangements?

Here electricity is produced due to chemical change.

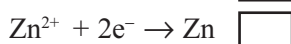
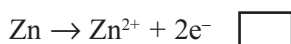
Galvanic cell or voltaic cell is an arrangement in which chemical energy is converted into electrical energy by means of a redox reaction.

You have understood from the reactivity series that Zn has higher reactivity than Cu.

- Which electrode has the ability to donate electrons in a cell constructed using these metals?

- Which one can gain electrons?

Identify the chemical reaction that takes place at the Zn electrode. Tick ✓ the right one.



Which reaction takes place here?

Oxidation/Reduction

That is, Zn loses two electrons and becomes Zn^{2+} . An electrode at which oxidation occurs is called anode. Anode has negative charge in this case.

The electrons liberated from Zn rod reach the copper electrode through the external circuit and these electrons are received by copper ions in the solution changing them into copper.

Write the chemical equation for the reaction taking place at the Cu electrode.

What is the reaction taking place here?

Oxidation/Reduction

The electrode at which reduction takes place is the cathode.

Cu rod has positive charge, hasn't it?

Salt Bridge

Salt bridge is a U-tube filled with a paste made by mixing gelatin or agar agar gel and a salt like KCl, KNO_3 or NH_4Cl . This completes the circuit by transfer of ions and maintains the electrical neutrality of the cell.

Direction of Electron Flow and the Direction of Flow of Electricity

In a Galvanic cell, electrons flow from the negative electrode (anode) to the positive electrode (cathode). But the flow of electric current is considered to be always from positive to negative. In earlier times, it was assumed that electricity moved from positive to negative and on the basis of this assumption many rules and equations were formulated. Owing to the difficulty in correcting these, it has been considered as 'conventional current' and the direction of the movement of electrons as electron current.

The electrode at which oxidation occurs is the anode and that at which reduction occurs is the cathode. Anode attains negative charge and cathode gets positive charge.

Shall we write the combined equation for the reactions at Zn and Cu electrodes?

In Zn electrode : $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$

In Cu electrode : $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$
 $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$

- It is a redox reaction, isn't it?

The transfer of electrons produced by this redox reaction causes the flow of electric current in the cell.

- Haven't you noticed the direction of electron flow is from anode to cathode.

Shall we construct a cell using silver and copper electrodes?

Materials required:

Silver wire, copper rod, two beakers, copper sulphate, silver nitrate, salt bridge, voltmeter, copper wire, water etc.

- Sketch the cell constructed.

- Note down the reaction of the Galvanic cell.

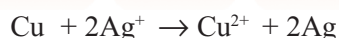
- Mark the direction of electron flow in the cell illustrated.

Write the reactions taking place at cathode and anode.

At cathode : -----

At anode : -----

Didn't copper act as the cathode in the cell constructed using zinc and copper? But what happened when silver and copper were used? See the redox reaction taking place here.



You have used three metals Zn, Cu and Ag. How many cells can be produced using these?

Complete the Table 3.4 by writing anode and cathode in each.

Cell	Anode	Cathode
• Zn - Cu		
•		
•		

Table 3.4

We are now familiar with the chemical reactions in which chemical energy is converted into electrical energy. If so, chemical reactions can also be carried out using electric energy.

Electrolytic cells

Electrolysis of water is a chemical reaction employing electrical energy. Haven't you learned about this chemical reaction in lower classes? What are the substances obtained when electricity is passed through acidified water? Do such type of chemical changes happen when electricity is passed through metals? Electrolytes are substances that undergo chemical changes on passing electricity through it.

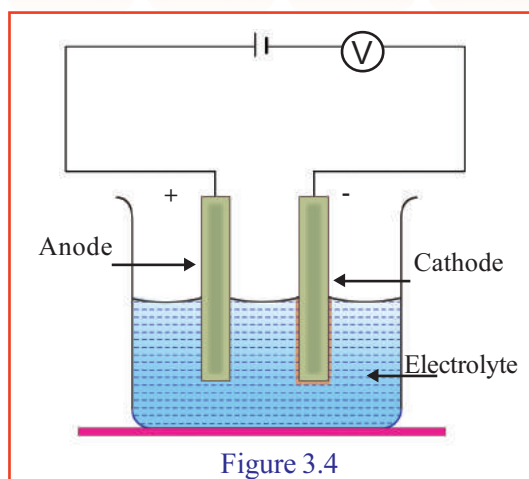
Electrolytes are substances which conduct electricity in molten states or in aqueous solutions and undergo chemical change. Acids, alkalis and salts are electrolytes in their molten state or in aqueous solution.

The process of chemical change taking place in an electrolyte by passing electricity is known as electrolysis.

In molten state or in aqueous solution, ions of the electrolytes can move freely. These ions are responsible for the conduction of electricity by the electrolytes.

It was Michael Faraday who gave a scientific explanation for electrolysis for the first time. Electrodes are substances which pass electricity to the electrolytes. During electrolysis one electrode is connected to positive terminal of a battery and the other to the negative terminal. The electrode which is connected to the positive terminal of the battery is the anode. The electrode which is connected to the negative terminal is the cathode.





Electrode at which oxidation takes place is anode and electrode at which reduction takes place is cathode. In an electrolytic cell oxidation takes place at the positive electrode and reduction takes place at the negative electrode.

Cations and Anions

The positive ions which are attracted towards the negative electrode are called cations and negative ions which move towards the anode are called anions.

- To which electrodes are the positive ions attracted during electrolysis?

- To which electrodes are the negative ions attracted?

- What changes happen to the ions which are attracted to cathode?

- What about the changes happening to the ions attracted to anode?

Electrolysis of molten sodium chloride

Sodium chloride in solid state is not an electrical conductor because its ions have no freedom of movement. But electricity flows through molten sodium chloride. When sodium chloride melts, the positively charged sodium ions (Na^+) and the negatively charged chloride ions (Cl^-) are free to move.



- Which ion is attracted to the positive electrode (anode)?

- What is the chemical reaction taking place there?

- Which is the gas liberated at the anode?

- Which is the ion attracted to the negative electrode (cathode)?
Write the change happening to it?

- Which is the metal deposited at the cathode?

Now, don't you get a clear idea of the products obtained at the positive electrode (anode) and the negative electrodes (cathode) when molten sodium chloride is electrolysed?

Electrolysis of sodium chloride solution

Ions like Na^+ , Cl^- , H_3O^+ , OH^- and H_2O are present in a solution of sodium chloride?

- Which are the ions attracted to the positive electrode?

- Which are the ions attracted to the negative electrode?

- Let us examine the chemical reactions take place at the anode and cathode during electrolysis.

Na^+ ions and H_3O^+ ions are attracted to cathode. As H_2O has a greater tendency to get reduced, compared to these ion, hydrogen is liberated at the cathode.

Cl^- ions and OH^- ions are attracted to anode. When compared to these ions and water, the tendency to get oxidised is greater for chloride (Cl^-) ions. Hence chlorine gas is liberated at anode.

Electrodes	Chemical change	Products
Anode	$2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$	Chlorine gas
Cathode	$2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$	Hydrogen gas

Table 3.5

As a result of electrolysis of sodium chloride solution, chlorine is obtained at the anode, hydrogen is obtained at the cathode and NaOH is obtained in the solution.

Practical utility of electrolysis

1. Production of metals

Metals like potassium, calcium, sodium and aluminium are produced by the electrolysis of their compounds.

2. Production of non-metals

Electrolysis can be utilised for the bulk production of non-metals. Hydrogen, oxygen, chlorine etc. are some of the non-metals produced by this method.

3. Production of compounds

Electrolysis can be employed to produce compounds like sodium hydroxide, potassium hydroxide etc.

4. Refining of Metals

Metals such as copper, gold etc. are refined by electrolysis.

Electroplating

The process of obtaining a coating of one metal over another metal using electrolysis is known as electroplating. This thin coating is helpful for improving the appearance of the metal and also in preventing metallic corrosion. Clean the article to be coated and connect it to the negative terminal of the battery. The metal to be plated is connected to the positive terminal of the battery. A salt solution of the metal to be coated is taken as the electrolyte.

Copper plating on Iron bangle

Observe the picture given below. This is the process of electroplating copper on an iron bangle.

- Which metal is connected to the negative terminal of the battery?

- Which metal is connected to the positive terminal of the battery?

- Which solution is used as the electrolyte?

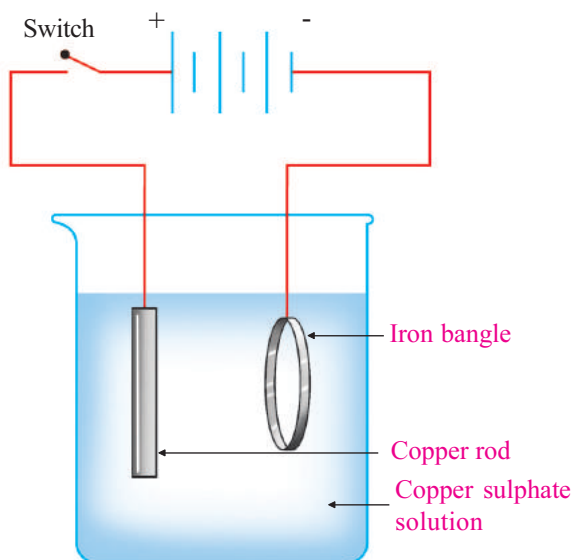
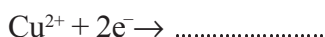


Figure 3.4

When electricity is passed through the Cu^{2+} ions of the solution, they are attracted to the negative electrode (iron bangle) or to the cathode.

What happens to Cu^{2+} ions at the cathode? Complete the equation.



What happened to the copper ions? Oxidation/Reduction?

In this way, Cu^{2+} ions are deposited on the iron bangle as Cu atoms.

Copper undergoes oxidation at the copper plate which is the positive electrode (anode).

Complete the equation given below.



Now, isn't it clear how the concentration of ions in the solution remains constant during electrolysis?

During electroplating, a suitable salt solution of the metal which is used for covering is used as the electrolyte.

Metals to be covered	Electrolyte
Silver	Silver nitrate solution/sodium cyanide + silver cyanide solution
Gold	Sodium cyanide + gold cyanide solution

- See some of the examples for electroplating.
 - Gold plated jewellery.
 - Chromium plated handle bars.
 - Silver plated utensils.
- Find out more examples and extend the list.
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Let us Assess

1. The solution of ZnSO_4 , FeSO_4 and CuSO_4 are taken in three different test tubes. Suppose, an iron nail is kept immersed in each one.
 - In which test tube the iron nail undergoes a colour change?
 - What is the reaction taking place here?
 - Justify your answer.
2. Compare the electrolysis of molten potassium chloride and solution of potassium chloride. What are the processes taking place at the cathode and the anode?
3. You are given a solution of AgNO_3 a solution of MgSO_4 , a Ag rod and a Mg ribbon. How can you arrange a Galvanic cell using these? Write down the reactions taking place at the cathode and the anode.



Extended Activities

1. Keep two carbon rods immersed in copper sulphate solution. Then pass electricity through the solution.
 - i) At which electrode does colour change occur - (anode or cathode).
 - ii) Is there any change in the blue colour of the copper sulphate solution?
 - iii) Write down the chemical equations for the changes occurring here.
2. When acidified copper sulphate solution is electrolysed oxygen is obtained at the anode. What arrangements are to be made for this? Find the element deposited at the cathode.
3. a) When Galvanic cells are made using the metals like Mg, Cu, Zn and Ag, what will be the nature of reactions in each cell?
(Reactivity : $\text{Mg} > \text{Zn} > \text{Cu} > \text{Ag}$)
b) How many Galvanic cells can be made by using the metals Ag, Cu, Zn and Mg?

4

Production of Metals



Discovery of metals is the most significant finding that has revolutionised the world. These are marked as metal ages in the history of human progress. The burden of labour was minimised by the use of metals instead of sharp rocks and wooden sticks for hunting and earning food. The development in the fields of agriculture and industry are the results of the invention of metals, aren't they? Think about it.

Iron which is used in making equipments ranging from pins to aeroplanes as well as copper and aluminium having various uses in our daily life are metals which changed the history. Gold, silver and platinum used for making jewellery are metals.

Have you ever thought how these metals are extracted from nature? Do we get them directly from nature the way they are used? Let's examine.

The chemically reactive metals are found in the combined state while the relatively unreactive metals (platinum, gold etc.) are found in the native state in the earth's crust. The metallic compounds generally seen in the earth's crust are called minerals. There could be many minerals having the same metal. For example, bauxite ($\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$), cryolite (Na_3AlF_6), clay ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) etc. are some of the minerals of aluminium. However all these minerals cannot be used for the extraction of metals.

What are the characteristics possessed, by minerals that are used for the extraction of metals?

- Abundance
- Easily and cheaply separable
- High metal content
-

A mineral from which a metal is economically, easily and quickly extracted, is called the **ore** of the metal.

Among the minerals of aluminium, bauxite possesses these properties. Hence bauxite is the ore of aluminium. All ores are minerals, but are all minerals ores?

Given below is a table (Table 4.1) showing certain metals, their ores and their chemical formulae. Analyse the table and find out the following.

Metal	Ores	Chemical formula
Aluminium	Bauxite	$\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$
Iron	Haematite, Magnetite	Fe_2O_3 Fe_3O_4
Copper	Copper pyrites Cuprite	CuFeS_2 Cu_2O
Zinc	Zinc blende Calamine	ZnS ZnCO_3

Table 4.1

- Which metal's ore is calamine?
- Which is the ore of aluminium?
- Which metals have sulphide ores?

Metallurgy involves all the processes leading to the separation of a pure metal from its ore. There are three important stages in metallurgy.

Concentration of ores

Extraction of metal from concentrated ore

Refining of metals

I Concentration of ores

The process of removing the impurities (**gangue**) from the ore obtained from the earth's crust is termed concentration of the ore. Depending on the nature of the ore and the impurities, there are different methods of concentration.

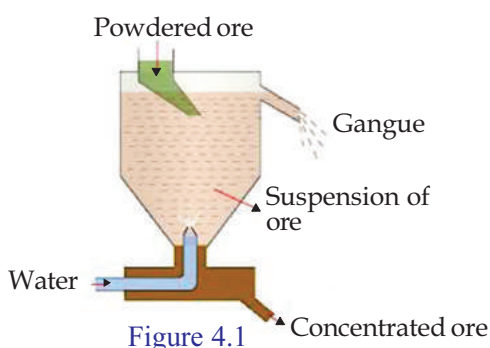


Figure 4.1

1. Levigation or hydraulic washing

When the impurities are lighter and the ore particles are heavier, the lighter impurities are removed by washing in a current of water (Figure. 4.1) e.g. concentration of oxide ores, concentration of the ores of gold.

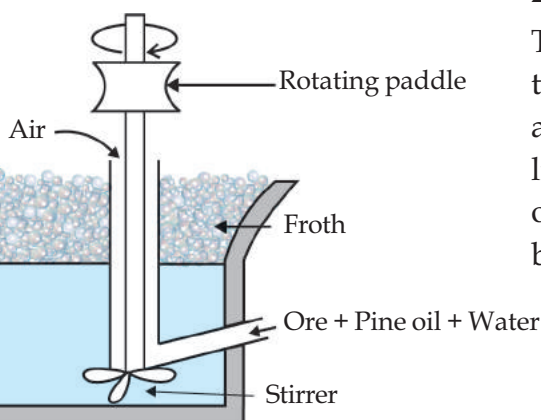


Figure 4.2

2. Froth floatation

This process is used when the impurities are heavier and the ore particles are lighter (Figure 4.2). Sulphide ores are usually concentrated by this method.

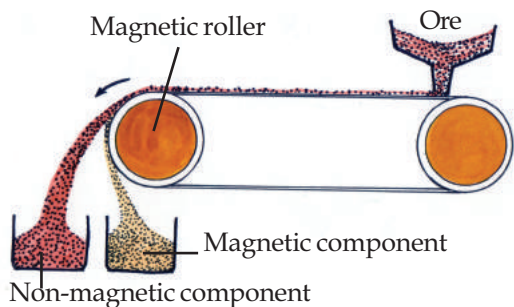


Figure 4.3

3. Magnetic separation

If either the ore or the impurity has magnetic nature, concentration is done by this method. (Figure 4.3). This method is used for the concentration of magnetite, ore of iron and also to separate iron tungstate, the magnetic impurity from tin stone (SnO_2), the non-magnetic ore of tin.

4. Leaching

On adding the ore to a suitable solution, a chemical reaction takes place and the ore dissolves. The insoluble impurities are filtered off. The pure ore is separated from the filtrate by a chemical reaction. Bauxite, the ore of aluminium is concentrated by this method.

Certain properties of metallic ores and the impurities present in them are given in the table. Identify the suitable method of concentration and complete the table (Table 4.2).



Properties of ores	Properties of the impurities present in the ore	The method of concentration
High density	Low density	.....
Magnetic in nature	Non - magnetic nature	.....
Lighter sulphide ores	High density	.....
Aluminium ores that get dissolved in a solution	Insoluble in the same solution	.....

Table 4.2

Write suitable method of concentration for the ores given in the Table (4.3).

Ore	Method of concentration
Tinstone	
Bauxite	
Zinc blende	

Table 4.3

II. Extraction of metals from concentrated ore

It has usually two stages.

- Conversion of the concentrated ore into its oxide.
- Reduction of the oxide.

a) Conversion of concentrated ore into its oxide

- Calcination** : Calcination is the process of heating the concentrated ore in the absence of air at a temperature below its melting point. Carbonates and hydroxides of metals decompose to form their oxides.
- Roasting** : Roasting is the process of heating the concentrated ore in a current of air at a temperature below its melting point. When the concentrated ore is subjected

to roasting, the moisture present in it is removed as vapour. Sulphide ore combines with oxygen to form oxide. e.g. Cu_2S ore is converted to Cu_2O by roasting.

b) Reduction of the oxide

The process of extraction of metal from the oxide is reduction. Suitable reducing agents can be used for this purpose.

During the process of the production of metal, electricity, carbon, carbon monoxide etc. are used as reducing agents on the basis of the reactivity of the metal.

Electricity is used as the reducing agent to extract highly reactive metals like sodium, potassium and calcium from their ores.

III. Refining of metals

The metal obtained by reduction may contain other metals, metal oxides and small quantities of non metals as impurities. Refining of metals is the process of removal of these impurities to get the pure metal.

Depending on the nature of metals and the impurities present in them, different methods are used for the refining of metals. Some methods are given below.

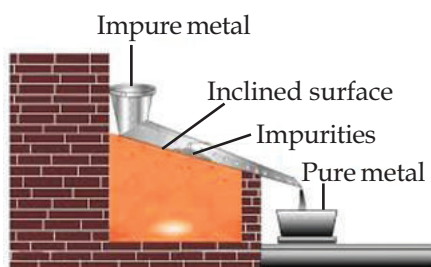


Figure 4.4

a. Liquation

Low melting metals like tin and lead may contain other high melting metals or metal oxides as impurities. On heating such metals on the inclined surface of a furnace, the pure metal melts and flows down leaving the impurities behind. (Figure 4.4). This process is termed liquation.



b. Distillation

This method is used for the refining of metals with low boiling points such as zinc, cadmium and mercury. When the impure metal is heated in a retort, the pure metal alone vapourises. The vapours are condensed to get the pure metal. This method is termed distillation.



c. Electrolytic refining

Electrolytic refining is the process of refining a metal by the electrolysis of a solution of the salt of the metal, using a small piece of pure metal as the negative electrode and the impure

metal as the positive electrode. Copper can be refined by this method. See the picture related to the refining of copper given below.

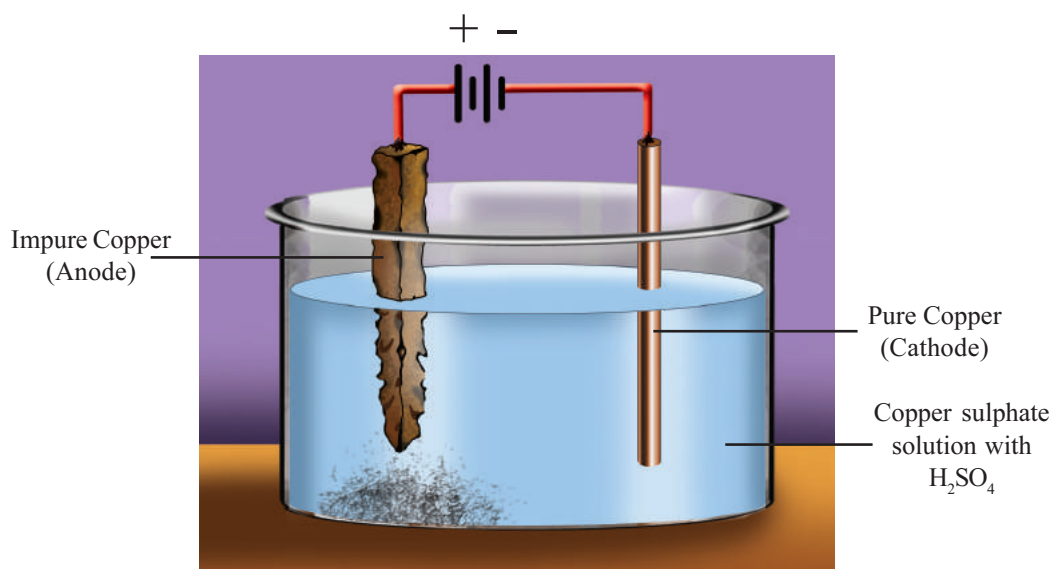


Figure 4.5

Observe the picture and complete the table.

Anode	
Cathode	
Electrolyte	
Equation of the chemical reaction taking place at anode	
Equation of the chemical reaction taking place at cathode	

Table 4.4

Industrial production of iron

Haematite, magnetite, iron pyrites etc. are the minerals of iron. Which are the ores of iron among these minerals? Have you thought of the reason for calling iron pyrites as fool's gold. It is known as fool's gold as it has a yellow brazen colour which resembles gold.

Iron is industrially prepared mainly from haematite. From this the impurities having low density are removed by washing. Magnetic separation is also employed for removing impurities.

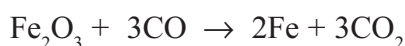
The ore thus obtained is subjected to roasting. During roasting, impurities like sulphur, arsenic, phosphorous etc. are removed as their gaseous oxides. Water is also expelled along with this. But the gangue, silicon dioxide present in the ore is not removed.

Hematite is converted into iron by using the blast furnace. Blast of hot air is passed through the bottom of the furnace. That is why this furnace is called blast furnace. Hematite, limestone and coke are fed into the furnace through a special arrangement at the top of the furnace.

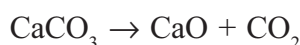
Let's examine the chemical reaction taking place at different parts inside the blast furnace.



The reduction of hematite into iron is done mainly by this carbon monoxide.



Calcium carbonate decomposes to give calcium oxide and carbon dioxide at high temperature in the furnace.



This calcium oxide (flux) reacts with SiO_2 (gangue) in the ore to form easily melting calcium silicate (slag).

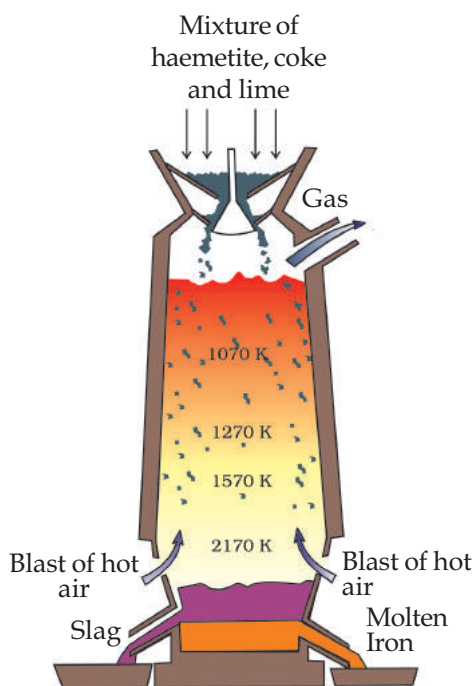
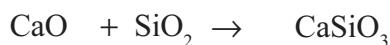


Figure 4.6

If the gangue is acidic in nature, basic flux is to be used. If the gangue is basic in nature, acidic flux is to be used.

The molten slag being less dense floats over the molten iron. Slag and iron are taken out separately from the furnace in the molten state.

The molten iron obtained from the blast furnace contains 4% carbon and other impurities like manganese, silicon, phosphorus etc. This is called pig iron.

Complete the Table (4.5) related to the production of iron, which is given below.

Ore of iron	
Raw materials fed into the blast furnace	
The compound used for reducing haematite	
Gangue	
Flux	
Slag	
Equation of formation of slag	

Table 4.5

Different types of Alloy steels

Alloy steels are prepared by adding other metals to steel. See the name, composition, properties and uses of different types of alloy steels given in the table (Table 4.6). Alloy steels have properties different from those of steel.

Alloy steels	Constituent elements	Properties	Uses
Stainless steel	Fe, Cr, Ni, C	Hard	For the manufacture of utensils, parts of vehicles
Alnico	Fe, Al, Ni, Co	Magnetic nature	For the manufacture of permanent magnets
Nichrome	Fe, Ni, Cr, C	High resistance	For making heating coils

Table 4.6

- Which alloy steel is used for the production of heating coils? Explain the reason.
- Even though nichrome and stainless steel contain the same components they possess different properties. Find out the reason.
- Which alloy steel is used for making permanent magnets?

Different types of alloys are prepared by changing the constituent elements and also by varying their proportion.

Extraction of Aluminium



Charles Martin Hall
(1863 - 1914)



Paul Heroult
(1863 - 1914)

Have you ever thought, how we make use of the various characteristics of the metal Aluminum in our daily life?

This metal is used for the transmission of electricity, for making cooking utensils, parts of vehicles, reflectors and also for many other uses. On the basis of its uses, list out the characteristics of this metal.

Uses	Characteristics
Transmission of electricity	
Kitchen utensils	
Reflectors	

Table 4.7

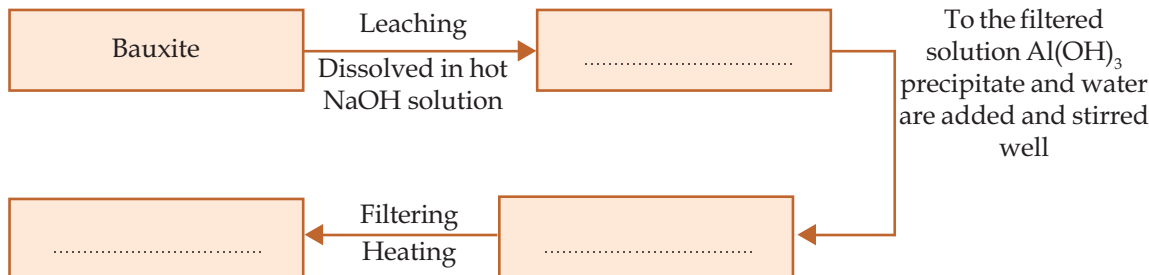
In olden days, the cost of extraction of Aluminium was very high and hence it was costlier than gold. This metal later became the common man's metal through the Hall-Heroult process.

Bauxite is the main ore of Aluminium. Aluminium is industrially produced through two important stages. They are concentration of bauxite and the electrolysis of concentrated alumina.

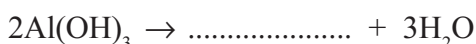
Concentration of Bauxite

Bauxite is concentrated through the leaching process. Impure bauxite is added to hot concentrated NaOH solution, where it gets converted into sodium aluminate. Impurities are then filtered off. A small quantity of freshly prepared aluminium hydroxide precipitate is added and diluted with water, to get more amount of $\text{Al}(\text{OH})_3$ precipitate. How is alumina obtained from this aluminium hydroxide? The precipitate is separated, washed and then heated strongly to get alumina.

Complete the flow diagram, related to concentration of bauxite, which is given below.



Complete the chemical equation for the reaction taking place when Aluminium hydroxide is heated.



Which method can be used for separating aluminium from alumina? Can we use carbon as the reducing agent? Why?

Aluminium is manufactured by the reduction of alumina using electricity as reducing agent since the reactivity of aluminum is very high.



Electrolysis of Alumina

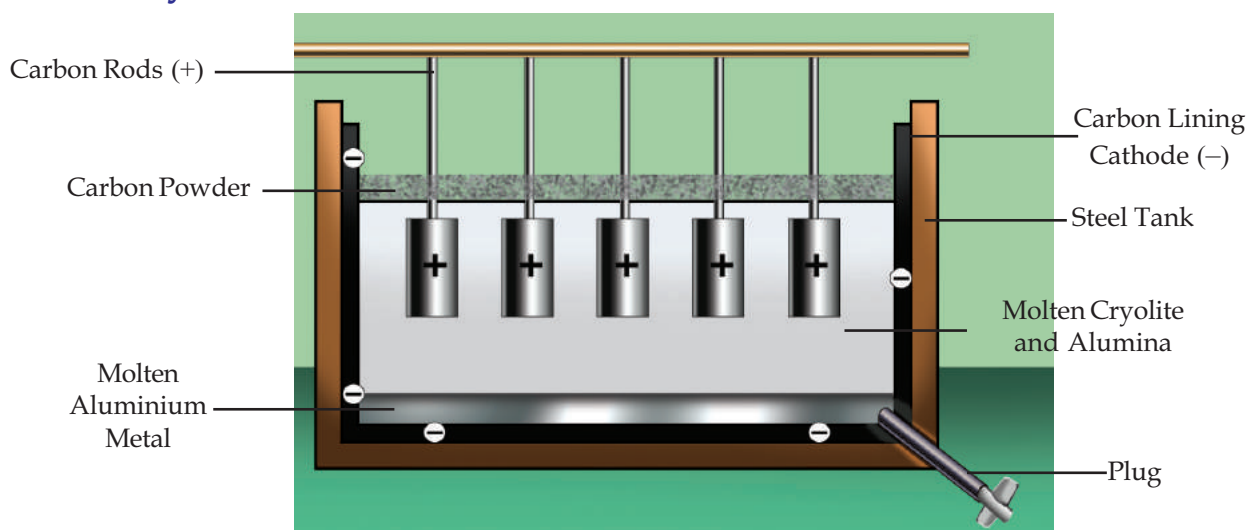
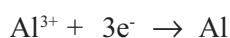
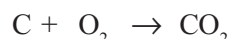


Figure 4.7

The alumina (Al_2O_3) obtained by concentration of bauxite is mixed with molten cryolite (Na_3AlF_6) and subjected to electrolysis. The melting point of alumina is very high. Cryolite is added to alumina to reduce its melting point and increase its electrical conductivity. Examine the equations of reactions taking place while electricity is passed through it.





- To which electrode does Al^{3+} move?

- What about oxide ion?

Complete the table related to the electrolysis of Alumina.

Anode	
Cathode	
Electrolyte	
Equation of the chemical reaction at anode	
Equation of the chemical reaction at cathode	

Table 4.8



Let us Assess

- Which of the properties of metals is utilized in the following instances?
 - Aluminum utensils are used for cooking.
 - Copper is used for making vessels.
 - Gold wires are used in ornaments.
- What are the factors to be considered while selecting minerals for the extraction of metals?
- Write the different stages involved in metallurgy?
- What are the different methods for the refining of metals?
- How is iron extracted industrially?
- Write the uses of the following:
 - Nichrome • Stainless steel • Alnico
- Explain the process of producing alumina from bauxite.
- Explain the method of obtaining pure aluminum from alumina by electrolysis. In this process carbon anodes are replaced from time to time. Why?



Extended Activities

You know that metals can be separated from molten compounds of metals by electrolysis.

Find out how metals like Na, Ca and Mg are extracted.