Republic of Iraq
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Goneral Directorate of curricula

CHEMISTRY

3

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PREFACE

Chemistry is an interesting and fundamental branch of science because it gives us the chance to explain the secrets of nature.

What is water? What do we use in our cars as fuel? What is aspirin? What are perfumes made of? These kinds of questions and their answers are all part of the world of chemistry. Chemists work everyday to produce new compounds to make our lives easier with the help of this basic knowledge. All industries depend upon chemical substances, including the petroleum, pharmaceuticals, garment, aircraft, steel, and electronics industries, etc.

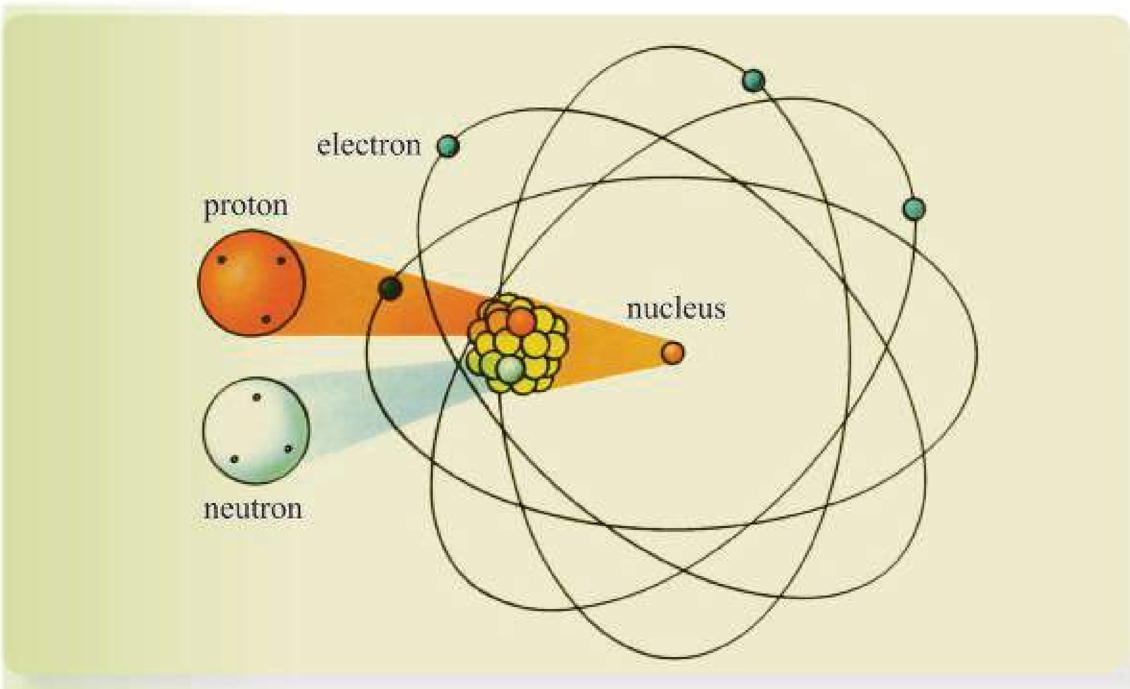
This book helps everyone to understand nature. However, one does not need to be a chemist or scientist to understand the simplicity within the complexity around us. The aim was to write a modern, up-to-date book where students and teachers can get concise information about chemical reactions and inorganic compounds. Sometimes reactions are given in detailed form, but, in general, excessive detail has been omitted. Throughout the book, different figures, colourful tables, important reactions are used to help explain ideas.

We hope that after studying this book, you will find chemistry in every part of your life.

The Author

CHAPTER 01

ATOMIC STRUCTURE FOR MATTER



After studying this chapter, student will be able to:

1- Identify the development in atomic concept.
2- Understand Modern Atomic Theory.
3- Write down the electron configuration.
4- Identify Lewis's order for elements.
5- Understanding properties of periodic table
6- Understanding the Periodic properties of elements in periodic table.

1-1 INTRODUCTION

In the previous study of chemistry, we have learned that all substances in the universe consist of tiny particles which form the basic unit of these substances ,these particles are called atoms. In Latin, (Atom) means indivisible. Interpretation of atomic structure in the past two centuries went through several theories .In this chapter, we will study how theories of atomic structure have evolved.

1-2 EVOLUTION OF THE CONCEPT OF THE ATOMIC STRUCTURE

Scientists proposed various models to account for the structure of the atom. Each model was the best representative at that time, then, after many observations and experiments ,this model has evolved to become more scientifically acceptable, now we will chronologically review these models:

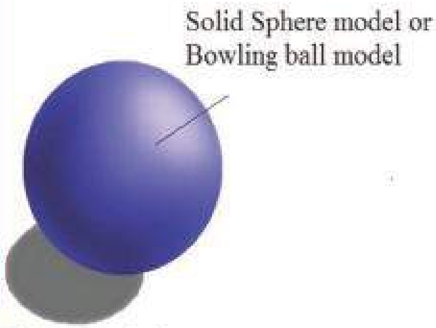


Figure 1-1
Dalton's Atomic Model

1-2-1 Dalton's Model:

At the beginning of the 19th century , Dalton perceived the atom as a hard, indivisible sphere (Fig.1-1), each element has a specific kind of atoms, these atoms are connected through simple methods to form combined atoms.

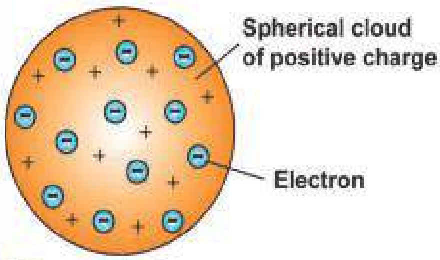


Figure 1-2
Thomson's Atomic Model

1-2-2 Thomson's Model:

By the end of the 19th Century Thomson gave another perception of the atom, (since he discovered that atoms consist of smaller particles having negative charge called electrons), in his opinion, the atom is a positively charged sphere on which negatively charged electrons are attached to balance the charge. Therefore, the atom has neutral charge. Figure 1-2 illustrates Thomson's atomic model.

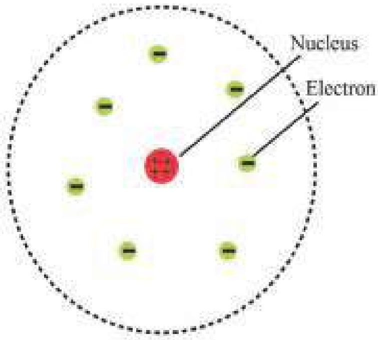


Figure 1-3
Rutherford's Atomic Model

1-2-3 Rutherford Model:

In the early 20th Century , and after the discovery of the proton (a positively charged particle, the mass of which is greater than that of the electron). Rutherford introduced his perception that protons are situated in a tiny area at the center of the atom called the nucleus which contains most of the mass of the atom and that the electrons circle around the nucleus. Therefore, most of the volume of the atom is avoid and the number of negative electrons rotates around the nucleus balance the positive charge of the protons. These electrons rotate around the nucleus in various orbits with varying distances from the nucleus as is the case of planets rotating around the sun. Therefore, this model is called the planetary astral model, see figure (1-3)

1-3 INTRODUCTION TO THE MODERN ELECTRON STRUCTURE

There had been problems with Rutherford's Model. Assuming that negative electrons are static (No.1 Assumption), these electrons will be drawn to (magnetized) nucleus with the positive charge, therefore, these electrons must be in constant motion (No.2 assumption). Given that moving electric charge which is under gravitational force releases energy, so there must be loss in the energy of the moving electron which would eventually slow down its motion. This slowing down electron would move around in a circular motion and finally falls into the nucleus. In both assumptions, the atom must collapse, and considering that the atoms don't usually collapse, so there must be something wrong in Rutherford's Atomic Model.

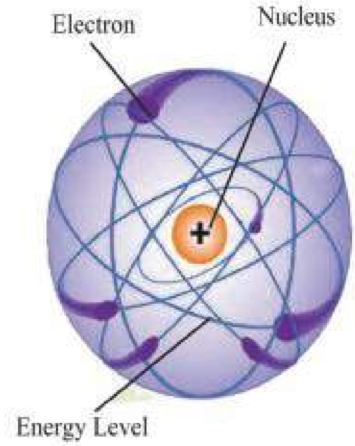


Figure 1-4
Bohr's Atomic Model

1-3-1 Bohr's Model:

The Danish scientist Bohr, proposed in (1913) that electrons rotate around the nucleus in a fixed and energy levels, see figure 1-4. Each energy level has a distinctive number describing its energy, this number is called principal quantum number. An electron in the first energy level has a principal quantum number of 1, while the electron in the second energy level has a principal quantum number of 2 and so forth. The farther from the nucleus the more the level of energy, for example first energy level is less than the second and so forth. An electron may travel within energy levels through gaining or losing energy.

Exercise 1-1
Which one of the followings has high energy level ?
A) First Energy Level
B) Second Energy Level
C) Third energy level
D) Fourth energy level

1-3-2 Modern Atomic Theory:

Bohr's Model was based on hydrogen atom, which is the simplest atomic structure because it contains one proton and one electron, yet, this model failed to explain for some natural phenomena of other elements containing more electrons. Many scientists worked hard to lay down scientific foundations of the modern atomic theory , whereby they developed the quantum Theory which stipulates that the electron might exist in a particular space surrounding the nucleus and not in specific dimensions as stated by Bohr. This space is called the (Orbital), which can be best expressed as the electron cloud surrounding the nucleus, as in figure 1-5. This atomic orbital has different shapes and sizes. The major hypotheses of the modern theory, which is modeled after Bohr's model are:

1- The atoms consists of a nucleus surrounded by electrons with varying levels of energy.

2- Electrons rotate around the nucleus on a distance, (according to the size of the atom), in energy levels,these levels are represented by numbers called principal quantum numbers; positive integers with the symbol (n).

In addition to this , and as we have learned earlier, the nucleus at the center of the atom and consists of the protons and neutrons.

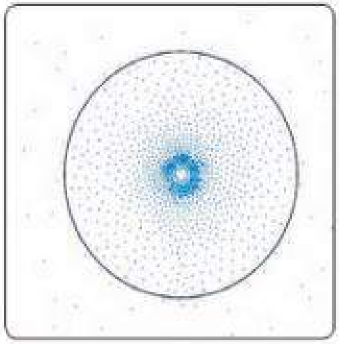


Figure 1-5
Ones of orbital shape (orbital cloud)

Exercise 1-2
What is the electron cloud?

1-4 ENERGY LEVEL

We have learned earlier that electrons rotating continuously around the nucleus on different orbitals with different energy,whereby they rotate in a different distances .The more the energy of the electron the further the it rotates around the nucleus. To express the different energy levels of electrons, scientists used numbers called secondary quantum numbers which describe fairly all features of the orbital as well as those the electrons in these orbital. In this chapter we will discuss one of these numbers mentioned earlier which is the principal quantum number.

1-4-1 Primary Energy Levels:

These levels are expressed by the principal quantum number (n), it holds a positive value equals 1,2,3,4,5,6,7.....each indicates a particular energy level, the greatest n has highest the energy.(n) cannot be zero at all. This concept is illustrated in table 1-1.

Table 1-1

Level symbol	K	L	M	N	O	P	Q
value of n	1	2	3	4	5	6	7

Energy increasing

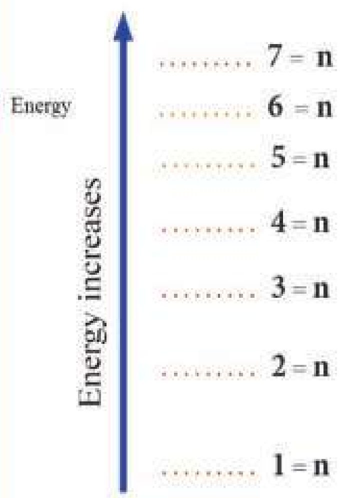


Figure 1-6
When value of n increases the energy level increases.

The higher the (n) value, the further the distance of the electron from the nucleus and consequently having more energy,i.e., the nearest of these levels to the nucleus is n =1 has the lowest energy level while n =7 has highest energy level which is the farthest from the nucleus and less attached to the nucleus, therefore it is easy to be removed (given away). See figure .1-6

1-4-2 Secondary Energy Levels:

Primary energy levels (K ,L ,M ,N,..) have secondary energy levels (s, p, d , and f). These levels differ in terms of shape and number of electrons. Orbital (s) has a spherical shape (figure 1-7), as for the second level (p) it has three orbitals and each orbital consists of two equivalent sides distributed in three vertical directions (P_z, P_y, P_x), as illustrated in (Figure.1-8), as for the secondary levels (d, f), they have more complicated interstitial forms.

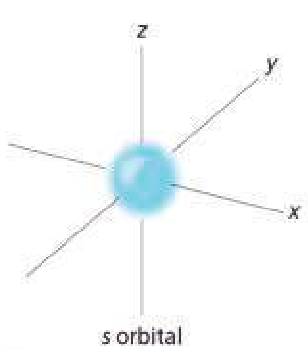


Figure 1-7
Shape of s orbital

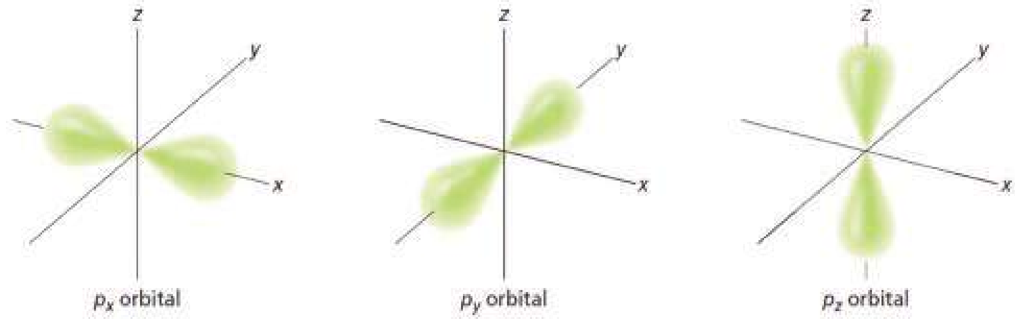


Figure 1-8

Primary energy levels have secondary energy levels as follows:

Primary level K (n=1) has only one secondary level type s

Primary level L (n=2) has two secondary levels p and s

Primary level M (n =3) has three secondary levels s, p and d

Primary level N (n =4) has four secondary levels type s, p, d and f

To determine the secondary level of any of the primary levels in symbols, (n) value is written from the primary level then the letter assigned to the secondary level, for example, the symbol of secondary level is written by indicating the number of the primary level before the secondary level, so it becomes (2s), and the secondary level d of the four primary level 4d and so as indicated in (figure 1-9).

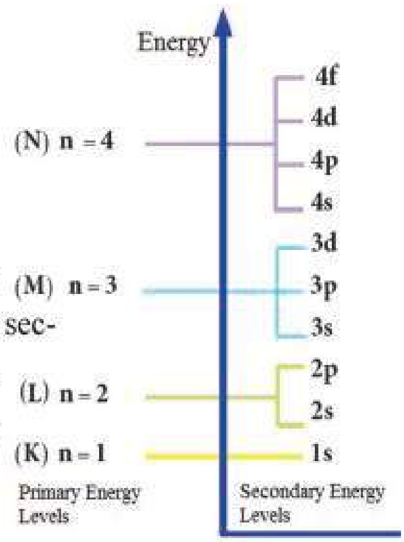


Figure 1-9

secondary energy levels that are found in primary energy levels.

1-4-3 Number of Orbitals and Electrons in secondary levels:

Secondary levels have many different orbitals indicated by □ as follows:

Secondary level s has 1 orbital □

Secondary level p has 3 orbitals □□□

Secondary level d has 5 orbitals □□□□□

Secondary level f has 7 orbitals. □□□□□□□

An orbital has as much as two electrons only , but an orbital can have one electron or empty,therefore,secondary level filled as follows:

s maximum hold up 2 electrons

p maximum hold up 6 electrons

d maximum hold up10 electrons

f maximum hold up14 electrons.

Electrons are supposed to repel each other in an orbital because they have the same negative charge. Have you thought why the electrons don't repel each other in an orbital? Each electron spins around itself at the same time as it spins around the nucleus, Figure 1-10a ,when two electrons are cou-

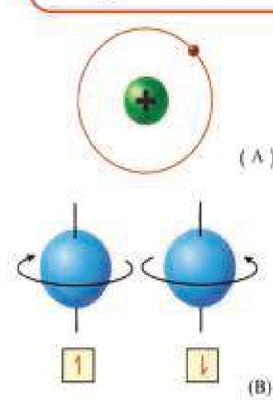


Figure 1-10

A) Electron spin around nucleus.

B)Two electrons spin around their own axis as they are in same orbital.

Exercise 1-3

A) What is the number of orbitals in the first and third primary energy levels?
B) What is the number of electrons of second and third primary energy levels?

pled in, figure 1-10a, when two electrons are coupled in one orbital [⇅] one would spin clockwise [↑] and the other would spin anticlockwise [↓] i.e., they cancel repulsion in this way figure1-10b.

1-5 ELECTRON CONFIGURATION

Various elements have different numbers of electrons, these electrons are configuration around the nucleus in the atom, this order is called the electron configuration. Therefore, atoms of every element have unique electron configuration whereby the electrons are ordered in the atoms in such a way that the total energy is at the minimum, and the following rules are considered when electron are order in levels:

1-5-1 Aufbau Principle:

This principle shows that secondary energy levels are filled with electrons according to their energy level ,from the lowest to the highest, they follow this order (figure 1-11):

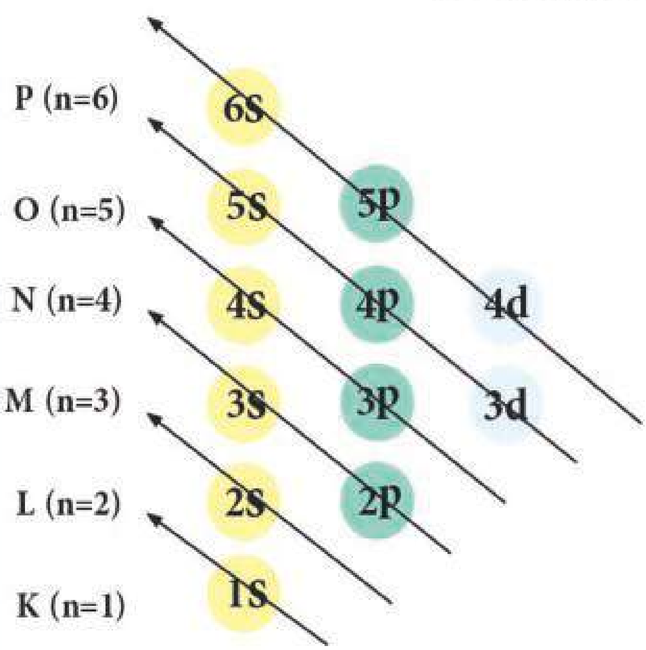


Figure 1-11

Arrangment of secondary energy levels.

While writing the electron configuration for any atom, the atomic number must be known, whereby the number of electrons of the electrically balanced natural atom must be equal to its atomic number, commonly written at left down corner side of the symbol. Orbital 1 s is filled first with electrons then 2s then 2p then 3s then 3p then 4s then 3d and so far :

1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f ....

It is noted that the higher the number of the primary shell, the higher the energy of the electrons and less distance between shells, therefore, there is an overlap between secondary shells which belong to various primary shells. Keep in mind, the number on the left of the symbol of the secondary energy level indicates the primary quantum number (n), while the number on the upper right of the symbol (s) represents the number of electrons in this level this goes to all symbols, as in figure.1-12

1-5-2 Hund's Rule:

This rule shows that no two electrons are doubly occupied in the sub shell (secondary level) unless its orbitals are singly filled. This rule applies to atoms whose electron configuration end with secondary energy levels of p, d and f. Two electrons cannot occupy one orbital until assigning one electron to each orbital in the secondary energy level.

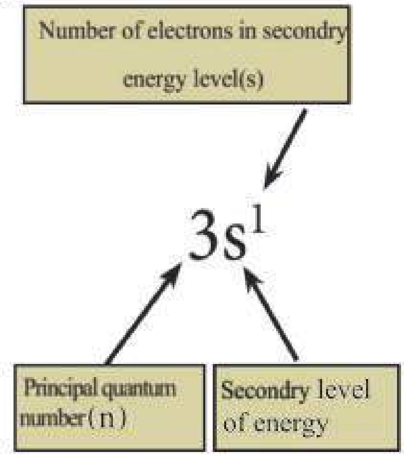
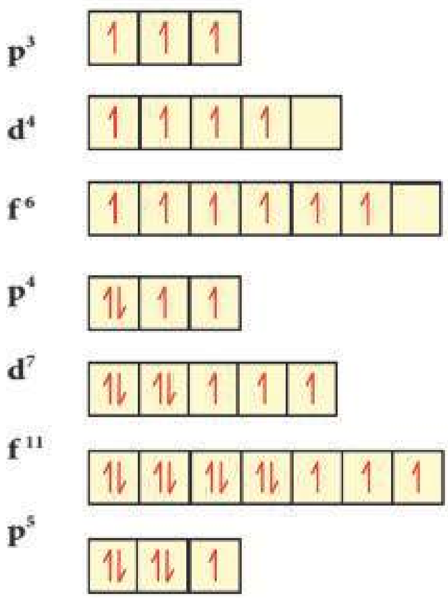


Figure 1-12
Electron configration writting method

Example 1-1

Write the electron configuration for the following subshells? p^3, d^4, f^6, d^7, f^{11}, p^5

Solution:



Example 1-2

Write the electron configuration for the followings elements?
${}_4Be$, ${}_3Li$, ${}_2He$, ${}_1H$

Solution:

Elements	Electron configuration
${}_1H$	$1s^1$
${}_2He$	$1s^2$
${}_3Li$	$1s^2\ 2s^1$
${}_4Be$	$1s^2\ 2s^2$

Example1-3

Write the electron configuration and order of electrons in the primary energy level for each of the following elements:
${}_{15}P$, ${}_{13}Al$, ${}_{12}Mg$, ${}_{10}Ne$, ${}_8O$, ${}_5B$

Exercise 1-4

Write the electron configuration for the following subshells? p^2, d^6, d^3, p^5

Exercise 1-5

Write the electron configuration for the following elements.
${}_9F$, ${}_{14}Si$, ${}_{18}Ar$

Solution:

Element	Electron configuration	Outermost energy level
$_{5}B$	$1s^2$ $2s^2$ $2p^1$	$2s^2$ $2p^1$
$_{8}O$	$1s^2$ $2s^2$ $2p^4$	$2s^2$ $2p^4$
$_{10}Ne$	$1s^2$ $2s^2$ $2p^6$	$2s^2$ $2p^6$
$_{12}Mg$	$1s^2$ $2s^2$ $2p^6$ $3s^2$	$3s^2$
$_{13}Al$	$1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^1$	$3s^2$ $3p^1$
$_{15}P$	$1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^3$	$3s^2$ $3p^3$

Exercise 1-6

Write the electron configuration for the following atoms then indicate the gradual energy according to the primary energy levels. $_{15}P$, $_{3}Li$

Exercise 1-7

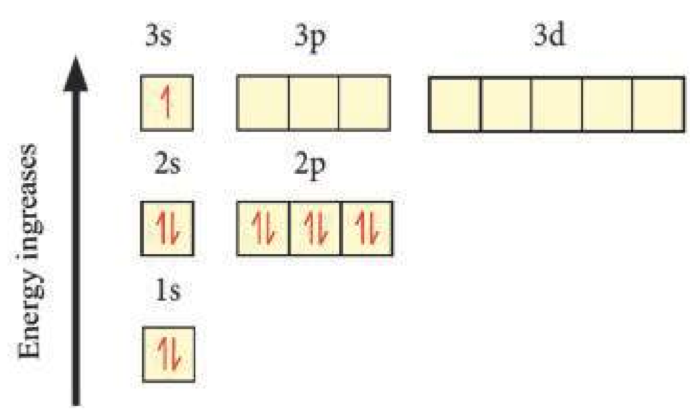
Write the electron configuration the for following atoms then indicate the gradual energy according to the secondary energy levels. $_{13}Al$, $_{8}O$

Example 1-4

Write the electron configuration of sodium atom $_{11}Na$ than,indicate the gradual energy according to the primary energy levels.

Solution:

$_{11}Na$ $1s^2$ $2s^2$ $2p^6$ $3s^1$

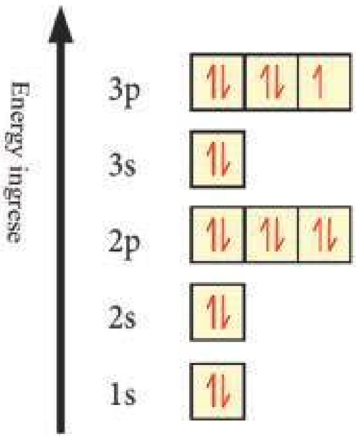


Example 1-5

Write the electron configuration of chlorine $_{17}Cl$ then indicate the order of secondary energy levels from lowest to the highest.

Solution:

$_{17}Cl$ $1s^2$ $2s^2\,2p^6$ $3s^2\,3p^5$



Example 1-6

State the number of electrons in each primary energy level around the nucleus.

$_5B$, $_{10}Ne$, $_{12}Mg$

Solution:

$_5B = \underline{1s^2}$ $\underline{2s^2\,2p^1}$

First primary energy level n = 1 contains 2 electrons.
Second Primary energy level n = 2 contains 3 electrons.

$_{10}Ne = \underline{1s^2}$ $\underline{2s^2\,2p^6}$

First primary energy level n=1 contains 2 electrons.
Second Primary energy level n=2 contains 8 electrons.

$_{12}Mg = \underline{1s^2}$ $\underline{2s^2\,2p^6}$ $\underline{3s^2}$

First primary energy level n = 1 contains 2 electrons.
Second Primary energy level n = 2 contains 8 electrons.
Third primary energy level n = 3 contains 2 electrons.

Exercise 1- 8

What is the number of electrons in each primary energy level for these elements: $_2He$ ، $_7N$

1-6 LEWIS ORDER (LEWIS SYMBOL)

Lewis's symbol depends of the number of electrons on the last shell (external energy level) which is called valence shell. Electrons of the outer shell of the atom are ordered in a symbolic way called Lewis symbol, as follows;
The symbol of the chemical element is written surrounded by dots, each dot represents one electron, two close dots represent a pair of electrons.
These dots are distributed in four directions in such a way that it has two

✽ It is important that the student know only the Atomic number for the first (20) elements from the periodic table to solve the chapter questions.

Figure 1-13
Some elements from periodic table with Lewis order.

dots on the right and two on the left, two dots above and two dots below, as illustrated (Figure 1-13), the order of some elements in the periodic table:

Example 1-7

Write Lewis symbol for the following :
$_{12}Mg$, $_{10}Ne$, $_{5}B$, $_{1}H$, $_{14}Si$

Solution:

We must order electrons first for each element to determine number of electrons in the outer shell. See the table below:

Element	Element configuration	Electrons in the outer energy level	Lewis symbol
$_{1}H$	$1s^1$	1	H·
$_{5}B$	$1s^2$ $2s^2\ 2p^1$	3	·B·
$_{10}Ne$	$1s^2$ $2s^2\ 2p^6$	8	:Ne:
$_{12}Mg$	$1s^2$ $2s^2\ 2p^6$ $3s^2$	2	·Mg·
$_{14}Si$	$1s^2$ $2s^2\ 2p^6$ $3s^2\ 3p^2$	4	·Si·

Exercise 1-9

Write Lewis symbol of the following elements.
$_{20}Ca$, $_{18}Ar$, $_{13}Al$

Example 1-8

An atom, the electrons of which are ordered as follows.

$1s^2\ 2s^2\ 2p^4$

1- What is the total number of electrons in this atom?

2- What is the atomic number ?

3- How many secondary energy level filled with electrons?

4- What is the number of single electrons?

5- Write Lewis symbol for this atom?

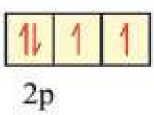
Solution:

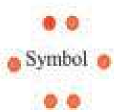
1- The number of electrons are 8.

2- The atomic number is 8 because it equals to the number of electrons.

3- The secondary level 1s and 2s are occupied by electrons as for 2p it is not filled, so the number of secondary levels filled with electrons is only two.

4- It is noted that the number of unpaired electrons are two only.



5- Lewis symbol is 

Exercise 1-10

If atomic number of an element is 6;

1- Write its electrons configuration.

2- How many secondary energy level filled with electrons?

3- What is the number of single electrons?

4- Write Lewis symbol for this atom?

1-7 PERIODIC TABLE

The periodic table is considered the most important tool for those who study chemistry,it is useful in predicting and understanding properties of elements. Once you know the physical and chemical properties of an element,you can predict ,to a large extent the properties of other elements in the same group or period. (Figure 1-14)

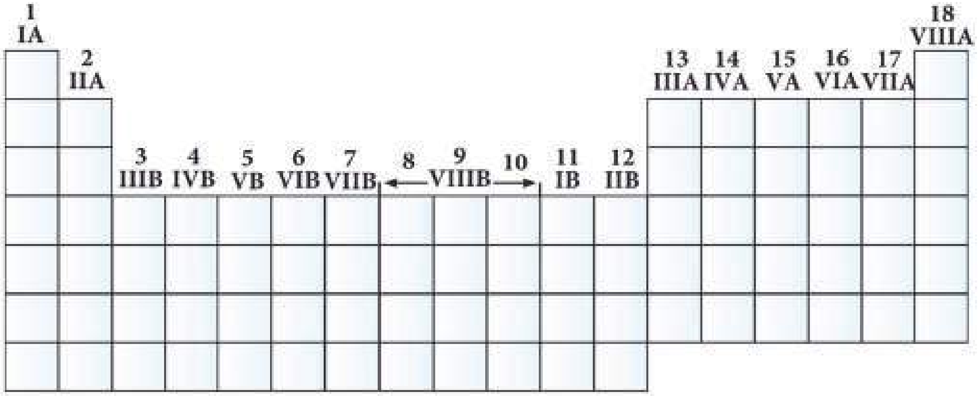


Figure 1-14

Periodic table

1-8 CLASSIFICATION OF ELEMENTS IN THE PERIODIC TABLE ACCORDING TO ELECTRON CONFIGURATION

Electrons play an important part in determining physical and chemical properties of an element, especially those electrons in the outer energy levels, known as valence electrons, classification of elements in the periodic table depends on these valence electrons. Elements can be divided into four blocks, according to the types of the secondary level with which the electron configuration of the elements ends with (s, p, d, f), as illustrated in fig.1-15.

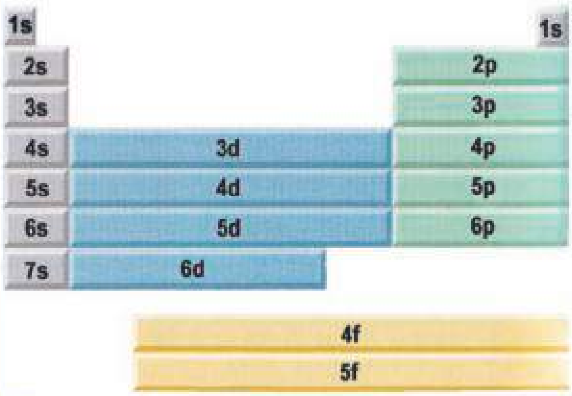


Figure 1-15

Perodic table blocks

1-8-1 s- Block Elements:

They are elements on the far left of the periodic table including groups IA and IIA, whose electron configuration ends with s, except for helium (He) ,it is added to the noble elements at the far right. Group IA includes elements whose last secondary energy level s, have one electron, for group IIA, it includes elements whose last secondary energy level have two electrons.

1-8-2 p-Block Elements:

These elements are located on the right side of the periodic table, see figure (1-15) whose electron configuration ends with p and include six groups, the first five of which are (IIIA,IVA, VA, VIA, VIIA) and the last group on the far right of the periodic table (group VIIIA or group zero), it is called the noble gases group. Elements partly filled with electrons at the secondary shells s and p, and noble elements are called (represented elements), other names are used for other groups like alkaline metals (IA),as for group IIA it is called alkaline earth metals,(VIIA) are called halogens.

1-8-3 d-Block Elements:

These are metal elements whose electron configuration ends with s and d, they are called transition elements or d- block elements, at the center of the periodic table. Figure (1- 16)

1-8-4 f-Block Elements

These elements are located at the bottom of the periodic table whose electron configuration ends with f , and called the inner transition elements, including 14 groups belonging to sixth and seventh periods.

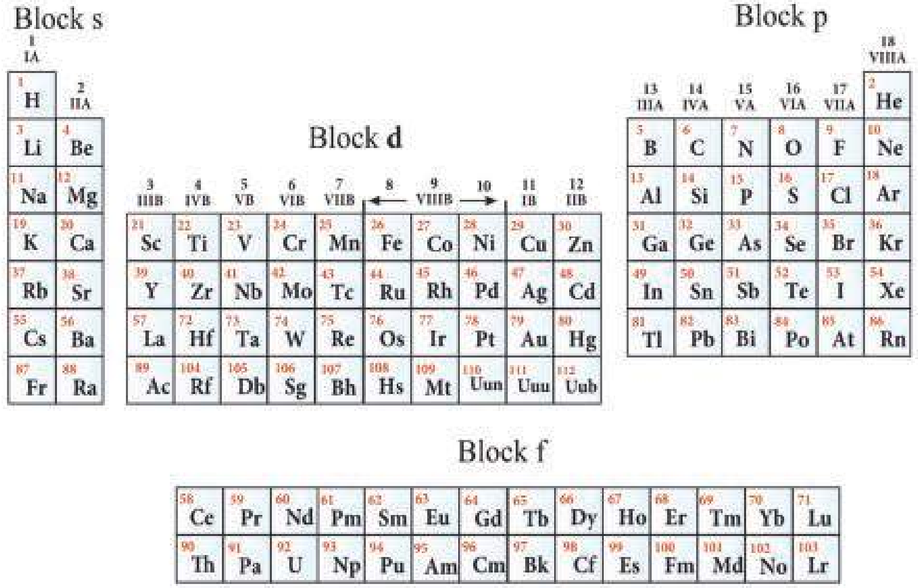


Figure 1-16
Atomic number is written on the top left corner in the periodic table.

1-9 FINDING PERIOD AND GROUP NUMBER OF ANY ELEMENT IN GROUP A

To find number of period and group for group A, the following steps hold be followed:

1- Write the electron configuration of the element.

2- The number of the period is the highest number of the n, which the electron configuration of the element ends.

3- The number of the group can be found as follows:

a- If the electron configuration ends with s, thus the number of electrons in this level is the number of the group.

b- If the electron configuration ends with the (p), thus the number of electrons at this level as well as the secondary level(s) in the primary level which fills before it represents the number of the group. If the total number of electrons is 8 ,then it means that this element is in the noble gases group, except for helium, the last energy level of it ends with s and contain two electrons only.

Example 1-9

What are the period and group for the following elements?

$_{19}K$, $_{10}Ne$, $_{17}Cl$, $_{8}O$

Solution:

$_{8}O = 1s^2\ 2s^2\ 2p^4$ The last main level is level (2). Thus, the period is the second period. The last secondary level (p) contains (4) electrons. 2 electrons from s are added before saturation and the total number is: 2 + 4 = 6 (group six) Oxygen is in the second period in group 6 in the periodic table.

$_{17}Cl = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ The last main level is level (3). Thus, its period

is the third period. Its last secondary level (p) contains (5) electrons in addition to (2) electrons from the underlying level (3s). The total number is (7). Chlorine belongs to group seven of the periodic table. Thus, chlorine is in the third period of group
(7) of the periodic table.

$_{10}Ne = 1s^2\ 2s^2\ 2p^6$ The last main level is level (2) so its 2nd period The last secondary level (p) contains (6) electrons in addition to (2) electrons from the underlying level (2s). The total number is (8). Thus, its group is the eighth. Accordingly, neon belongs to the second period in the (zero) group or (VIIIA) group of the periodic table.

$_{19}K = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$ The last main level is level (4) and its period is the fourth. The last secondary level (s) contains one electron and its group is the first. Based on this, potassium belongs to the fourth period in the first group in the periodic table.

Exercise 1-11

What are the period and group for the following elements?

$_{13}Al$, $_6C$, $_3Li$

Example 1-10

What is the common property between the locations of the following elements in the periodic table?

$_{12}Mg$, $_{11}Na$, $_3Li$

Solution:

$_3Li = 1s^2\ 2s^1$ group (1A) / 2nd period

$_{11}Na = 1s^2\ 2s^2\ 2p^6\ 3s^1$ group (1A) / 3rd period

$_{12}Mg = 1s^2\ 2s^2\ 2p^6\ 3s^2$ group (2A) / 3rd period

According to the above, the common property between Li and Na is that they both have the same group (Group 1A). The common property between Na and Mg is that they have the same period 3rd period.

Example 1-11

What is the common property between the locations of the following elements in the periodic table? $_4Be$,$_5B$, $_7N$

Solution:

$_4Be = 1s^2\ 2s^2$ group (2A) / 2nd period

$_5B = 1s^2\ 2s^2\ 2p^1$ group (3A) / 2nd period

$_7N = 1s^2\ 2s^2\ 2p^3$ group (5A) / 2nd period

All these elements are in the same period 2nd period. They differ from each other with respect to groups. Each element belongs to a different group. Beryllium (Be) is in the second group, Boron (B) in the third group and Nitrogen (N) in the fifth group.

Exercise 1-12

What is the common property between the locations of the following elements in the periodic table?

$_{15}P$, $_6C$, $_{14}Si$

1-10 PERIODIC PROPERTIES

The physical and chemical characteristics of the elements in the groups and periods of the periodic table vary according to their atomic radius, ionization energy, electron affinity and electronegativity as arranged below.

1-10-1 Atomic Radius:

The radius of the atom determines its volume. Theoretically, atom radius can be calculated by the last occupied level of electrons. One of the means used to measure the atomic radius involves calculating the distance between the identical and chemically combined nucleus of two atoms and then divide the outcome by two as in the following figures. Thus, the atomic radius can be defined as: "Half of the minimum distance between two identical and chemically-combined nuclei of the element."It is noticed that the radius of the elements in one period decreases as we move from left to right, as their atomic numbers increase. The attraction energy between the electrons within one main level and the positive charge of the nucleus increases with increasing in the number of electrons in it. The radius of the elements in periods, on the other hand, the elements radius increases as we move from top to bottom in the periodic table and as the outer electrons keep distance from the nucleus, as in the figure below.

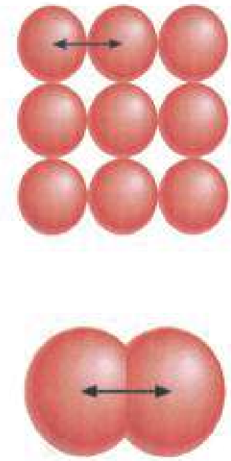


Figure 1-17
Atomic Radius

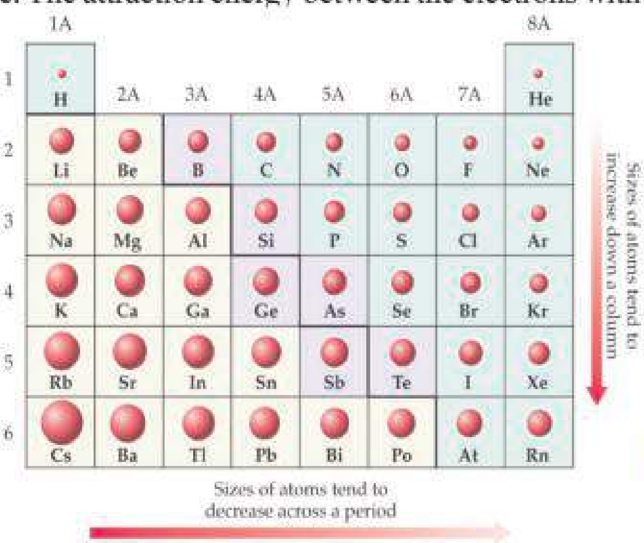


Figure 1-18
Atomic Radius of some elements

Exercise 1-13

Arrange the following elements according to the increase in their atomic radius.
$_{20}Ca$, $_{12}Mg$, $_{4}Be$

Example 1-12

Arrange the following elements according to increasing in their atomic radius.
$_{9}F$, $_{6}C$, $_{8}O$, $_{3}Li$

Solution:

$_{3}Li = 1s^2\ 2s^1$
$_{6}C = 1s^2\ 2s^2\ 2p^2$
$_{8}O = 1s^2\ 2s^2\ 2p^4$
$_{9}F = 1s^2\ 2s^2\ 2p^5$

Notice that all the elements above end with the second main level. This Means that they are all in second period of the periodic table. Thus, the arrangement of these elements according to the increase in their radius is as follow:

$_{3}Li > _{6}C > _{8}O > _{9}F$

1-10-2 Ionization Energy:

Ionization Energy is defined as: The amount of energy required to remove one electron from the outer energy level of a gaseous atom."As in the ionization of Sodium atom:

$$Na_{(g)} + \text{ionization energy} \rightarrow Na^+ + e^-$$

Ionization energies are arrange in the groups from top to bottom. As the

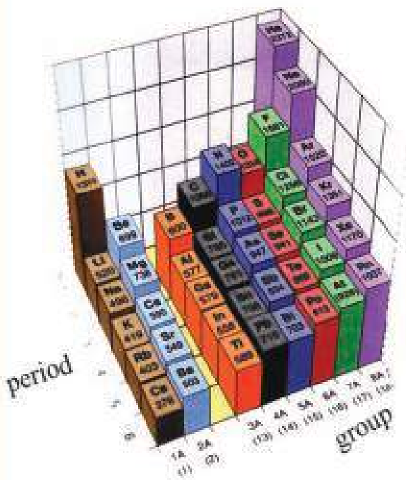


Figure 1-19
Arrangement of the some elements according to their ionization energy

atomic number becomes greater, the ionization energy of an element decreases. The reason behind this is that the outer shells' electrons stay away from the nucleus which in turn,increases the tendency of the atom to lose one of the electrons. The ionization energies in the periods increase as the atomic number of an element increases because of the increase in the positive charge of the nucleus and the occurrence of the electrons in the same main level of energy. The attraction energy to attract the electron by the positive charges of the nucleus becomes greater. However, there is an exception to this.

If an atom has a secondary saturated shell such as (ns^2) or half saturated shell such as np^3,its ionization energy is greater than the ionization energy of the following atom. An example for this is $_7N$ which has greater ionization energy than the ionization energy of $_8O$ in spite of the fact that oxygen atom has a bigger atomic number than the atomic number of nitrogen and that they both belong to the same period. Noble gases have the greatest ionization energy so they do not lose electrons easily.

1-10-3 Electron Affinity:

Electron affinity is defined as:

"The amount of energy released when a neutral gaseous atom acquires one electron."As in fluoride atom:

$$F + e^- \rightarrow F^- + \text{energy}$$

The electron affinity of the elements in the periods increases as the atomic number increases. However, the elements in the same group face more difficulty to acquire an electron as their atomic numbers increase. The bigger the atomic number of an element, the more difficult it is for the element to acquire an electron. Nobel elements are known to have the lowest electron affinity because it is very hard to add electrons to them.

1-10-4 Electronegativity:

In many chemical compounds, the negative charge of the bonded electrons is centered near a certain atom. This greatly affects the chemical properties of the compound. Electronegativity is defined as: "The tendency of an atom to attract bonded electrons towards itself in any chemical compound.

Fluoride, of all other elements, has the greatest electronegativity and thus, is given number (4) as a measure for its electronegativity. This number fluoride electronegativity is used as a measurement for all other elements. Electronegativity increases as the atomic number increases in the period with some exceptions. In groups, electronegativity decreases as the atomic number increases. As for the noble gases, they are considered exceptional because some of them do not combine with others to make compounds. Thus, the noble gases which have the tendency to make compounds, tend to have a very high electronegativity.

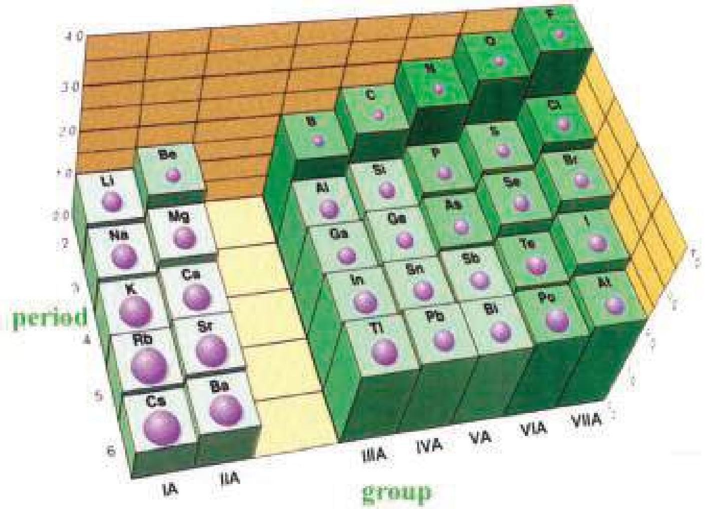


Figure 1-20
Ordering of some element's according to electronegativity.

1-10-5 Metallic and Nonmetallic Properties:

The metallic and nonmetal properties change according to the changes in the atomic number of the atoms in a same group and in a same period. As the atomic number of the atoms in the same period increases, the metallic properties decrease on one hand, and the nonmetallic properties increase on the other hand. For example, lithium and beryllium in the second period show metallic Boron and silicon come after with properties of metalloid.
The rest of the elements in the period such as nitrogen, oxygen and fluoride come at the end with nonmetallic properties. In one group, the metallic properties increase and the nonmetallic properties decrease as the atomic number increases. All the elements in Group IA and Group IIA are metals. The elements in Group VIA and Group VIIA are nonmetals.
The elements in the rest of the groups are not of the same type. For example,nitrogen in Group VA shows nonmetallic properties whereas antimony and arsenic show metalloid properties. Bismuth is the last element in group V and it shows metallic properties. As far as the periods are concerned, the two elements in the first period (hydrogen & helium) are nonmetals. In the following four periods, there is a gradual change from metallic to nonmetallic properties. All the elements in the sixth period are metals except the last two elements which are nonmetals. The seventh period includes only metals, taking into account the fact that transitional elements, lanthanide and actinides which are internal transitional elements show metal properties.

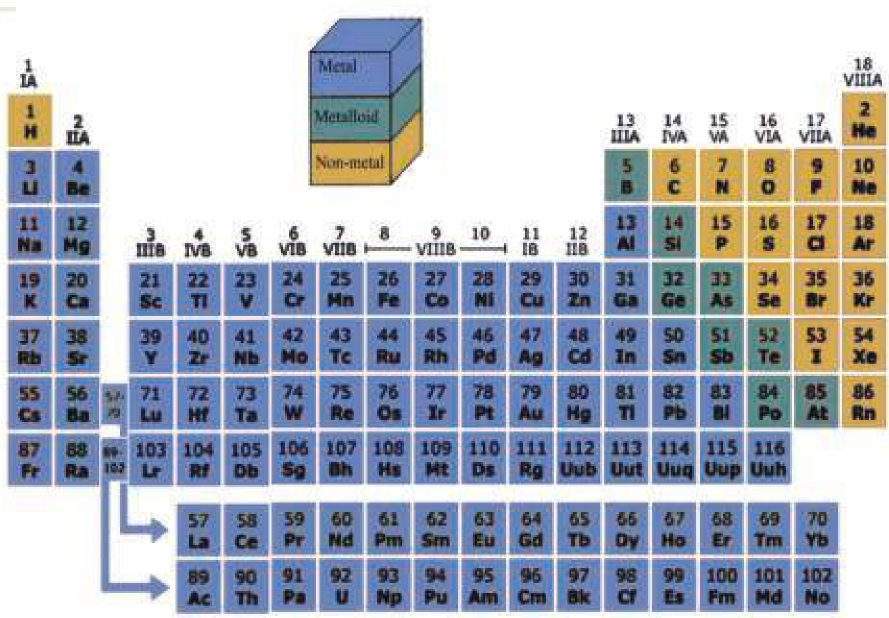


Figure 1-21
Metal and Non-metal

CHAPTER QUESTIONS 01

1.1 Choose what is correct from the following :

1- The most stable electron is that located in :

a) Fourth primary energy level.
b) Third primary energy level.
c) Second primary energy level.

2- Which one of the following primary energy levels has more electrons :

a) First primary level.
b) Second primary level.
c) Third primary level.

3- Maximum how many electrons are there in second primary energy level (n=2)?

a) 32 eletrons.
b) 18 electrons.
c) 8 electrons.

4-What is the number of orbital of (f) sublevel?

a) 3 orbitals.
b) 7 orbitals.
c) 5 orbitals.

5-Which of the following electron configuration is correct for d sublevel which has 6 electrons according to Hund's Rule?

a)	↑↓	↑	↑	↑	↑
b)	↑↓	↑↓	↑↓		
c)	↑	↑	↑	↑	↑↓

6- The third main energy level contains a number of orbitals :

a) 4 orbitals
b) 9 orbitals
c) 16 orbitals

7- Electron configuration of one of elements is as follows: $1s^2\ 2s^2\ 2p^3$ What is the atomic number of this element?

a) 5 b) 4 d) 7

8- Electronic arrangement of neon : $_{10}Ne$

a) $1s^2\ 2s^2\ 2p^6$
b) $1s^2\ 2s^2\ 2p^6\ 3s^1$
c) $1s^2\ 2s^2\ 2p^6\ 3s^2$

9- In the periodic table the elements of block d are located :

a) Below the periodic table.
b) on right of the periodic table.
c) middle of the periodic table .

10-In the periodic table the elements that assemble the right of the periodic table are

a) Block p elements
b) Block f elements
c) Block s elements

11- Halogens are the elements of the group

a) lA
b) VIIA
c) VIIIA

12- What is the electron configuration of an element which ends with $3p^3$?

a) $1s^2\ 2p^6\ 3p^3$
b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
c) $1s^2\ 2s^2\ 2p^6\ 3p^3$

13- The discovery of the nucleus of the element is attributed to the scientist :
a) Rutherford
b) Bohr
c) Thomson

14- Atom element ends with electuonic level $3s^1$ atomic number of this element is:
a) 8
b) 13
c) 11

15- The amount of energy required to remove one electron from the outer energy level of agaseous atom is called :
a) Ionization energy.
b) Electronegativity.
c) Electron affinity.

16- An atom of an element ends with electronic order in secondary level $2p^5$, what it's group and period:
a) Fifth group, second period.
b) Second group, fifth period .
c) Seventh group, second period.

17- An element in the fifth group and the third period, the final secondary energy level is :
a) $3p^5$
b) $5p^3$
c) $3p^3$

18- Which of the following elements has highest electronegativity?
a) Fluorine.
b) Chlorine
c) Bromine

19-The radius of elements increases within same period as :
a) it has less atomic number .
b) it has larger atomic number .
c) as we move from left to right in same period in the periodic table.

20-Which of the following is true for the Lewis structure of argon ($_{18}Ar$) element?

a) $\cdot\dot{\mathrm{Ar}}\cdot$ b) $:\ddot{\underset{..}{\mathrm{Ar}}}:$ c) $\cdot\mathrm{Ar}\cdot$

1.2 Explain Rutherford's atomic model and why his model was failed?

1.3 Write briefly about :
1) Ionization energy
2) There is no electronic repel in same orbital
3) Thomson atomic model
4) secondary energy levels
5) Electronegativity

1.4 Two elements $_{12}Mg$ and $_{16}S$
1) Write the electronic configration for them indicating the secondary energy levels
2) Period and group of each
3) What is common between these two elements in their location in the periodic table?
4) Lewis order for both of them?

1.5 Electron configration for fluorine is $1s^2\ 2s^2\ 2p^5$
1) What is the atomic number for fluorine
2) What is the number of secondary energy levels that full with electrons, and named it
3) What is the number of un paired electrons in fluorine atom

1.6 Arrange elements by decreasing in their atomic size:

$_2He$, $_{10}Ne$, $_{18}Ar$

1.7 What is the common thing between the following elements :

1) $_3Li$, $_1H$
2) $_{13}Al$, $_{17}Cl$

1.8 Name the period and group for each element : $_{18}Ar$, $_{11}Na$

1.9 Write Lewis symbol for each of the following : $_{16}S$, $_5B$

1.10 Which elements are called noble gases in the periodic table and what is the most important characteristic of these elements ?

1.11 How did elements blocks in the periodic table are arrange, and what it's position?

1.12 How many secondary levels and orbitals and electrons in each of primary energy level (second ، third)?

1.13 Answer the following questions according to $_{17}Cl$ and $_{11}Na$?
1- Write electron configuration of them
2- Show Lewis structure
3- Show primary and secondary energy levels
4- Write number of unpaired electrons
5- Number of electrons for each primary energy level around each nucleus
6- Number of secondary energy level that are filled with electrons
7-period and group for each atom and what is the common characteristic between them

1.14 HowMetal and nonmetallic properties are classified in for each (second period ، fifth group)

CHAPTER 02

GROUPS IA & IIA

By the end of this chapter, the students are able to:

1- Identify the names and symbols of the elements in Group IA and Group IIA.
2- Know the reason why these elements were put in these two adjacent groups.
3- Identify the location of each group in the periodic table.
4- Distinguish the difference among the elements based on their properties.
5- Recognize sodium and identify its compounds.
6- Recognize calcium and identify its compounds.
7- Use flame test to identify some of the elements in the two groups.
8- Conclude why the elements in these two groups do not occur as free elements in nature.

2-1 ELEMENTS IN GROUP IA & GROUP IIA

Elements in group IA and group IIA are found on the left side of the periodic table as in the figure below. The first group (IA) consists of the alkali metals: Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Cesium (Cs) and Francium (Fr). Francium is the only element in this group which is prepared industrially. Group IIA consists of the alkali earth metals: Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba) and Radium (Ra).These elements are arranged according to the increase in their atomic numbers.

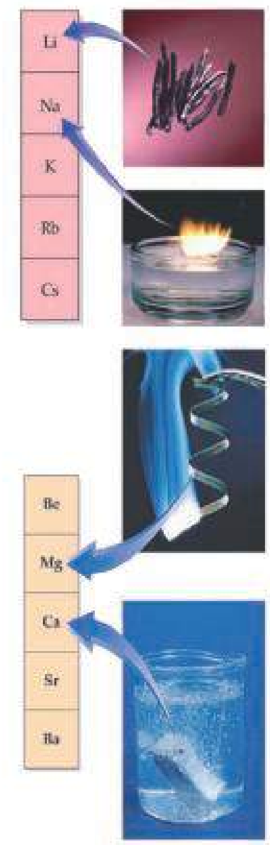
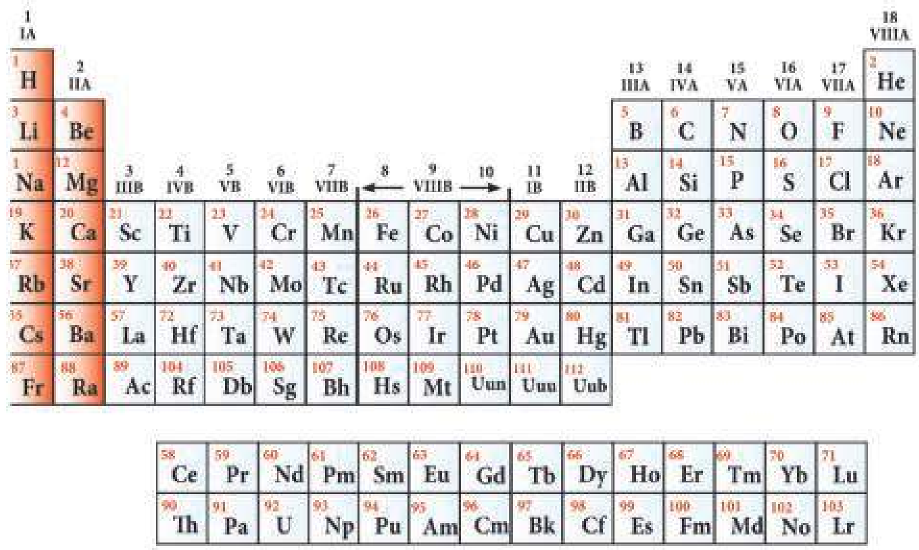


Figure 2-1
Place of first and second groups in the periodic table.



2-2 GENERAL PROPERTIES OF GROUP IA AND IIA ELEMENTS

1- The elements in these two groups have low electronegativity and low ionization energy.

2- The outer shells of all the elements in group IA have one electron whereas the outer shells of the elements in group IIA have two electrons.

3-Because of their reactivity they can not occur in the free form in nature.

However, there is a very small difference in the general properties between these two groups elements. The metallic properties of the elements in Group IIA are lower than those of the elements in Group IA. The ionization energy of the elements in Group IIA is greater than those of the elements in Group IA because of the decrease in the atomic volume.

The most important physical properties of group IA and IIA elements:

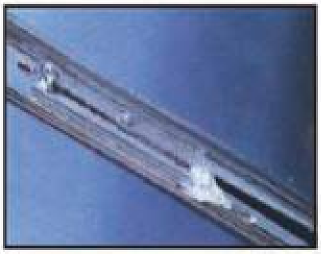
1- Melting and boiling points decrease when the atomic numbers of the elements increase.

2- The compounds of these metals such as chlorides NaCl and KCl, etc, give different colors to the flame of Benzene Lamp. These colors distinguish each metal individually. Lithium gives scarlet color and sodium compounds give shiny yellow color. The same goes with rest of the metals in Group IIA such as calcium which gives dark red color, strontium gives scarlet color and barium gives yellowish green and so on.

3- The increase and decrease in the density of elements are irregular to the increase in their atomic numbers, taking into consideration that the density of the first three elements(Li, Na, and K)is lower than the density of water at the temperature of (25°C).

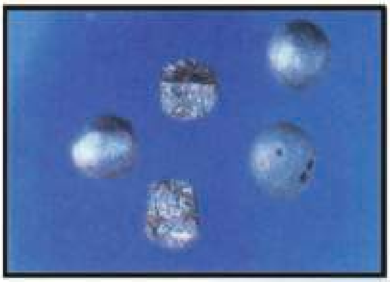
Sodium (Na)

Lithium (Li)



Cessium (Cs)

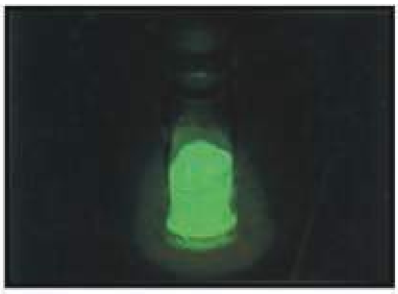
Magnesium (Mg)



Beryillium (Be)

Strontium (Sr)

Calcium (Ca)



Radium (Ra)

Barium (Ba)

(A)

(B)

(C)

Flame color of elements
a. Calcium
b. Strontium
c. Barium

Elements of I and IIA groups

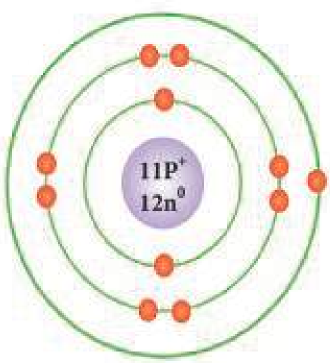
Some Chemical Properties:

1- The elements in Group IA have one valence electron and the elements in Group IIA have two valence electrons in their outer shells. They have the tendency to lose their valence electrons when they enter into a chemical reaction. Elements in group IA form positively charged ions (M^{+}) and elements in group IIA form (M^{++}).

2- The combine with nonmetals to form stable salts with high solubility except lithium which is less soluble in water. Because, lithium has small volume and the great attraction energy of its nucleus to electrons.

3- These elements are very active reducing agents. They tend to lose the external covalence electrons easily because they are easily oxidized. Elements of group IA are called "alkaline metals" because their solutions are highly basic. Elements of group IIA are called "alkaline earth metals" because some of their oxides are known as "alkaline earth"

2-3 SODIUM



Electron configuration of sodium element.

Chemical symbol : Na
Atomic number : 11
Mass number : 23

Symbol of energy level	Energy level	Number of electron
K	1	2
L	2	8
M	3	1

2-3-1 Occurrence:

Sodium does not occur as a free element in nature due to its high reactivity. It occurs in nature combined with other elements forming stable compounds such as sodium chloride, sodium sulfates and sodium silicates. It is preserved in liquids, with which it does not react like pure benzene and kerosene because it burns when exposed to air.

2-3-2 Properties of Sodium:

A- Physical Properties:

Sodium is a soft metal and has a bright silvery luster when it is readily cut. Its density is less than the density of water. It melts down at (97.81°C). Molten sodium boils at (882.9°C).

B- Chemical Properties:

Free sodium is a very active element. It combines directly with most of the nonmetals to form ionized compounds as it forms positively charged sodium ion (Na^+).Most important chemical properties of sodium are:

Reverse Sodium in the white gas

1- It directly combines with oxygen. When a freshly piece of sodium is exposed to moist air, its bright color vanishes after a very short time and the piece gets a white cover.

2- It directly combines with chlorine and burns when heated together:

$$2Na + Cl_2 \rightarrow 2NaCl$$

Sodium Chlorine gas Sodium chloride

3- It reacts vigorously with water forming sodium hydroxide and releasing hydrogen gas;

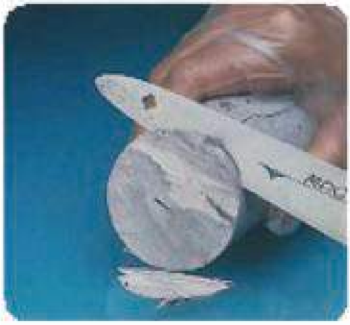
$$2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$$

Sodium Water Sodium hydroxide Hydrogen gas

4- It reacts vigorously with the dilute acids forming salt and releasing hydrogen gas

$$2Na + 2HCl \rightarrow 2NaCl + H_2\uparrow$$

Sodium Hydrochloric acid Sodium chloride Hydrogen gas



Sodium has bright color

5- It reacts with many oxides and chlorides as in the following equations:

$$2Na + MgO \rightarrow Na_2O + Mg$$

$$3Na + AlCl_3 \rightarrow 3NaCl + Al$$

2-3-3 Uses of Sodium:

1- Sodium is used as an active reducing agent in some of the organic interactions because of its high oxidation.

2- It is used in the production of sodium cyanide which is used in purifying gold and in many other industrial applications.

3- It is used in mining to remove the oxygen of air which is combined with the metals or which is found in their molten.

Reaction of sodium with water

2-3-4 Test of sodium ion in its compounds:

Flame test (dry detection) is used for this purpose as mentioned earlier in the properties of the elements of Group IA to which sodium belongs. Sodium gives the flame the yellow color.

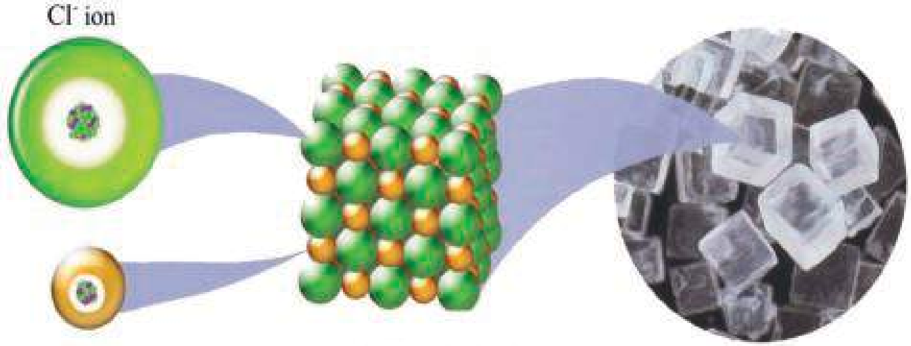
Flame of sodium yellow color

2-3-5 Sodium Compounds:

Sodium compounds are very abundant in nature. The most important compounds of sodium are rock salts (sodium chloride) and a mixture of double salts. Under the effects of erosion such as rain or air which contains carbon dioxide gas, some of these salts convert into sodium carbonates, pure mud and sand.

1- Sodium Chloride (Table Salt):

Table salt (sodium chloride) NaCl is the most abundant sodium compound in nature. It occurs in nature as rock salts in many countries around the world. It also occurs as underground salt deposits. It is abundant with huge quantities in springs, seas and lakes.



a- Extraction of Salt:

If salt exists with high concentrations in sea water, the water is pumped into large shallow pools to be vaporized by the sun. These processes are being used now in southern part of Iraq (FAO salts).

b- Uses of Sodium Chloride:

Table salt is very essential to human beings. It is indispensable in our food. Also, table salt is industrially important:

1- It is used as an essential raw material in the preparation of many sodium compounds such as sodium carbonates (washing soda) and sodium hydroxide.

2- Sodium chloride is used in preservation of consumable food for certain period of time such as meat and fish. The concentrated sodium chloride liquid kills harmful bacteria which case putridity.

3- Sodium chloride is used in leather tanning, production of ice for cooling and painting adhesives.

c- Properties of Sodium Chloride:

The following experiment can be done to show some properties of sodium chloride:

Put some crystals of pure sodium chloride in a glass bowel and put some salt (table salt) in another. Put the two glass bowels in humid air and label the bowels individually. After one or two days, check the salt in the bowels. You notice that the regular salt becomes humidified and the pure salt stays unaffected. This indicates that sodium chloride does not absorb water from air, i.e. it does not hydrate. Regular salt has the property of absorbing water (humidity) from air. The process of absorbing water from air being wet is called "Hydrolysis". Therefore, table salt is a hydrated substance. The reason for this hydration is that it contains impurities of calcium chloride or magnesium chloride or both. These two compounds have strong tendency for absorbing water from air (becomes hydrated in humid air). So, what is the difference between table salt and sodium chloride ? Why ?

Exerecise(**2-1**)
What is the difference between pure sodium chloride and they a ffected by heat?

2- Sodium Hydroxide (NaOH):

Sodium hydroxide is a solid substance and it is hydrated when exposed to humid air. The hydrated layer of sodium hydroxide reacts with carbon dioxide in air to form a layer of sodium carbonates Na_2CO_3 which is insolube in concentrated NaOH solution. A dry layer is formed on sodium hydroxide grains.

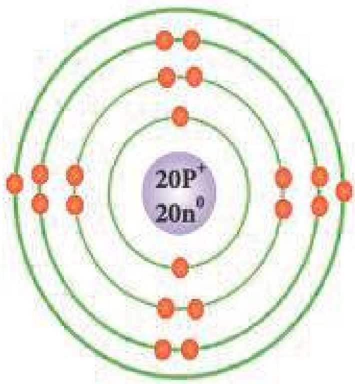
$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

Sodium hydroxide   Carbon dioxide   Sodium carbonate   Water


Sodium Hydroxide

Sodium hydroxide is a base with a great tendency to dissolve in water. It is used in many industrial fields such as soap and detergent industries, textile, and paper manufacturing. It is also used as an essential raw material in the preparation of many chemical compounds used in various industries.

2-4 CALCIUM



Electron configuration of calcium element.

Energy level	Principal quantum number	Number of electron
K	1	2
L	2	8
M	3	8
N	4	2

Chemical symbol : Ca
Atomic number : 20
Mass number : 40

2-4-1 Occurrence:

Calcium does not occur as a free element in nature because of its high activity. It occurs in combination of other elements as in the forms of carbonates such as alabaster and limestone, sulfates such as plaster, phosphates such as calcium phosphates or silicates. Calcium is obtained by the method of electrolyzes of molten calcium chloride and fluoride. It occurs in some kinds of food such as milk and fish.

Some food that contain calcium.

2-4-2 Some Calcium Compounds:

1- Calcium Hydroxide, $Ca(OH)_2$:

It is prepared by adding water to calcium oxide CaO (quicklime).This process is called "hydrating lime" which results calcium hydroxide which is known sometimes as "hydrated lime". Pure calcium hydroxide solution is called "pure lime water" as in the following equation:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

When exposed to carbon dioxide, CO_2, lime water becomes impure because of calcium carbonate as in:

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3\downarrow + H_2O$$

Solution (lime water) — Calcium Carbonate (White precipitate) (turbid solution)

Calcium hydroxide

2- Calcium Sulfates:

Calcium Sulfates occur in the form of plaster $CaSO_4.2H_2O$ whereby two molecules of water (crystallization water) combine with solid calcium sulfates. When heating gradually removes crystallization water, plaster turns into "Paris Plaster" $(CaSO_4)_2.H_2O$
Paris plaster is used in building, statue making and casting.

CHAPTER QUESTIONS 02

2.1 Choose from the brackets to complete the scientific meaning in the following :

1- Which one is the first group elements?

a) Helium b) Radium c) Sodium d) Boron

2- Why potassium is more active element than lithium?

its atom has two valence electron , its atomic radius bigger , its atom don't have valence electron , because its free in nature.

3- What is the oxidation number of magnesium element in its compounds?

(1 ,2 ,3 ,4)

4- If Lithium atom loses its equivalence electrons, it convert to (single positive charge ion , a negative charge , dipositive charge ion , dinegative charge ion)

2.2

1- What is the difference between normal plaster and Paris plaster?

2- Why sodium chloride is important for industry?

3- Barium has more metallic properties than beryllium. Why?

2.3 Explain the reason of followings;

1) Aluminum, $_{13}Al$, is not found in IA group.

2) Sodium is stored in petroleum.

3) IA group is called alkaline metal.

4) Sliced Sodium loses its shining after some time.

5) When granules NaOH are left in wet atmosphere, they first fade and then form a hard shell.

2.4 Explain :

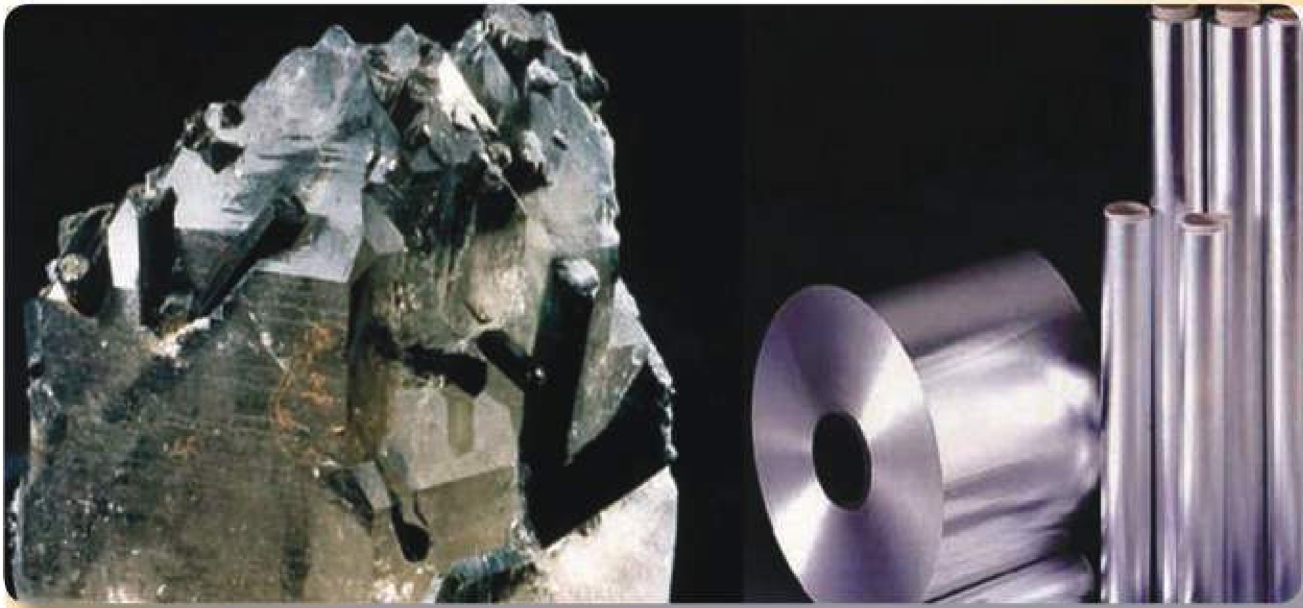
1- Calcium loses two electrons easily.

2- Put the elements Lithium, Sodium, and Potassium within the same group, although different in the atomic number.

2.5 What is the difference between pure salt NaCl and inpure NaCl

CHAPTER 03

GROUP IIIA ELEMENTS



At the end of this chapter, the student is able to:

1- Identify the names and symbols of group III elements.

2- Know the general features of group III elements.

3- Know that aluminum does not exist as a free element in nature.

5- Identify the atomic symbol and number and the mass number of aluminum.

6- Recognize the physical importance and benefits of aluminum compared to iron.

7- Recover-practically- the aluminum ion in the aqueous solutions of its compounds.

8- Identify some aluminum compounds.

3-1 GROUP IIIA ELEMENTS

The main reason behind putting the elements of group IIIA in one group is the same reason that we had in groups IA and IIA. The reason is that the outer shell in 3A group atoms contains same number of electrons despite they are different in their atomic numbers. The elements of this group are: Boron (B), Aluminum (Al), Gallium (Ga), Indium (In), Thallium (Tl), as illustrated in the following periodic table.

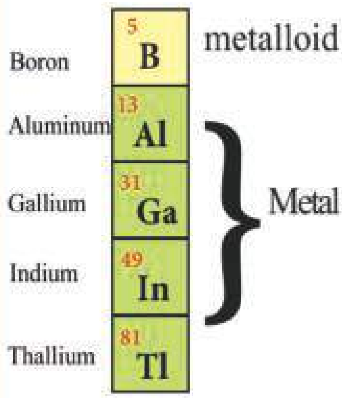
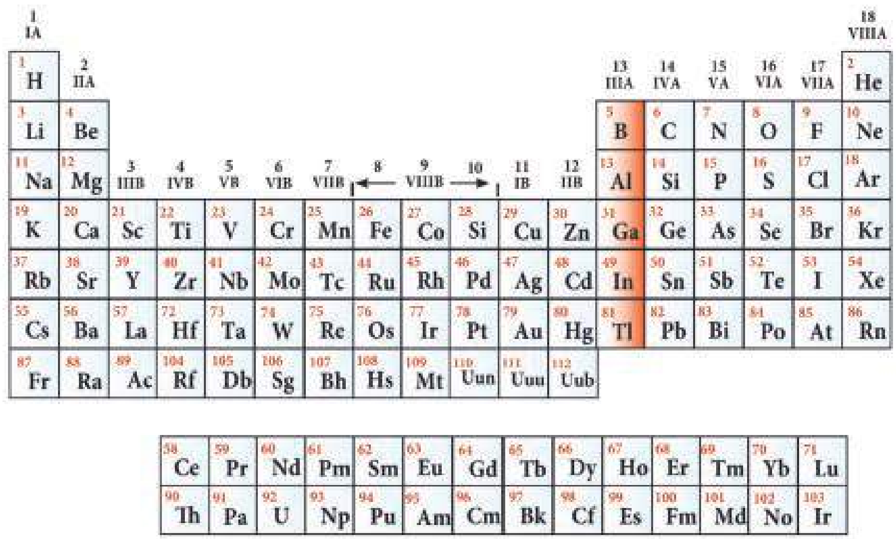


Figure 3-1
Place of element of group IIIA in the periodic table



3-2 GENERAL CHARACTERISTIC PROPERTIES OF GROUP III A ELEMENTS

1- The elements of this group are metals except Boron which is metalloid.

2- The ionization energy of these elements is less than the ionization energy of group IIA elements. The main reason for this is that the elements of this group contain one electron in the secondary shell (p) following a saturated secondary shell (whether s or p). The outer shell of group IIA elements, on the other hand, is the saturated secondary shell ns^2).

The increase in the atomic number of the elements of this group (up to bottom) generally results in a decrease in the ionization energy of their atoms because of magnitude of their atomic volume .

3- Considering valence electrons of this group elements, it is expected that the oxidation number of these atoms is (+3). However, they tend actually to form covalent bonds.

4- The oxides and hydroxides of the elements of this group are characterized with an increase in the alkaline characteristic and a decrease in the acidic characteristics as the atomic number increases. Thus, the aqueous solutions of boron oxides are acidic, whereas the aluminum oxides are amphoteric.

Exercise 3-1
Compare between the ionization energy of elements in group IIIA and IIA.

Boron (B)

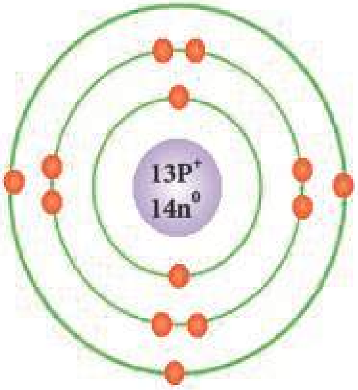
Aluminum (Al)

Gallium (Ga)

Indium (In)

3-3 ALUMINUM

Shell Symbol	Shell Number (n)	Number of Electrons
K	1	2
L	2	8
M	3	3



Electron configuration of Aluminum
Chemical symbol: Al
Atomic number : 13
Mass number : 27

3-3-1 Occurrence:

Aluminum metal is too reactive chemically to occur natively. Instead, it is found combined in a great number of different compounds. Aluminum is the most abundant metal in the earth's crust.

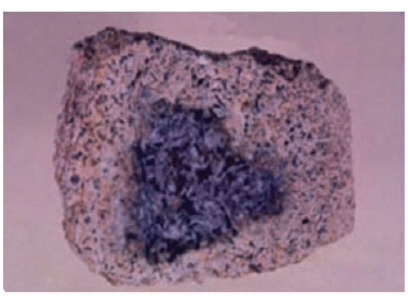
Aluminum Oxide

It makes up about 8% by weight of the earth's solid surface. The row material of aluminum is bauxite $Al_2O_3.2H_2O$. It is the aqueous aluminum oxide and it is the main source for aluminum extraction. Cryolite (Na_3AlF_6) is a fluoride of sodium and aluminum (sodium hexafluoroaluminate) it is one of the most important sources used in the extraction of aluminum.

3-3-2 Extraction of Aluminum:

There are many processes for extracting aluminum from its compounds. The Hall process is the major industrial process for aluminum extraction in the present time. It is the best and reliable process and is widely used in industry. It involves electrolyzing pure alumina (Al_2O_3) in molten cryolite bath at a temperature of (1000°C) by using carbon electrodes. Alumina (Al_2O_3) does not occur naturally. It exists in the ore of Bauxite ($Al_2O_3.2H_2O$) with other impurities of iron and others. The Bauxite ($Al_2O_3.2H_2O$) is chemically purified to exclude impurities to obtain pure aluminum oxide (Al_2O_3) (alumina) which has a high melting point and being melted in molten cryolite. The molten cryolite decreases the melting point of alumina. The molten, then, is poured in an electrolytic cell. As the current passes through,aluminum accumulates at the bottom of the cell. Then, the molten aluminum is pulled gradually.

Land is natural staple of Aluminum



Bauxite

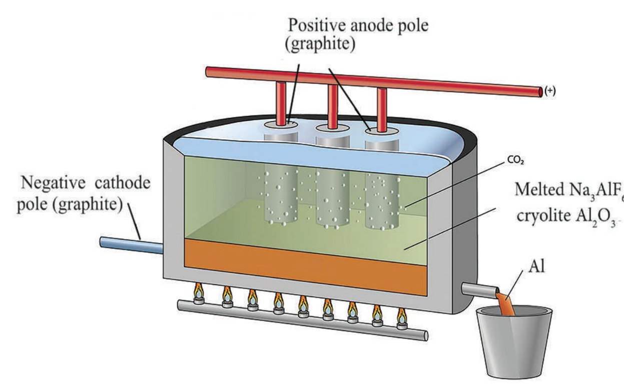
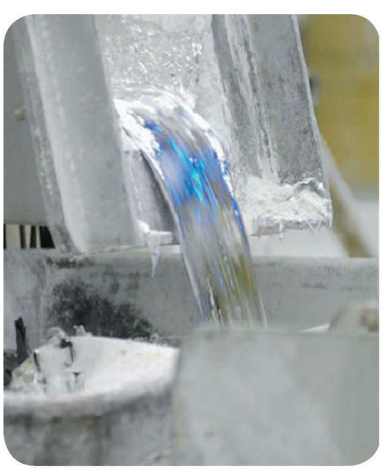


Figure 3-2 Hall cell which is used to obtain aluminum.



Molten aluminum

3-3-3 Properties of Aluminum:

1- Physical properties:

Aluminum is a fine silvery metal with a remarkable low density and is a good conductor for heat and electricity.

2- Chemical properties:

a- Oxygen effect on Aluminum

It has been mentioned earlier that the surface of Aluminum oxides when exposed to air. Aluminum is then covered with a thin layer of its oxide which sticks firmly to its surface and prevents further oxidation. This thin layer gives aluminum the ability to resist corrosion. This does not happen with iron.

b- Aluminum powder burns vigorously with a bright flame releasing great energy. The reaction occurs according to the following equation:

$$\underset{\text{Aluminum Powder}}{4Al} + 3O_2 \rightarrow 2Al_2O_3 + \text{Energy}$$

c- Aluminum is a reducing agent :

Put a mixture of aluminum powder and Iron III oxide Fe_2O_3 in a crucible with some sand. Also, put a tape of magnesium of an appropriate length in the container and light the end of the tape and keep a distance from the container not less than three meters. Try to notice the reaction between the aluminum powder and iron (III) oxide The reaction is so vigorous with a great amount of heat, shiny flame and a lot of sparks. The reaction results in molten iron as the aluminum reduces iron (III) oxide and releases molten iron due to excessive heat, this reaction is called " Thermite process" , as in following formula:

$$\underset{\text{Aluminum Powder}}{2Al} + \underset{\text{Iron (III) oxide}}{Fe_2O_3} \rightarrow \underset{\text{Aluminum Oxide}}{Al_2O_3} + \underset{\text{Iron}}{2Fe} + \text{high temperature}$$

This reaction is used in welding steel machines and railways bars. Aluminum is also used to extract some metals from their ores which exist in the form of oxides relying on its "reduction" potential.

d- Reaction of aluminum with acids and bases:

Aluminum reacts with dilute hydrochloric acid easily to produce hydrogen gas and aluminum chloride component:

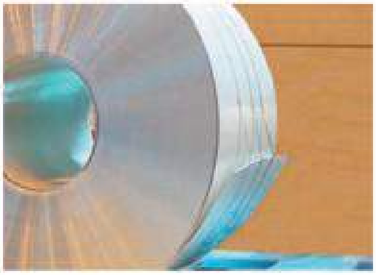
$$\underset{\text{Aluminum}}{2Al} + \underset{\text{Dilute hydrochloric acid}}{6HCl} \rightarrow \underset{\text{Aluminum chloride}}{2AlCl_3} + \underset{\text{Hydrogen gas}}{3H_2}$$

Aluminum does not reacts with both concentrated and dilute nitric acid continually. Because aluminum oxide (Al_2O_3) forms a layer which isolates the acid from the metal, therefore the reaction stops. This property helps to use aluminum containers for storing nitric acid.

Thermite Reaction

Exercise(3-2)
Compare between Aluminum and iron oxidation reactions that effected by Air .

Figure 3-3
Welding of railway with thermite process



Aluminum reacts with basic solutions like sodium hydroxide or potassium hydroxide to release hydrogen gas and aluminum salt . It is worth noting that aluminum reacts with acids and bases to release hydrogen gas in both cases . This behavior is called Amphoteric Behavior.

3-3-4 Uses of Aluminum:

Aluminum and its alloy have a very high mass, and when exposed to air, it forms a thin but firm layer of aluminum oxide which sticks to the metal and protects it from oxidation, therefore, aluminum is a metal with "self- protection" against erosion. This is not the case with iron why ? Because the thin layer of iron oxide (erosion) is very thin and fragile, it lets air, oxygen and humidity penetrate the metal. Therefore, the erosion continues.

Aluminum can be used in electrical wires whereby its connectivity is twice as much of that of copper, considering the mass of both elements, therefore, the diameter of Aluminum wires is larger than that of copper. However, aluminum is used in electrical wires in on a limited level because is expands and shrinks 39% more than copper when exposed to the same heat. Recently, thin layers of aluminum are used to foods, medications and other household appliances as well as various shapes and sizes of cans. Thin aluminum alloys are used to make kitchen utensils, plates, chairs and many other products in Iraq. Aluminum alloy locally is known as "Fafon " is found in every house in Iraq.

Aluminum alloys are also used to make cans and containers to preserve liquids at a very low temperature such as oxygen, argon and nitrogen ..etc , this is because of the fact that the lower the temperature the harder aluminum gets. As for the elements mixed with aluminum in making alloys, they are lead, copper, zinc and magnesium.

3-3-5 Aluminum Alloys:

The most important aluminum alloys are:

1- Duralumin Alloy:

This alloy consists of a high percentage of aluminum and a small amount ratio of copper and magnesium. It might contain manganese as well. This alloy is light and hard so it is used for building aircraft parts.

Usages of aluminum

2- Aluminum Bronze Alloy:

This alloy consists of a small percentage of aluminum and a high ratio of copper and other metals sometimes. It is characterized by resistance to erosion, its color changes according to the colors of its component parts, ranging from copper color to gold color and silver color, therefore it is used to make decoration materials.

Manufactured window from Aluminum

3-3-6 Aluminum Compounds:

1- Aluminum hydroxide $Al(OH)_3$:

It is result of a reaction between aluminum aqueous solutions of aluminum salts like (aluminum sulfate) $Al_2(SO_4)_3$ with sodium or potassium hydroxide

Aluminum hydroxide is a white gelatin material insoluble in water.

2- Aluminum Oxide Al_2O_3:

Results from excessive heating of aluminum hydroxide as in the following formula:

$$2Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + \mathbf{3}H_2O$$

3- Alum:

When two equal amounts of aqueous aluminum sulfate and potassium sulfate are mixed and allow the mixture so that water evaporates, the result would be salt crystals containing aluminum sulfate and potassium sulfate along with crystallized water molecules in a fixed mass ratio.

Aluminum alloy

The general formula for Alum is $KAl(SO_4)_2.12H_2O$. It is also called Potassium alum. Normal Alum has many uses as a sterile minor cuts, whereby it helps blood to clot easily because it dissolves in water and $Al(OH)_3$ deposits on the wound and stops blood so it clot. It is also used to make dye permanent on textiles and in purifying drinking water.

3-3-7 Test of Aluminum Ions in Solution of Aluminum Compounds:

Aluminum ion is identified in its compounds by basic solution such as sodium hydroxide or potassium hydroxide whereby they react with aluminum ion Al^{3+} to form a white gelatin deposit which is aluminum hydroxide $Al(OH)_3$ as in the following formula:

$$\underset{\text{Aluminum ion}}{Al^{3+}} + \underset{\text{Sodium hydroxide}}{3NaOH} \rightarrow \underset{\text{Aluminum hydroxide}}{Al(OH)_3\downarrow} + \underset{\text{Sodium ion}}{3Na^+}$$

Aluminum oxide in the precious stones

For example:

$$AlCl_3 + 3NaOH \rightarrow Al(OH)_3\downarrow + 3NaCl$$

This precipitate, $Al(OH)_3$, dissolves when sodium hydroxide NaOH is added because dissolved sodium aluminate is formed, it ($Al(OH)_3$) also dissolves when an acid is added because of the amphoteric behavior.

CHAPTER QUESTIONS 03

3.1 Which of the following elements is not found in group IIIA.

a) $_{31}Ga$ b) $_{13}Al$ c) $_{12}Mg$ d) $_{5}B$

3.2 Choose from the brackets to complete the scientific meaning in the following terms :

1-What is the role of Aluminum for Thermite reaction?

a) Catalysis

b) Reducing agent

c)Oxidizing agent

2-What is the percentage of aluminum in aluminum bronze alloy?

a) High b) Small c)100%

3- Galium Ga is a member of group (first , second , third)

3.3 Complete the following statements

1-Aluminum reacts with acids to release .... gas, while when reacts with bases it release ...., because ....

2- The effect of oxygen in air on Aluminum don't lead to corrosion as in the case of iron because of .... , ...

3- Heavy heating of Aluminum hydroxide gives .... , ...

4- Salt composed from potassium and aluminum elements called ....

5- The Aluminum behavior when reacts with acids and bases is called ....

3.4 Explain the extraction of aluminum and draw the figure.

3.5 Select from list (B) what fits each statement in the list (A)

list A

1- An element with amphoteric behavior.

2-A reaction in which Aluminum reacts as reduced agent and releases high heat energy that dissolves iron.

3-Aluminum oxide

4-Double salt of potassium sulphate and aluminum

5-One element of group IIIA which is semi-metal

list B

1-Thermite

2-Alum

3-Alumina

4-Aluminum

5-Indium

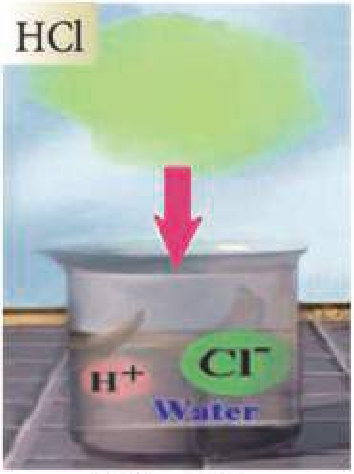
6-Boron

CHAPTER 04

SOLUTIONS AND EXPRESSIONS FOR CONCENTRATION

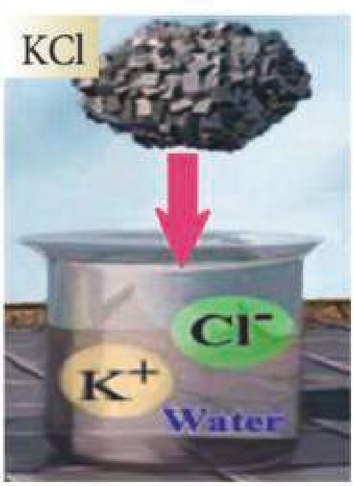
After reading this chapter, students are supposed to be able to:

1- Identify solutions and their nature.
2- Distinguish types of solutions.
3- Understand solubility and factors affecting it.
4- Identify some expressions for concentration, which are mass ratio and volume ratio.



Acidic solution

Basic solution



Salt solution

Figure 4-1
Different types of solutions

4-1 INTRODUCTION

Solutions are important in chemistry science with a great extent, especially liquid solutions because they are the medium for chemical reactions, whereby they help to happen interaction among reacting substances.

4-2 SOLUTIONS

It is a homogeneous mixtures composed of two or more pure substance having no chemical reaction between them, the substance with majority in the solution is called the (solvent) and the material with less existence in the solution is called the (solute). This relation can be represented by the following equation.

Solute + solvent $\longrightarrow$ solution

4-2-1 Types of Solutions:

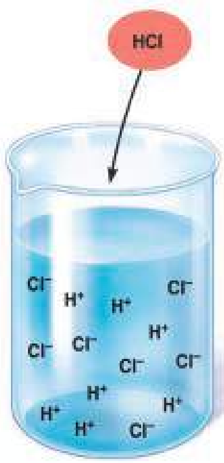
There are several kinds of solutions, the most important and most common are liquid solutions, i.e., when the solvent is liquid. Such solutions can be prepared by dissolving a solid material in a liquid, as in the case of dissolving salt (NaCl) in water to get the saline solution or dissolve sodium hydroxide in water (basic solution), or dissolving liquid in another liquid, like dissolving alcohol in water. A gas can be dissolved in a liquid such as dissolving hydrogen chloride (HCl) in water, the resulting solution is called hydrochloric acid solution (acidic solution), Figure (4-1)

$$\underset{\text{Hydrogen chloride gas}}{HCl} \xrightarrow{H_2O} \underset{\text{Solution of hydrochloric acid}}{HCl}$$

There are other types of solutions such as dissolving gas in another gas like air or a solid solution in another solution like various alloys, mostly coins and gold alloys, in this chapter we will only study liquid solutions.

4-2-2 Nature of Solutions:

Names of solutions vary according to the amount of the solvent and the solute and also the nature of the dissolving process. A saturated solution is the solution which contains a greater amount of the solute and the solvent can dissolve no more of solute at the given temperature and pressure. When the amount of the solute is greater in any solution that the solvent is able to dissolve it under normal conditions, this solution is called super saturated solution, this kind of solution is not stable whereby it deposits the extra amount of the solute, turning it into a saturated solution. An unsaturated solution is the solution which contains less amount of the solute that is required for saturation at a particular temperature and pressure. (Figure 4-2)
When the solute molecules ionize in the solution, it is called electrolytic solution. The solute can be strongly ionized when its molecules are completely ionized in the solution like hydrochloric acid. (Figure 4-3)



$HCl \longrightarrow H^+ + Cl^-$

Figure 4-3

A strong electrolyte solute ionizes completely in a solvent.

Saturated solution

Super saturated solution

Unsaturated solution

Figure 4-2

The solute can be weak electrolyte, i.e. its molecules are partially, moderately or slightly ionized like hydrofluoric acid, whereby it slightly ionizes in the solvent, its ions are at equilibrium with the non-ionized molecules. In the formula, $HF \rightleftharpoons H^+ + F^-$, reversed arrows indicate that the slightly ionized substance is at equilibrium with the resulting ions.(Figure 4-4)
There are compounds whose molecules don't ionize at all, these are called non-electrolytic solutions such as sugar or ethyl alcohol in water.

4-3 SOLUBILITY

Solubility is known as the maximum amount of a solute which can be dissolved in a given amount of a specific solvent to result in a saturated solution at a given temperature. Solubility varies according to the nature of the solute and the solvent, temperature and pressure. Such factors will be discussed in detail below.

4-3-1 Nature of the solute and the solvent:

When a small amount of table salt is added into water in a beaker, the salt crystals dissolve slowly if the beaker is shaken, the salt crystals dissolve more quickly, whereby the process of shaking helps to contact the surface of crystals with water even greater, because the process of solubility has to do with surfaces which are exposed to dissolution, this is why we stirred with a spoon when sugar is added, figure 4-5. Sugar powder dissolves faster than lumps of sugar because the surfaces of the powder is greater than those of the lumps of sugar,therefore, it is concluded that the more exposed the surface of the solute in the solvent, the greater the solubility .
For the solvent, the nature of polarity determines its solubility, according to a rule which says: Like dissolves like,i.e.
Polar solvents dissolve polar solutes and vice versa. It is worth nothing though that insoluble substance ever dissolves no matter how long they are left in the solution or how hard they are stirred.

Figure 4-4

Figure 4-5

4-3-2 Temperature:

When a spoon of sugar is added into two glasses filled with liquid, one glass is filled with a hot liquid and the other is filled with a cold liquid. Sugar in the hot liquid dissolves faster than that in the cold liquid because the motion energy of the liquid molecules increases, making it more likely to collide with surfaces of sugar crystals, this is why it dissolves quickly. See figure 4-6.

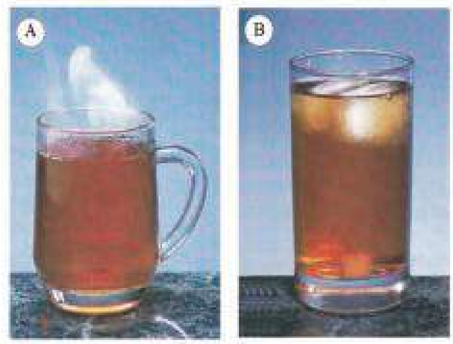


Figure 4-6

A) Sugar dissolves in cold water slowly.

B) Sugar dissolves in hot water quickly.

4-3-3 Pressure:

The effect of pressure on solubility is best shown on gaseous materials whereby their solubility increases as the pressure of gas on the surface of the solution increases. For example, in carbonate beverages, the concentration of dissolved carbon dioxide CO_2 in the liquid depends on the pressure of CO_2 on the surface of the beverage. When the cover is removed, CO_2 pressure will decrease and making it less soluble, bubbles are formed and move up in the liquid. See figure 4-7

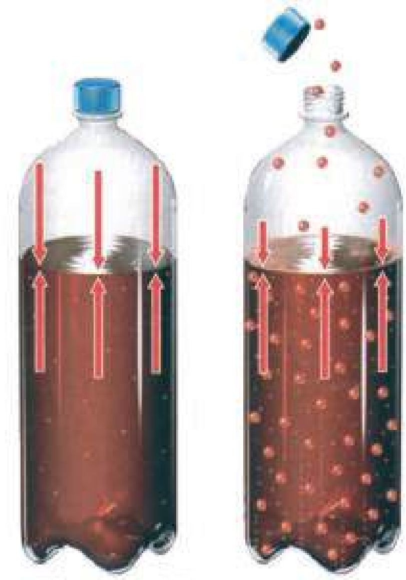


Figure 4-7

4-4 CONCENTRATION OF SOLUTION:

It has already been noted that a solution consists of two major parts: the solute and the solvent. Solutions vary in the amount of the solute and the solvent. There are ways to express these amounts and their relations to each other. This relation is often referred to "concentration of the solution"; it is the amount of solute in a particular solvent or solution. The concentration of the solution can be descriptively or qualitatively expressed, the terms "dilute" and "concentrated" are used to describe concentration of the solutions, see figure 4-8. Solutions with relatively small amount of solute are called "dilute", whereas solutions with large amount of the solute are called "concentrated". A concentrated solution can be changed into dilute by adding a larger amount of the solvent. As in qualitative expression, concentration of the solution can be expressed in various ways:

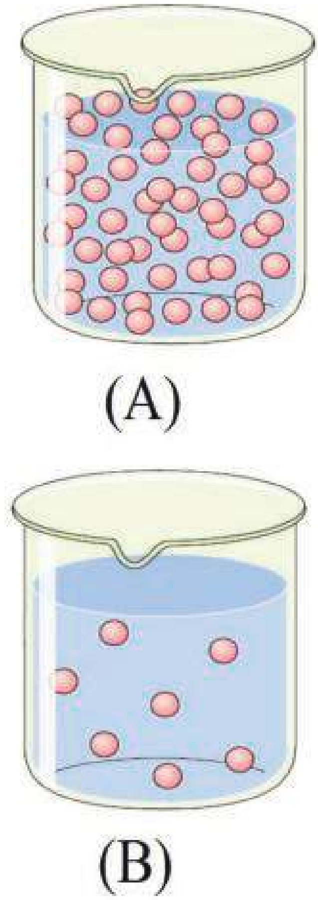


Figure 4-8
A) Concentrated solution
B) Dilute solution

4-4-1 Concentration by Mass percentage:

It is the number of grams of the solute which are dissolved in 100 grams of the solution. The percentage of mass ratio of the solute and the solvent is calculated as follows:

$$\text{Percentage concentration of solute} = \frac{\text{mass of solute } (m_1)}{\text{mass of solution } (m_1 + m_2)} \times 100\%$$

$$\text{Solute \%} = \frac{m_{solute}}{m_{solution}\,(m_T)} \times 100\%$$

$$\text{Percentage concentration of solvent} = \frac{\text{mass of solvent } (m_2)}{\text{mass of solution } (m_1 + m_2)} \times 100\%$$

$$\text{Solvent \%} = \frac{m_{solvent}}{m_{solution}\,(m_T)} \times 100\%$$

Whereby (m_1) refers to solute mass, (m_2) refers to solvent mass and (m_T) refers to the solution mass (total masses of both solute and solvent (m_1+ m_2)). Generally the mass percentage of any component can be expressed in the following mathematical relation:

$$\text{Mass ratio of any component of the solution} = \frac{\text{mass of component}}{\text{mass of solution}} \times 100\%$$

Example 4-1

What is the mass ratio of the solute and the solvent of a solution made of 15.3 g of salt dissolved in 155 g of water.

Solution:

Mass of solute: m_1 = 15.3 g
Mass of solvent: m_2 = 155 g
Mass of solution = m_T
$m_T = m_1 + m_2 = 15.3 + 155 = 170.3$ g

Exercise 4-1
A solution is formed by dissolving 48.2 g of sugar in 498 g of water. What is the mass ratio of sugar and water in the solution?

$$\text{Mass percentage of the solute} = \frac{m_1}{m_T} \times 100\%$$

$$\text{Solute \%} = \frac{15.3\ g}{170.3\ g} \times 100\% = \mathbf{8.98\ \%}$$

$$\text{Mass percentage of the solvent} = \frac{m_2}{m_T} \times 100\%$$

$$\text{Solvent \%} = \frac{155\ g}{170.3\ g} \times 100\% = \mathbf{91.02\ \%}$$

Exercise 4-2
20 g of hydrochloric acid is diluted by 80 g of water. What is the mass ratio of the acid and water in the solution?

Example 4-2
A sample of vinegar contains 4% of acetic acid by mass. How many grams of vinegar is required to obtain 20 g of acetic acid?

Solution:

$$\text{Mass percentage of the solute} = \frac{m_{solute}}{m_{solution}} \times 100\%$$

$$4\ \% = \frac{20\ g}{m_{solution}} \times 100\%$$

$$m_{solution} = \frac{2000\ g}{4} = 500\ g \text{ of vinegar is necessary.}$$

4-4-2 Concentration in volume percentage :
It is ratio of volume of each component of the solution compared to the total volume of the solution multiplied by 100.

$$\text{Percentage of volume for solute} = \frac{\text{volume of solute } (V_1)}{\text{volume of solution } (V_1 + V_2)} \times 100\%$$

$$\text{Solute \%} = \frac{V_{solute}}{V_{solution}\,(V_T)} \times 100\%$$

$$\text{Percentage of volume for solvent} = \frac{\text{volume of solvent } (V_2)}{\text{volume of solution } (V_1 + V_2)} \times 100\%$$

$$\text{Solvent \%} = \frac{V_{solvent}}{V_{solution}(V_T)} \times 100\%$$

Whereby volume of solute is V_1, volume of solvent is V_2, and volume of solution is V_T (total volumes of solute and solvent (V_1+V_2). Generally the mathematical formula can be written to express concentration in terms of percentage of volume.

$$\text{Percentage of volume for any component} = \frac{\text{volume of component}}{\text{volume of solution}} \times 100\%$$

Units of volume which are commonly used Liter (L) or milliliter (mL) or cubic centimeter (cm^3). Conversions between these units are as follows:

1 L = 1000 mL
1 L = 1000 cm^3
1 mL = 1 cm^3

A) Dilute acidic solution
B) Concentrated acid Solution

Example 4-3

Calculate the percentage of volume for both acetic acid and water in a solution formed by mixing 20 mL of acetic acid and 30 mL of water.

Solution:

Volume of the solute: V_1 = 20 mL
Volume of the solvent: V_2 = 30 mL
Volume of the solution V_T: (V_1+V_2) = 20 + 30 = 50 mL

$$\text{Percentage of volume for solute} = \frac{V_1}{V_T} \times 100\%$$

$$\text{Percentage of volume for solute} = \frac{20 \text{ mL}}{50 \text{ mL}} \times 100\% = \mathbf{40\%}$$

$$\text{Percentage of volume for solvent} = \frac{V_2}{V_T} \times 100\%$$

$$\text{Percentage of volume for solvent} = \frac{30 \text{ mL}}{50 \text{ mL}} \times 100\% = \mathbf{60\%}$$

Example 4-4

What is the volume of ethyl alcohol expressed in mL that is required to be added into water so that the total volume of the solution would be 50 mL, and its percentage of volume would be 80%.

Exercise 4-3

If 20 mL of sulfuric acid is added to 80 mL of pure water what will be percentage of volume for both sulfuric acid and water?

Answer:

Acid: 20 %

Water: 80 %

Solution:

$$\text{Percentage of volume of component} = \frac{V_1}{V_T} \times 100\%$$

$$80\% = \frac{V_1}{50\ \text{mL}} \times 100\% \Rightarrow \mathbf{40\ mL}\ \text{of ethyl alcohol is required.}$$

4-3-3 Expressing Concentration by Mass /Volume :

Sometimes, concentration is expressed by mass unit of the solute (gram) in a given volume of the solution (liter), the unit for this kind of concentration is (gram/liter) (g/L).

$$\text{Concentration (g/L)} = \frac{\text{Mass of the solute (m)}}{\text{Volume of the solution (V)}}$$

It is worth noting this expression of concentration itself is the definition of density which is the unit for volume mass. If density is symbolized by the Latin character (ρ), Mass (m) and Volume (V), therefore, density is expressed by the following relation:

$$\text{Density (g/L)} = \frac{\text{Mass (g)}}{\text{Volume (L)}} \Rightarrow \rho\ \text{(g/L)} = \frac{m(g)}{V\ (L)}$$

Other units can be used for volume like (mL) or (cm^3).

Exercise 4-4

What should be mass of sodium hydroxide dissolved in 1 L of pure water in order to obtain a solution with 0.5 g/L concentration?

Answer:

Sodium hydroxide: 0.5 g

Example 4-5

5 grams of copper sulfate are dissolved in 0.5 L of distilled water. Calculate the concentration of solute in the solution with g/L unit.

Solution:

$$\text{Concentration (g/L)} = \frac{m(g)}{V\ (L)} = \frac{5\ g}{0.5\ L} = 10\ g/L$$

Example 4-6

Calculate the mass percentage of methyl alcohol in a solution containing 27.5 g of methyl alcohol and 175 mL of water and assume that density of water is 1.00 g/mL.

Exercise 4-5

KCl is 5.80 % by mass in a solution. Calculate mass of KCl in 0.337 L of the solution. (Suppose that density of the solution is 1.05 g/mL.)

Answer:

Mass of KCl: 20.52 g

Solution:

$$\rho\ \text{(g/mL)} = \frac{m(g)}{V\ (mL)} \Rightarrow m(g) = \rho\ (g/mL) \times V\ (mL)$$

$m(g) = 1\ (g/mL) \times 175\ (mL) = 175\ g$

Mass of methyl alcohol: $m_1 = 27.5\ g$

Mass of water: $m_2 = 175\ g$

Mass of solution: $m_T = m_1 + m_2 = 27.5\ g + 175\ g = 202.5\ g$

$$\text{Mass percentage of methyl alcohol} = \frac{m_1}{m_T} \times 100\%$$

$$= \frac{27.5\ g}{202.5\ g} \times 100\% = \mathbf{13.6\%}$$

CHAPTER QUESTIONS 04

4.1 Describe the following

Solution, saturated solution, solubility, electrolytic solution, concentrated solution, concentration by mass percentage, concentration in volume percentage.

4.2 1-Which answer is true example for solid solution?

a) Juice
b) Coin
c) Salt solution

2-What is the definition of weak electrolyte solution?

a) if solute ionize completely in solvent
b) if solute not completely ionize in solvent
c) if solute fast ionize in solvent

3-The solubility of the sugar in hot water is faster than cold water. What is the main reason of this?

a) The energy of water molecule reduces under high temperature.
b) The energy of water molecule increases under high temperature.
c) The energy of sugar molecule increases under high temperature.

4-How can we convert concentrated solution to dilute solution?

a) by the help of increasing concentration of solute
b) heating solution
c) by the help of adding much more solvent to solution

4.3 Compare the following terms;

a) Dilute and concentrated solution.
b) Weak electrolytic and strongly electrolytic solution.
c) Super saturated and unsaturated solution.

4.4 There is 19 g dissolved solute in 158 g solvent, find mass percentage of the solution.

4.5 5 g of copper sulfate is dissolved in 20 g of pure water, calculate mass percentage of solute and solvent.

4.6 How many liters of water is needed to add 10 g of potassium hydroxide to obtain a solution with 2.5 g/L concentration?

4.7 If 25 mL HCl and 75 mL water are mixed, what will be percentage of acid and water by volume in the solution?

4.8 Calculate the mass percentage of NaCl in the solution, if 15.3 g NaCl and 155.09 g water are mixed.

4.9 A solution is prepared by dissolving 27.5 g of methyl alcohol in 175 mL water. Calculate the concentration of the solution in g/L.

4.10 A sample of water is taken from The Habbaniyah Lake. Assume that It contains 8.5 % carbon dioxide. What is the mass of carbon dioxide in 28.6 liters of the Lake water? (Density of the Lake water is 1.03 g/mL.)

4.11 Mass percentage of sugar is 11.5% in juice also juice contain 85.2 g sugar, what is the volume of juice? ($\rho_{solution}$ = 1 g/mL)

4.12 What are the factors that effected on solubility ?

4.13 Calculate the mass percentage concentration of the following solutions.

a) 10.2 g NaCl in 155 g of water
b) 48.2 g sucrose in 498 g of water
c) 0.245 g acetic acid in 4.91 g of water

4.14 Find mass percentage of sugar which contains 309 grams water and 45 grams sugar.

4.15 The mass percentage of NaCl in ocean water is 3.5%. How many grams of NaCl can be obtained from 274 grams of ocean water?

4.16 Find the volume of alcohol in millilitters present in the following solution:
1-480 ml of a solution containing 3.7 % volumetric percentage of the alcohol
2- 103 of a solution containing 10.2% volumetric precentage of the alcohol
3- 0.3 L of a solution containing 14.3% volumetric percentage of the alcohol

4.17 How many grams of KCl is present in each of the following solutions?

a) 19.7 g solution consists of 1.08 % solute by mass.
b) 23.2 kg solution consists of 18.7 % solute by mass.
c) 38 mg solution consists of 12 % solute by mass.

4.18 Fill in the blanks.

substance	mass of solute	mass of solvent	mass of solution	percentage mass of solute
A	15.5 g	238.1 g		
B	22.8 g			12 %
C		183.3 g	212.1 g	
D	31.52 g			15.3 %

4.19 Fill in the blanks.

substance	vol. of solute	vol. of solvent	vol. of solution	percentage vol for solute
A	2.55 ml	25.0 ml		
B	4.58 ml			3.8 %
C	1.38 ml		27.2 ml	
D	23.7 ml			5.8 %

CHAPTER 05

GROUP IVA

At the end of this chapter, the student is able to:

1- Identify the location of group IVA in the periodic table and the names and symbols of its elements.
2- Know the general characteristics of group IVA elements.
3- Write the electron configuration for the silicon atom.
4- Know the occurrence of silicon in nature and its importance.
5- Understand the process of preparation of silicon industrially and in laboratories.
6- Recognize the physical and chemical properties of silicon.
7- Recognize the natural and industrial silicon compounds.
8- Know Silicon uses.

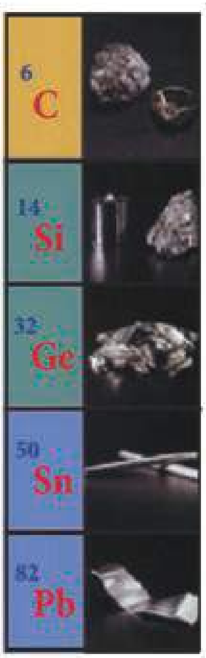
5-1 GROUP IVA ELEMENTS

Group IV A consists of the following elements: Carbon (C), Silicon (Si), Germanium (Ge), Tin (Sn) and Lead (Pb). The following table shows the location of group IVA in the periodic table. (Figure 5-1)

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						

Figure 5-1

Location of Group IVA periodic table



5-2 GENERAL CHARACTERISTICS OF GROUP IVA

Group IVA is more various and numerous in the characteristics of its members than other groups in the periodic table. The members of this group show a clear tendency to transfer from the nonferrous to metal characteristics as we go higher to lower in the group, as the atomic number increases.i.e.Carbon is nonferrous, silicon and germanium are metalloid and tin and lead are pure metals. Thus, tin and lead have the physical characteristics of metals such as high density and thermal and electro conductivity together with bright color and high malleable and ductile prone. The melting and boiling points of group IV elements also decrease as we go from the top to bottom.

The elements of this group are also known to have four valence electrons in their outer shells. They need to gain, lose or combine four electrons to reach the stable electron configuration. Due to the difficulty of gaining or losing four electrons, the elements of this group tend to combine four electrons via making covalent bonds to reach the tetra-oxidation case (+4). In fact, silicon and carbon compounds are actually covalent compounds of tetra-oxidation.

Germanium, tin and lead, on the other hand, combine to make ionic and covalent compounds. In the ionic compounds, only two electrons are lost to make Ge^{2+}, Sn^{2+} and Pb^{2+}. The elements of this group whether metalloid or nonmetals, have low level of activity. They react with the nonmetals such as oxygen but they need heat to do so.

5-3 SILICON

The figure 5-2 shows the electron configuration of silicon. It shows that silicon has four electrons in its outer shell. As it is so difficult for an element to gain or lose four electrons, silicon combines with its four electrons to form compounds, most of which are covalent silicon compounds. Its valence electrons is four.

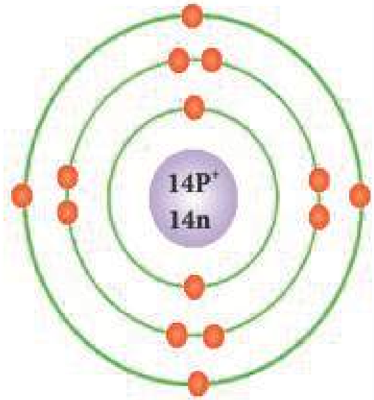


Figure 5-2
Electron configuration of silicon atom.
Chemical symbol: Si
Atomic number : 14
Mass number : 28

Shell symbol	Shell number(n)	Electron number
K	1	2
L	2	8
M	3	4

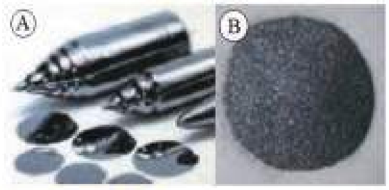


Figure 5-3
Types of silicon
A) crystallized
B) non-crystallized

5-3-1 Occurrence in Nature:

Silicon is the most abundant element in the earth's crust after oxygen. It constitutes more than one quarter of the earth's crust, approximately 28%. It occurs mostly in combination with oxygen in soil or as various forms of sand and clay deposits. It does not occur as a pure free element in nature. It is most widely distributed in rocks as silicon dioxide (SiO_2). It is in the form of quartz and sand. Silicon has two main forms (Figure 5-3). The first form of silicon is crystallized of dark brown color. The second form is non-crystallized of dark gray color. The crystallized form is less active than the non-crystallized one. Both forms have a formula similar to diamonds.

A-Preparation In Laboratory:

Non-crystallized silicon can be produced by heating potassium element in silicon tetra fluoride (SiF_4) according to the following equation:

$$SiF_4 + 4K \xrightarrow{\Delta} Si + 4KF$$

Scientist Berzelius

The crystallized silicon can be obtained by melting silicon in aluminum then cooling the solution. Finally, silicon crystals can be separated from the solution.

B- Industrial Preparation:

Silicon (Si) can be prepared industrially by reducing silica (SiO_2) using high temperature and carbon or magnesium as a reducing element, as in the following equation:

$$SiO_2 + 2C \xrightarrow{\Delta} 2CO\uparrow + Si$$

5-3-3 Properties of Silicon:

A-Physical Properties:

Silicon is a metalloid. It is a very rigid element, with a high melting point of approximately (1410 °C). It has a gray color and a metallic luster. It is also a semi conductor. Due to this property, it is used in manufacturing of electrical devices and applications and also in computer industry. In addition, it is used in manufacturing solar cells which convert the solar energy into electricity.

B-Chemical Properties:

Silicon does not react with most acids. It melts in aqueous solution of bases according to the following reaction:

$Si + 2NaOH + H_2O \rightarrow Na_2SiO_3 + 2H_2$

Silicon is very reactive with chlorine as in the following equation.

$Si + 2Cl_2 \rightarrow SiCl_4$

Silicon is not prone to react with air at room temperatures.It reacts at(950°C). Silicon and its natural compounds (silica and silicate) are not poisonous.

Silicon at high temperature

5-3-4 Uses of Silicon:

Silicon has a wide variety of uses. It is used in:

1-Electronics industry, electrical appliances and in manufacturing solar cells. (Figure 5 - 4)

2-Metal bars used in different industries.

3-Glass, cement and ceramics industries.

4-Organic silicon materials which are very important commercially in the production of oils and plastics.

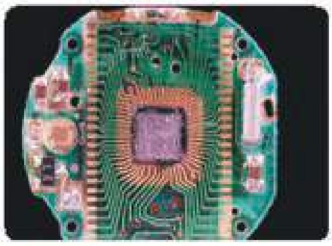


Figure 5 - 4
Use of silicon in integrated circuit industry

5-3-5 Silicon Compounds:

Silicon forms a great number of compounds such as:

a- Silicon compounds with hydrogen silicon hydrates. (Silane)

These compounds consist of silicon and hydrogen. SiH_4 is an example of such compounds. It is prepared by the reaction of magnesium silicide Mg_2Si with the acids such as hydrochloric acid as in the following equation:

$Mg_2Si + 4HCl \rightarrow SiH_4 + 2MgCl_2$

Figure 5 - 5
A sample of pure silicon

Hydrates are so active compounds. For example silicon (IV) hydride burns spontaneously in atmosphere and forms silicon dioxide and water as in the following reaction.

$$SiH_4 + 2O_2 \rightarrow SiO_2 + 2H_2O$$

b- Silicon Compounds with Oxygen

1- Silicon Dioxide (Silica) SiO_2

It occurs in nature as pure silica such as quartz and flints (Figure 5-5). They are highly solid substances and are used in cutting glass and scratching steel. The other form of silicon dioxide (Silica) (SiO_2) is the impure silica such as sand and clay (Figure 5-6). It contains different quantities of impurities which give it a wide range of different colors. The most important properties of silica are:

a- It is not reactive when reacts with chlorine, bromine, hydrogen or most of the acids.

Figure 5 - 6

b- It reacts with hydrofluoric acid and bases:

c- It reacts with oxides or metal carbonates by high heating. The resultant compounds are known as (silicates).

Figure 5 - 7 Silica gel as a desiccant factor

d- Silica gel is mainly used as a drier due to its large surface and great ability to absorb water. (Figure 5-7)

2- Silicates

Silicate occurs so widely in nature.

Among other types of silicates, sodium silicate is the most widely used. It is soluble in water and its concentrated aqueous solution is called "water glass" or "liquid glass".
It is commonly used in various industrial fields such as providing passive fire protection for textiles and papers. It is also used as a cheap adhesive. Cement can be strengthened by mixing it with sodium silicate in order to be used in buildings.

Figure 5-8
Soil is one of natural silicates.

c- Silicones:
These compounds are organic compounds of silicon. They aren't poisonous and are very stable along a very wide range of temperature variation. Silicon oils are the most important of these compounds. They make the surfaces anti moisture and are used to cover the roofs of buildings.
Silicone rubber, maintains flexibility at a wide range of temperature variation. It is used in manufacturing of molds and as a sealing substance in baths and kitchens. Silicone resin is used in electrical insulation and in making construction materials water proof ,too.

CHAPTER QUESTIONS 05

5.1 Write the following reaction equation:
1) Magnesium and silicon dioxide
2) Magnesium silicide and hydrochloric acid
3) Silicon dioxide and carbon

5.2 Write electron configuration of following elements and ions; Si and Si^{4+}

5.3 Where are silicon and its compound used? Write them.

5.4 Explain with writing chemical equation how to prepare silicon?

5.5 Complete the following:

1- There are two types of silicon dioxide (silica) in nature, first one pure as ...., and .... and non-pure type such as ...., and ....

2- It can be prepare...................... from extreme heating silica with metal carbonate or metal oxide.

3- The elements of the fourth group have common oxidation .... , ...

4- The oxidative state .... is more stable in carbon and silicon .

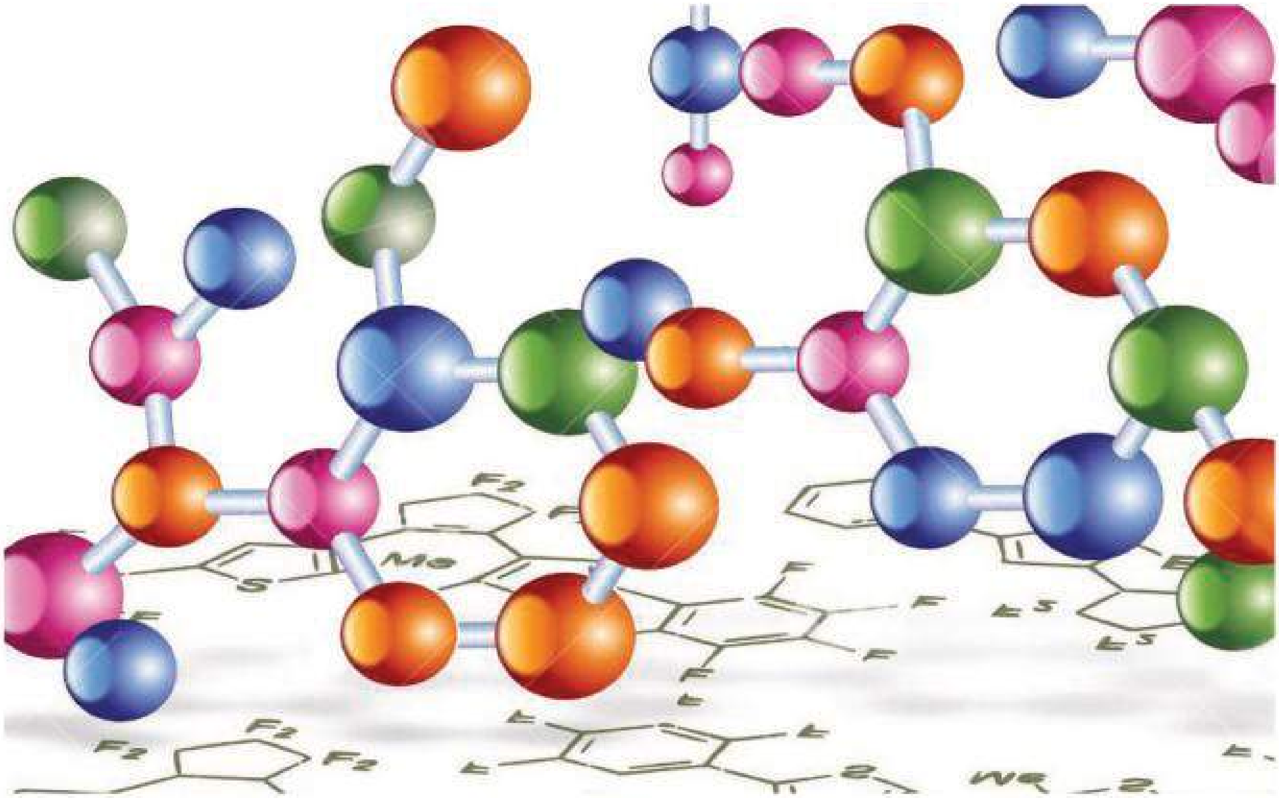
5- The silicon reacts when it heated to (950 c°) with oxygen or aerated air to give ....

6- The more the characteristics in group IVA..... .... when we move from the top of the group to the bottom in this group, also the elements of this group .... decrease as we move from the top to bottom.

7-Silicon has two main forms, the first form of silicon is .... has .... color, the second form ...., and has .... color.

CHAPTER 06

INTRODUCTION TO ORGANIC CHEMISTRY



After completing this chapter , students will be able to:

1-Realize importance of organic compounds.
2-Identify characteristics and features of organic compounds.
3-Relate organic chemistry with the environment and life.
4-Distinguish between methane, ethylene and acetylene gases.
5-Prepare methane, ethylene and acetylene gases, and understand. the properties of each them.

6-1 INTRODUCTION

During our study of chemistry in previous years, we have addressed in some detail: Carbon and some of its important compounds in our life, such as (carbon dioxide and calcium carbonate). Earlier in this book, we have addressed group 4A (IVA) which includes the elements (C, Si and Ge). Organic chemistry will be discussed in this chapter in keeping with knowledge expansion in all aspects of chemistry and due to the considerable importance of carbon for its unique features as it the major and principal element in the molecules of living organisms and their nutrition. It also contributes in several aspects of our daily live (drugs, fragrances and paints and in what is known now as Organic Chemistry. Therefore this chapter will be devoted to the study of this branch of chemistry, a study in some detail of the general properties and some organic compounds like methane, ethylene and acetylene as well as ethyl alcohol, benzene, acetic acid and phenol.

6-2 IMPORTANCE OF ORGANIC COMPOUND

Organic compounds are important in our lives as they represent

1- All forms of basic food materials for human and animals, which are: proteins, carbohydrates, animal fat and plant oil .

2- Many natural and synthetic products like cotton, wool, natural and synthetic silk, paper and plastics.

3- Fuel like petroleum, natural gas and wood.

4- Medical drugs as well as vitamins, hormones and enzymes.

Organic compounds in our lives

6-3 EXISTENCE OF CARBON IN ORGANIC COMPOUNDS

Carbon is the essence of the organic compound and to prove its existence in such compounds, the following experiments can be used:

1- When lighting a candle or a piece of paper or (any organic material), carbon dioxide, CO_2, is released which can be found by adding calcium hydroxide solution, $Ca(OH)_2$, which makes it turbid, whereby calcium carbonates are formed, $CaCO_3$.

2- When sugar, an organic substance, is burnt in a test tube, a black substance is formed which is carbon. This indicates that carbon is found in sugar as a component.

Burning of sugar

6-4 GENERAL FEATURES OF ORGANIC COMPOUNDS

Organic compounds in general have distinctive features, including the followings:

1- All organic compounds contain carbon in their compositions and are subject to decomposition or combustion by heating, particularly if heated to high temperature.

2- Atoms in the organic compounds are bonded by covalent bonds, making them react slowly.

3- Many organic compounds do not dissolve in water but soluble in some organic liquids such as alcohol, ether, acetone and carbon tetrachloride.

Exercise 6-1

How can you prove presence of carbon in organic compounds experimentally?

6-5 COVALENT BONDS OF CARBON ATOMS IN ORGANIC COMPOUNDS

Carbon has an atomic number of 6, therefore the electron configuration can be illustrated in figure (6-1). One can observe that the outer shell (valence shell) of carbon atom contains four electrons. Therefore, for the carbon atom to reach stability it must share the four valency electrons with other atoms, so the number of electrons surrounding each carbon atom would be eight.

As you have already learned that each valence bond needs two electrons (one from each atom), therefore, carbon atoms bind in the following way by four single bonds with hydrogen in a methane molecule (CH_4).

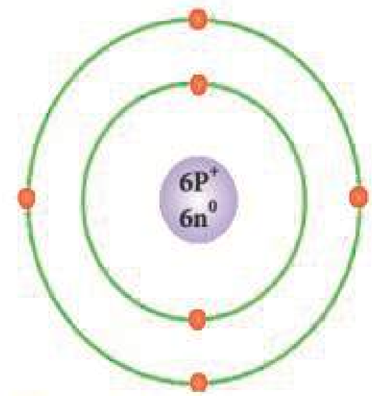
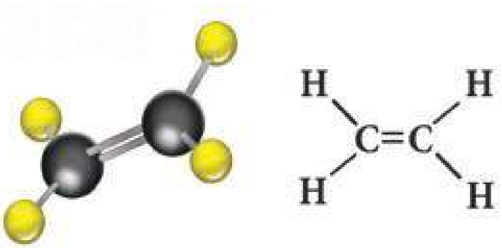


Figure 6-1
Electron configuration of carbon atom

Methane (4 single bonds)



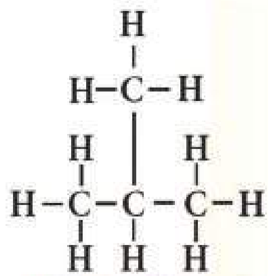
Ethylene: A double bond and 4 single bonds

Carbon atoms might bond with each other in triple bonds, as in acetylene molecule:

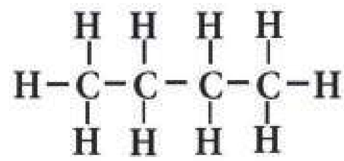
Acetylene : One triple bond and two single bonds;

Such various bonding possibilities for carbon atom in compounds add versatility to this atom in having various valence bonds, not to mention carbon atoms' ability to bond with each other to form open or closed chains (rings).

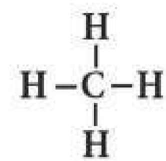
These chains include single, double or triple bonds between carbon atoms or other atoms. Therefore, there are thousands of organic compounds in nature and can also be synthesized as well. The following examples illustrate various forms of Organic compounds:



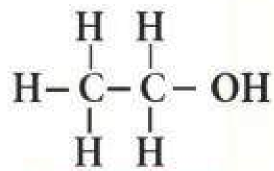
Organic compound (branched chain) Isobutane



Organic compound (unbranched chain) Butane

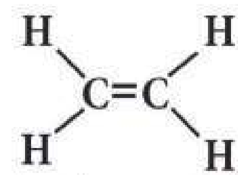


Organic compound with single covalent bond (Methane)



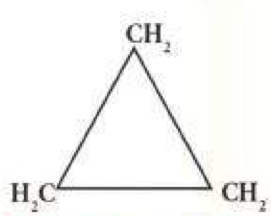
Organic compound containing oxygen element (Ethyl alcohol)

Organic compound with triple covalent bond (Acetylene)

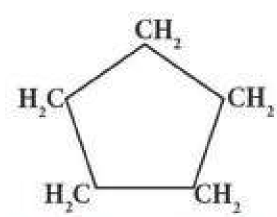


Organic compound with double covalent bond (Ethylene)

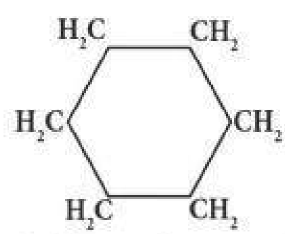
In this chapter, we will study several types of these organic compounds three of which are hydrocarbons, i.e., containing carbon and hydrogen only. These hydrocarbon compounds are: Methane, CH_4, Ethylene, C_2H_4, Acetylene, C_2H_2. Methane represents an example of organic compounds which contain single valence bonds,this type of saturated hydrocarbon compounds is called (alkanes).



Cyclic organic compound in triangular shape (Cyclopropane)



Cyclic organic compound in pentagon shape (Cyclopentane)



Cyclic organic compound in hexagonal shape (Cyclohexane)

As for ethylene molecule C_2H_4, it contains double bonds between carbon atoms, these compounds are called alkenes. Acetylene has triple bond between two carbon atoms. These compounds are called alkynes, both ethylene and acetylene are called unsaturated hydrocarbons.
As for the types which will be addressed in this chapter, they are organic compounds in which carbon atom bonds as well as hydrogen and Oxygen. We will study Ethyl alcohol, acetic acid in addition to benzene and phenol compounds which are examples of closed chain organic compounds.

6-6 SOME ORGANIC COMPOUNDS

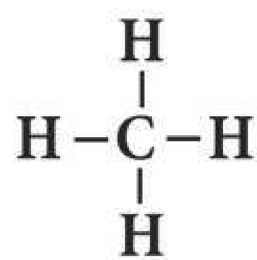
At this stage, we will study some organic compounds such as saturated and unsaturated hydrocarbons, alcohols and acids:

6-6-1 Hydrocarbons:

As it is known from its name, it contains only carbon and hydrogen only, either saturated or unsaturated, these hydrocarbons include:

1- Methane (CH_4):

Its molecular formula is CH_4 whereby a carbon atom is bonded with 4 hydrogen atoms in a single bond.



Structure of Methane

a) Existence in nature:

It is the simplest hydrocarbon compound, it is found in large amounts as natural gas which accompanies crude petroleum, it is emitted from cracks of coal mines, it is also formed when organic materials are decomposed in stagnant waters of ponds and swamps.

b) Preparation of Methane Gas in Laboratory:

Methane is prepared by using the apparatus below (figure 6-2), whereby sodium acetate is heated at high temperature along with sodium hydroxide or calcium hydroxide (because the mixture will have little effect on glass and ensures higher melting point for sodium hydroxide) in a test tube, the resulting gas is collected by removing the water further down.

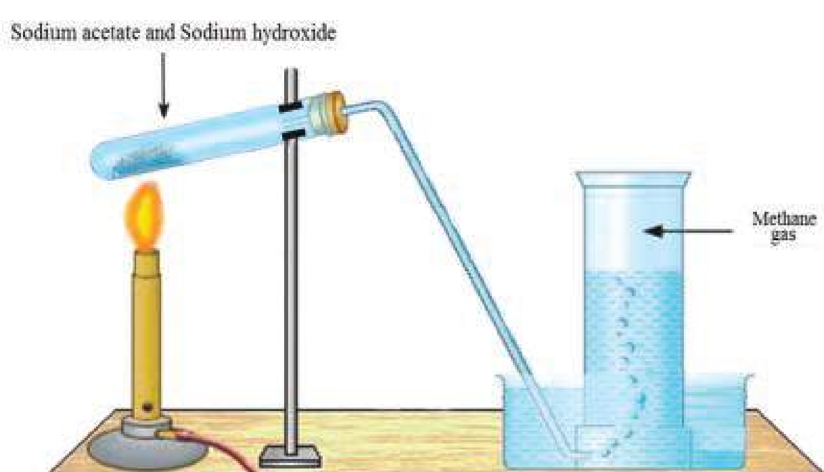


Figure 6-2
An apparatus for preparation of methane gas

$$\underset{\text{Sodium acetate}}{CH_3COONa} + \underset{\text{Sodium hydroxide}}{NaOH} \xrightarrow{\Delta} \underset{\text{Methane}}{CH_4\uparrow} + \underset{\text{Sodium carbonate}}{Na_2CO_3}$$

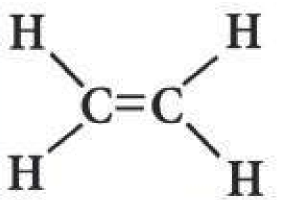
c) Physical and chemical Properties of Methane gas:

1- Colorless and odorless.
2- Highly insoluble in water.
3- Flammable, smokeless flame, releasing carbon dioxide CO_2 and water vapor and energy, as in the following equation:

$$\underset{\text{Methane}}{CH_4} + \underset{\text{Oxygen}}{2O_2} \xrightarrow{\Delta} \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water vapor}}{2H_2O} + \text{Energy}$$

2- Ethylene (C_2H_4):

Ethylene has the molecular formula of C_2H_4 in which two carbon atoms combine with each other through double bond. It is one kind of unsaturated hydrocarbons which are called "Alkenes".



Structure of Ethylene (C_2H_4)

a) Preparation of Ethylene Gas In Laboratory

Ethylene can be produced by heating ethyl alcohol, C_2H_5OH, with sufficient amount of concentrated sulfuric acid up to 170 °C as in the figure 6-3 below.

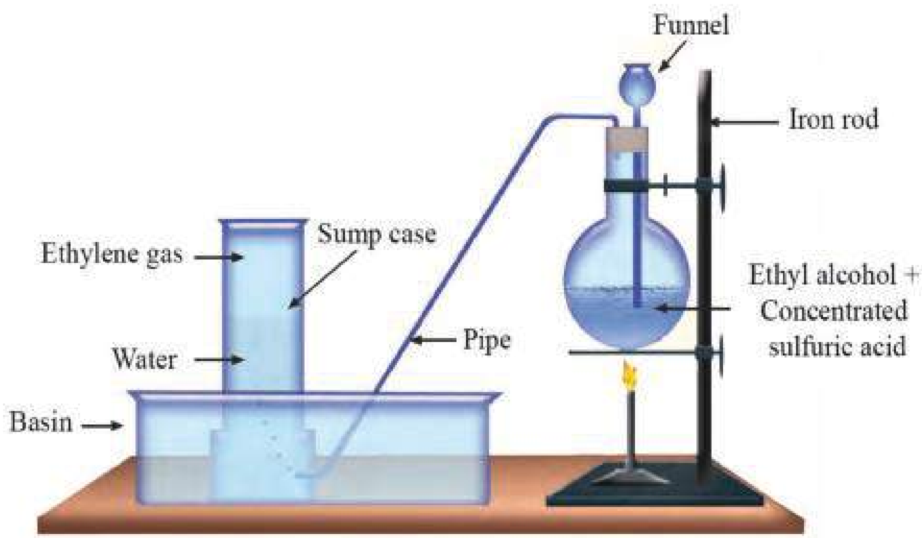


Figure 6-3
An apparatus for preparation of ethylene gas

The sulfuric acid removes water molecule from the of alcohol according to the following equation:

$$\underset{\text{Ethyl alcohol}}{C_2H_5OH} \xrightarrow[170°C]{\text{Concentrated } H_2SO_4} \underset{\text{Ethylene}}{C_2H_4\uparrow} + \underset{\text{Water}}{H_2O}$$

b) Physical and chemical Properties of Ethylene

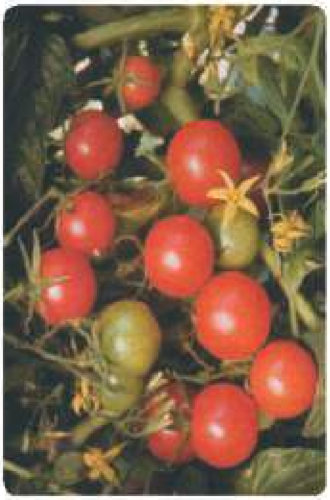
1- It is colorless with sweet and musky odor and insoluble in water.
2- It burns with a smoky flame producing carbon dioxide and water.

$$C_2H_4 + 3O_2 \xrightarrow{\Delta} 2CO_2 + 2H_2O$$

3- It reacts with the red bromine water and removes its color.
This process can distinguish between ethylene and gaseous methane.

Methane does not react with the red bromine water and color does not disappear. Ethylene, on the other hand reacts with the red bromine water and the color disappears.

Ethylene + red bromine water → red color disappears
Methane + red bromine water → red color doesn't disappear



Ethylene gas is used to ripen tomato.

3- Acetylene (C_2H_2):

It is a hydrocarbonic compound with the molecular formula of (C_2H_2) in which the two carbon atoms combine with each other in triple covalent bonds. It is an example of the unsaturated hydrocarbons called "Alkynes".

Acetylene (C_2H_2) molecule

a) Preparation of Acetylene :

Acetylene can be produced by the reaction of calcium carbide, CaC_2, with water. $CaC_2 + 2H_2O \rightarrow C_2H_2\uparrow + Ca(OH)_2$

It is an industrial process of acetylene production also. In the laboratory, acetylene can be produced as shown in the figure 6-4 by putting calcium carbide in an erlenmeyer flask. Water is added very slowly and gradually using a tube. The reaction which happens immediately produces the gaseous acetylene which can be collected from the bottle by removing water downward.

b) Properties of Acetylene:

1- It is a colorless gas with a bad smell. It smells like garlic.
2- It is insoluble in water.
3- Combustion of acetylene in air forms a smoky flame.
4-It burns with oxygen gas in making a faded blue flame and high temperature:

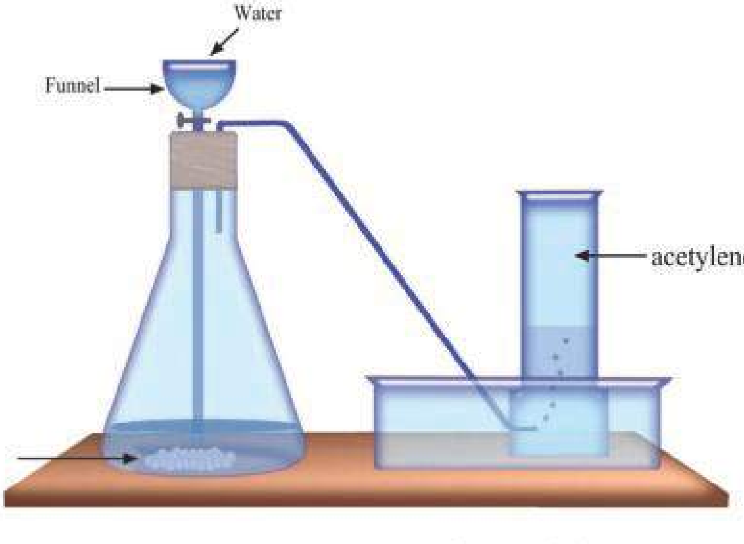


Figure 6-4
An apparatus for preparation of acetylene

$$2C_2H_2 + 5O_2 \xrightarrow{\Delta} 4CO_2 + 2H_2O + \text{Energy}$$

5-It reacts with the red bromine water and removes its color.
This reaction is used to distinguish between acetylene and methane gas. Acetylene removes the red color of the bromine water whereas methane has no such effect according to the following equations:

Acetylene + red bromine water → red color disappears
Methane + red bromine water → red color doesn't disappear

c) Uses of Acetylene:

1- The mixture of the gas and oxygen is used to produce the oxyacetylene for cutting or welding metals.

2- The gas is used as a raw material in the production of rubber,plastics and acetic acid.

4- Ethanol (Ethyl Alcohol) (C_2H_5OH):

Alcohol is an Arabic word from which the Latin word "Alcohol"is derived. It was known long time before and was produced then by fermenting molasses, dates or grapes in isolated air . By the effect of zymase enzyme, its occurs naturally in yeasts sugar is converted into simpler sugar which in turn is converted into carbon dioxide and ethanol by effect of enzyme.

$$\text{Simple sugar} \xrightarrow{\text{zymase enzyme}} \text{Ethyl alcohol} + \text{Carbon dioxide}$$

Alcohol is then separated from its aqueous solution by the process of distillation. Ethanol or ethyl alcohol can be produced industrially from oil products through the reaction of gaseous ethylene, C_2H_4, with water with the existence of concentrated sulfuric acid and other factors such as heat and pressure.

$$\underset{\text{Ethylene}}{C_2H_4} + \underset{\text{Water}}{H_2O} \xrightarrow{\text{Concentrated } H_2SO_4} \underset{\text{Ethanol or ethyl alcohol}}{C_2H_5OH}$$

a) Properties of Ethanol (Ethyl Alcohol):

1- It is a liquid with a boiling point lower than the boiling point of water. Its freezing point is very low.

2- It is a volatile liquid with a very distinguishing smell.

3- It is an active solvent to many organic substances.

4- Complete combustion of ethanol produces a faded blue flame and forms carbon dioxide (CO_2) and water vapor.

b) Uses of Ethanol (Ethyl Alcohol):

1- Ethyl alcohol is used as a raw material in many industries especially cosmetics, commercial rubber, ink, many types of paints and perfumes.

2- It is used in the production of alcoholic beverages and drugs.

3- It is used as a motor fuel through mixing it with other oil products.

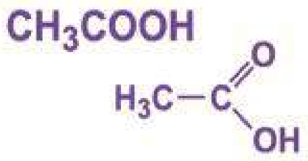
4- Used as a sterilizer by mixing it with some iodine and it is poisonous.

5- Ethyl alcohol is very cheap for industrial purposes. It is undrinkable as some poisonous substances like methyl alcohol are added to it and by then known as inactivated alcohol (sperto) . Also, some dyeing substances are added to it to make its color different from pure ethyl alcohol.

c) Effect of Ethyl Alcohol on Human Beings:

Drinking alcohol disturbs the consistency between the muscular and nervous systems. Very clear changes in mood, recognition and feelings are noted. These changes in the human body caused by alcohol slow down the functions of nerve cells in the nervous system. Addiction to alcohol is detrimental to health. Addicted people go to hospitals and health institution in order to be treated to stop addiction because of its lethal health damages rather than its social consequences. People addicted to alcohol behave strangely and sometimes dangerously. Therefore, some governments impose high taxes to reduce alcohol consumption and to eliminate its social, health and economic damages.

5- Acetic Acid (CH_3COOH):



Acetic Acid

a) Industrial Preparation:

Acetic acid is produced industrially by the reaction of acetylene with water using sulfuric acid and other facilitating factors. A chain reaction occurs and finally produces acetic acid

b) Properties of Acetic Acid:

1-It is a liquid at room temperature.
2-It is a volatile compound.
3-It reacts with sodium hydroxide to form water soluble sodium acetate.
4-It can be mixed with water at any rate.

6- Benzene (C_6H_6):

Benzene can be extracted from coal tar which is one of the petrol products and is fugitive (vapor quickly). Benzene is a hydrocarbonic compound consisting of carbon and hydrogen. Its complete combustion results in a very smoky flame because of the high percentage of carbon. Benzene is the simplest compound in the group of hydrocarbons which are called "Aromatic Hydrocarbons" because of their distinctive smells. Benzene vapors very quickly and boils at (80°C). It is not soluble in water and is used as an important industrial solvent to paints and many important industrial products. It is also used in the production of insecticides, nylon, modern detergents, etc.

CHAPTER QUESTIONS 06

6.1 How can methane gas be produced in laboratory, draw shape of equipments and write the reactions?

6.2 Give example about following terms;
Branched chain, unbranched chain, cyclic chain

6.3 Choose the most appropriate of the brackets that complete the following expressions :
a. All organic compounds contain one of the following elements in their composition (hydrogen , oxygen , nitrogen , sulfur , carbon)

b. The bond covalent between two carbon atoms in the satu rated hydrocarbons is a..................

a) Single b) double c) triple

c. The gas that is found in large amounts in natural gas is ....
(Methane , Ethylene , Acetylene)

d. In acetylene; two carbon atoms are bound each other by ....

a) Single covalent bond
b) Two covalent bonds
c) Three covalent bonds

6.4 How can be produced acetylene gas in laboratory, draw shape of equipment and write the reaction eqaution?

6.5 What are the general features of the organic compound?

6.6 Write balance equations of the following.
1) Heating of Sodium acetate and sodium hydroxide
2) Burning of Methane, ethylene, acetylene gases in air
3) Reaction of water with calcium carbide.

6.7 Explain the effect of normal alcohol on the humans body after drinking it?

6.8 What is inactivated alcohol (Sperto).

6.9 1. Compare the methane, ethylene and acetylene gases about;

a) Color
b) Solubility in water
c) Burning in air in normal form
d) Reaction with red bromine solution

2. What is used with acetylene gas to produce strong flame?

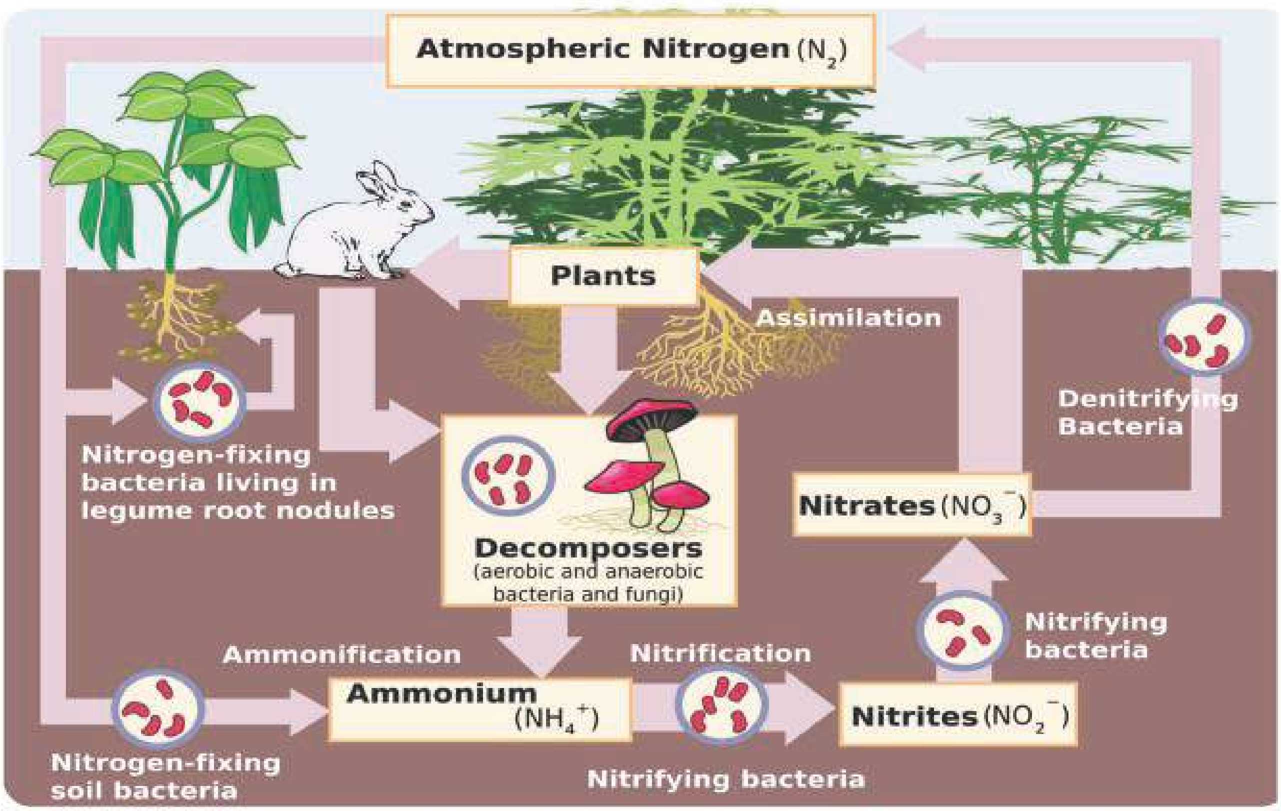
6.10 What is the importance of benzene?

6.11 What is the methane gas that is reflected in each of the following observations:
a. The gas is collected when it is prepared by pushing the water down.
b. Gas does not react with bromine.
c. The gas burns with a smokeless flame.

6.12 Both acetylene and Benzen are ignited with an smoke flame, what do you deduce from this observation.

CHAPTER 07

GROUP VA



At the end of this chapter, the students would be able to:

1-Know the names and symbols of Group VA elements.

2-Know the place of Group VA elements in the periodic table.

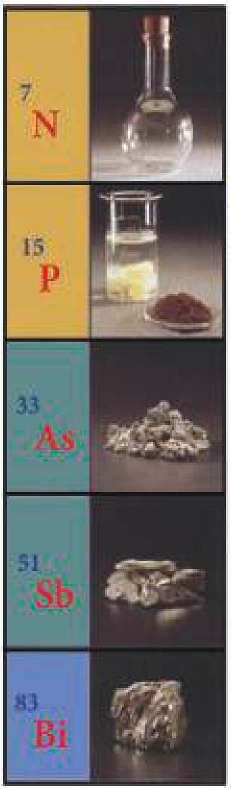
3-Know why these elements are put in one group (Group Five).

4-Know name and symbol of nitrogen and its molecular formula in air.

5-Know some compounds of nitrogen and their preparation and uses.

6-Know the name and symbol of phosphorus and recognize its chemical and physical forms.

7-Know the importance of phosphate fertilizers, their production and their role in plants growth.



7-1 ELEMENTS OF GROUP VA

Group VA (group five) consists of nitrogen (N), phosphorus (P), arsenic (As), antimony (Sb) and bismuth (Bi) as shown in the periodic table below. All the elements in this group have five electrons in their outer shells.

Figure 7-1

Place of group VA elements in periodic table.

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						

Arsenic

7-2 GENERAL CHARACTERISTICS OF GROUP VA

Although the five elements of this group form less than 0.2% of the Earth's crust, they are very important in nature. The elements of this group have some similar chemical behaviors but they differ in some others. The similarity between these elements reflects the similar aspects in the electron configuration. The most important properties of the group VA elements are:

1- The properties of the elements vary gradually from being nonmetals (nitrogen and phosphorus) to metals (bismuth). Arsenic and antimony are metalloid.

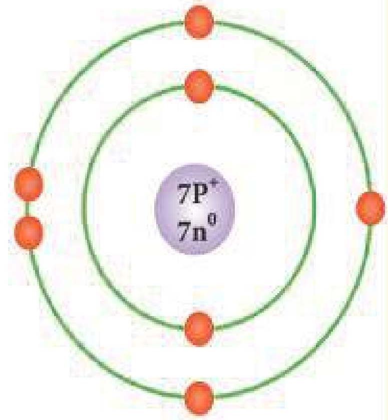
2- Nitrogen is gaseous. The rest of the elements are solids in normal conditions. The chemical properties vary on a regular basis from phosphorus to bismuth. Phosphorus and nitrogen have the propensity to form covalent compounds. Other elements like bismuth and arsenic form ionized compounds. The acidic and basic properties of the elements' oxides also vary from being acidic (phosphorus) to basic (bismuth).

Antimony

7-3 NITROGEN

Chemical symbol : N
Atomic number : 7
Mass number : 14

Shell symbol	Shell number	Electrons number
K	**1**	**2**
L	**2**	**5**



Electron configuration of Nitrogen

7-3-1 Occurrence in Nature:

Nitrogen constitutes 78% of the Earth's atmosphere. It is mostly an inert gas in standard conditions. In ancient times, it was called "Azote", which means in Latin "the Lifeless". Yet, nitrogen compounds are very important in food, fertilizers and explosive industries.

7-3-2 Preparation of Nitrogen:

Nitrogen can be produced in two ways:

1- Preparation in Laboratory:

A mixture of ammonium chloride (NH_4Cl) and Sodium Nitrite $NaNO_2$ is put to a heating source with some water to prevent any possibility of explosion occurrence, as in the figure below. The reaction can be expressed by the following equations:

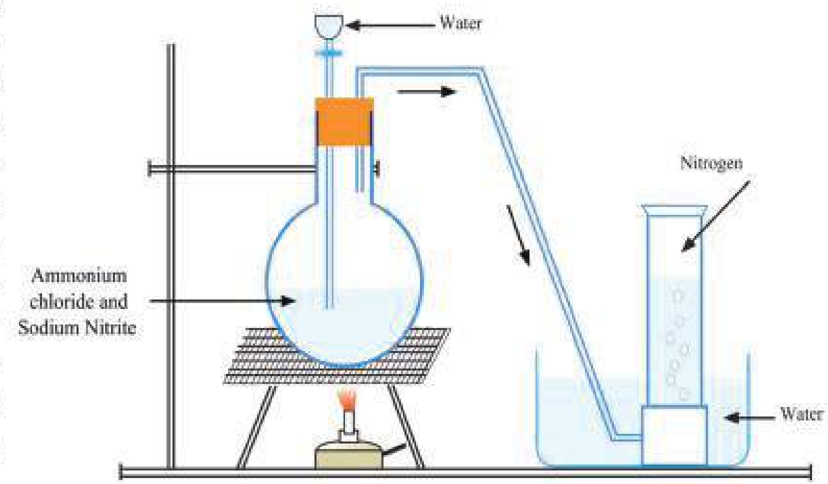
$$\mathbf{NH_4Cl + NaNO_2 \xrightarrow[\Delta]{H_2O} NaCl + NH_4NO_2}$$

$$\mathbf{NH_4NO_2 \xrightarrow{H_2O} 2\,H_2O\uparrow + N_2\uparrow}$$

2- Industrial Preparation:

Large quantities of gaseous nitrogen can be industrially produced by the fractional distillation of liquid air which must have no carbon dioxide (CO_2). In this process, nitrogen distills first leaving oxygen behind because the boiling point of nitrogen (-198°C) is lower than the boiling point of oxygen (-183°C). The produced nitrogen contains very small quantities of oxygen which can be removed by passing the gas through heated copper fillings which react with oxygen to form (CuO).

Figure 7-2
Preparation of nitrogen from ammonium nitrite



7-3-3 Properties of Nitrogen:

1- Physical Properties:

Nitrogen is colorless, odorless and tasteless. It has the form of diatomic molecule (N_2) at room temperature. It is less soluble in water and is almost inactive in normal conditions.

2- Chemical Properties:

Under certain conditions, nitrogen reacts with some other elements. For example, heating nitrogen leads to direct interaction between nitrogen and magnesium, lithium and calcium. When mixed with oxygen and the mixture is put under a spark, nitrogen produces nitrogen oxides (NO_2 and NO). On the other hand, heating nitrogen with gaseous hydrogen under high pressure and with an appropriate catalyst produces ammonia (Haber - BOSCH process), according to the following equation:

Liquefied Nitrogen Gas

$$N_2 + 3H_2 \xrightarrow[\text{Catalyst}]{\Delta \text{ high pressure}} 2NH_3$$

Catalyst : A substance that changes the speed or yield of a chemical reaction without being consumed or chemically changed by the chemical reaction.

Do you know

There is other diatomic molecule like H_2 , Cl_2 F_2 and O_2

7-3-4 Uses of Nitrogen:

Nitrogen has a very wide range of uses:

1- It is used to produce ammonia industrially. It is the most important use of nitrogen due to the vital importance of this substance in the production of fertilizers and in the production of nitric acid (Ostwald process).

2- It is used in cooling and freezing food products by putting the products into the liquid nitrogen gas.

3- The liquid nitrogen is used in the petroleum industries. It is used to cause an increase in the pressure in the petrol producing wells to push the petrol up the wells.

4- It is used as an inert agent in containers and tanks of flammable materials.

7-3-5 Nitrogen Compounds:

Nitrogen atom has five electrons in its outer shell. It has the propensity to form covalent bonds which can be single bond as in the molecule of ammonia (NH_3) or triple bond as in the molecule of nitrogen (N_2). Nitrogen atom can also gain three electrons or one electron according to its combination with the atoms of other elements in their compounds. The most important compounds of nitrogen are:

1- NH_3 (Ammonia):

It is one of the important compounds of nitrogen and hydrogen. It occurs in nature as a result of the process of decay of animals and plants upon death. Ammonia occurs also in soil in the form of ammonium salts.

a) Preparation of Ammonia in Laboratory:

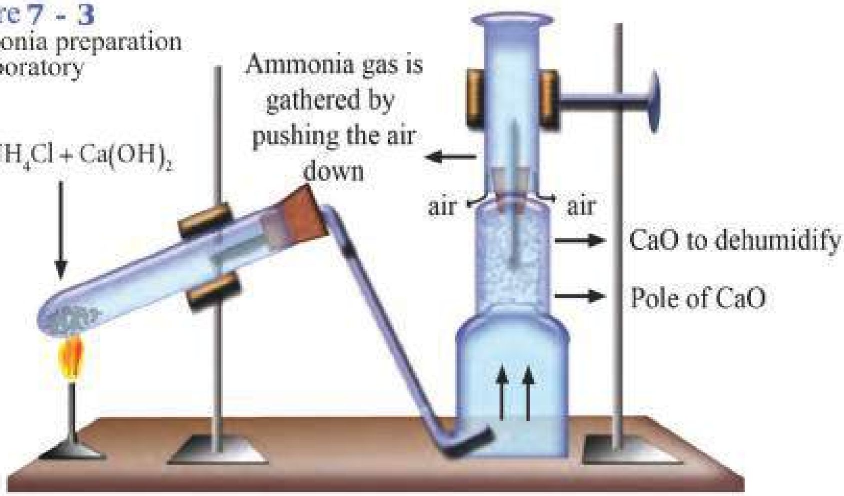
Gaseous ammonia can be produced in the laboratory by heating the salt of ammonium chloride with calcium hydroxide, as in the following equation:

$$2NH_4Cl + Ca(OH)_2 \xrightarrow{\Delta} CaCl_2 + 2H_2O + 2NH_3$$

The gas ammonia is lighter than air. It is, then, collected by downward removal of air after passing it in a pole of calcium oxide to remove any moisture with the gas, as in the figure below:

Scientist:
FREDS HABER

Figure 7 - 3
Ammonia preparation in laboratory



b) Industrial Preparation of Ammonia:

Large quantities of ammonia can be produced industrially by Haber-BOSCH Process which involves the direct combination of nitrogen and hydrogen as in the equation and figure below:

$N_2 + 3H_2 \rightarrow 2NH_3$

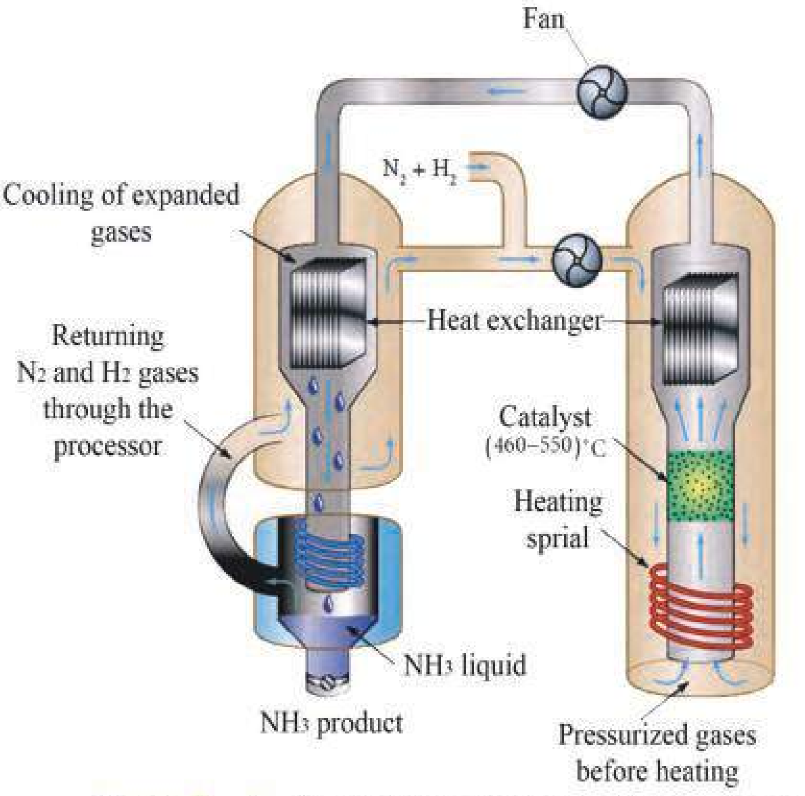


Figure 7 - 4 Ammonia production by Haber process

Physical Properties of Ammonia

1- Ammonia is a colorless gas with a characteristic pungent smell. It is lighter than air.

2- It has strong propensity to be soluble in water. Its aqueous solution is called "Ammonia Water" (NH_4OH). If this aqueous solution is heated or exposed to air, the solution loses ammonia gas. The high solubility of ammonia in water can be clearly shown by the fountain experiment. The device used in this experiment consists of a glass. Half of the glass is filled with water with two drops of phenolphthalein It also consists of a round bottom flask provided with a rubber cover with two holes. A long glass tube goes through one of these two holes down to the bottom of the flask. A dropper tube goes through the other hole of the cover. The flask is filled with dry ammonia gas and then turned upside down on the water glass. The dropper tube is used to add some water drops with the colorless phenolphthalein. The gas reach with the water and starts to dissolve. This process changes the pressure inside the flask and the water pushes from the glass to the flask as a fountain. The solution becomes pink- red because of its basically (ammonia solution is act as a base).

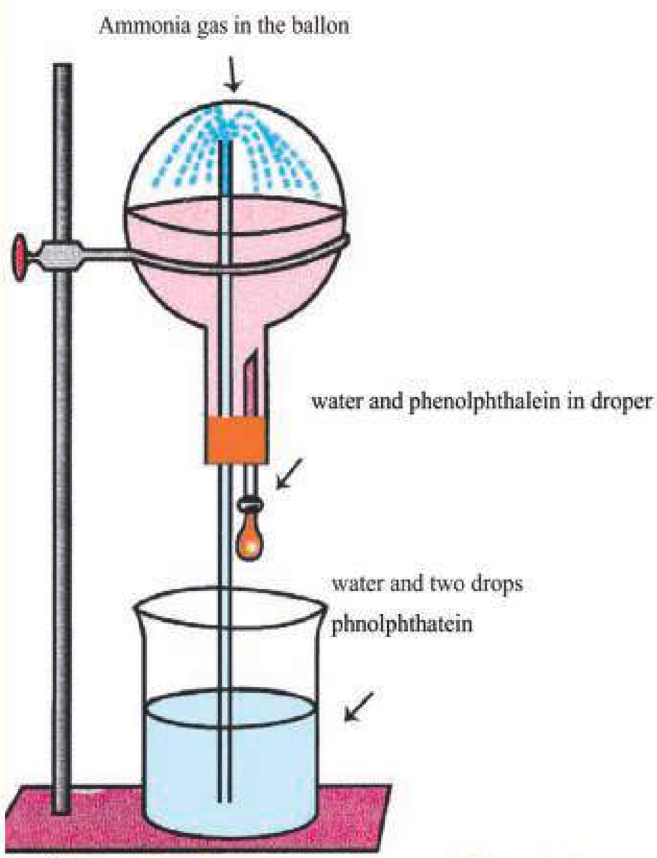


Figure 7 - 5
Ammonia gas fountain

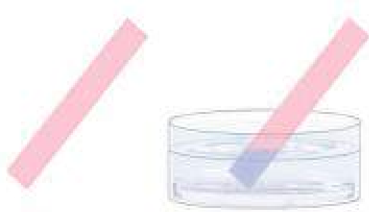
3- It can be liquidized at room temperature with 8-10 atm pressure. The boiling point of liquid Ammonia is (-33.5°C) under the normal atmospheric pressure. It vapors at high temperature and for this reason it is used in refrigeration and ice production.

Chemical properties of ammonia:

1- Ammonia molecule is chemically stable, yet it can release nitrogen and hydrogen when you pass gas on a hot metal surface, or when passing an electric spark through the gas.

2- Ammonia gas is flammable in an atmosphere of oxygen, as in the following equation:

$$4NH_3 + 3O_2 \xrightarrow{\Delta} 2N_2 + 6H_2O$$


Bases turns red litmus to blue color

3- Ammonia solution turns the red litmus paper into blue.

Test of Ammonia:

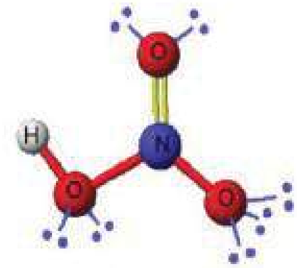
Ammonia can be detected by the following method.

When ammonia reacts with hydrogen chloride, it produces white dense vapor which is ammonium chloride.

$$\underset{\text{Ammonia}}{NH_{3(g)}} + \underset{\text{Hydrogen chloride}}{HCl_{(g)}} \rightarrow \underset{\text{Ammonium chloride}}{NH_4Cl_{(g)}} \uparrow$$

2- Nitric acid, HNO_3:

Nitric acid is the most important oxygenated acids of nitrogen which has a molecular formula HNO_3.



Nitric Acid, HNO_3

Preparation of Nitric Acid in Laboratory:

This acid is usually prepared by heating a mixture of Potassium nitrate salt with sulfuric acid in the glass retort,and the nitric acid vapor resulting from the interaction is condensed in a water-cooled vessel (Figure 7-6) the interaction can be expressed in the following equation.

$$KNO_3 + H_2SO_4 \longrightarrow KHSO_4 + HNO_3$$

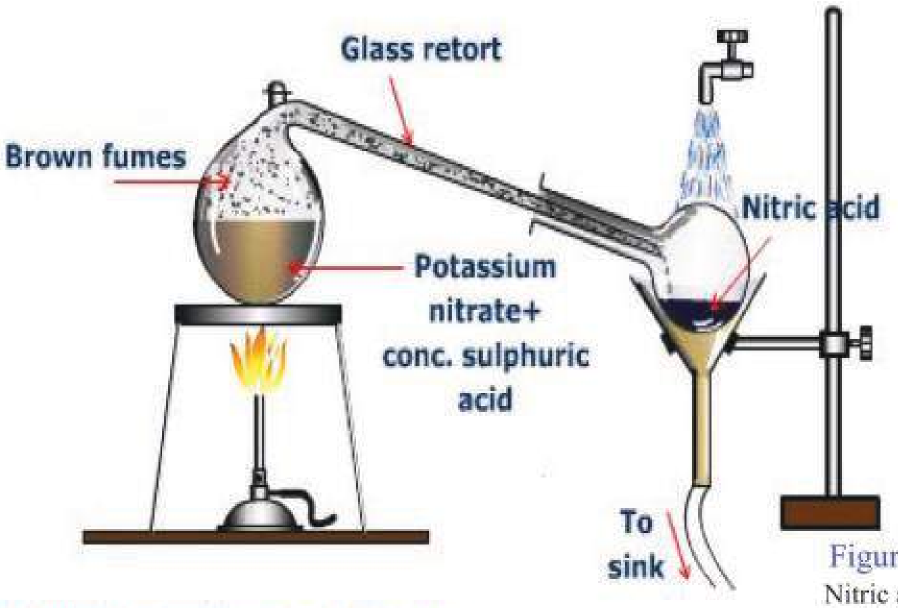


Figure 7 - 6
Nitric acid preparation in laboratory

Scientist
Fredrick Wilhelm Oswald

Industrial preparation of the acid:

The acid can be prepared artificially in commercial quantities by method of Ostwald whereby ammonia is oxidized in air, platinum acts as a catalyst.

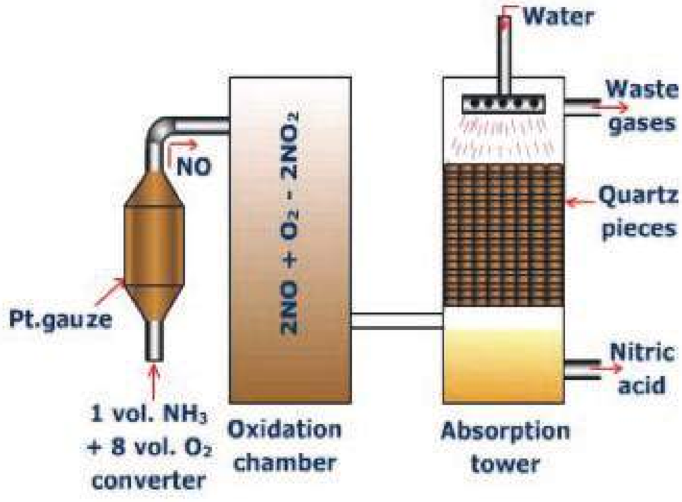


Figure 7 - 7 Nitric acid preparation industrial

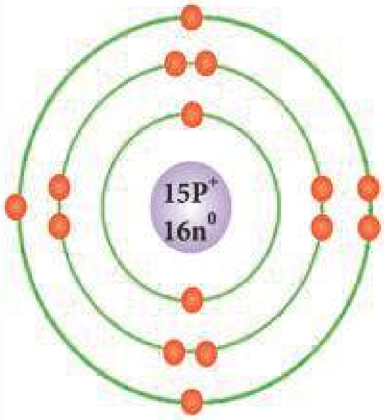


Figure 7-7
Electron configuration of phosphorus
Chemical Symbol: P
Atomic Number :15
Mass Number :31

Properties of Nitric acid:

Pure acid is colorless, it has odorous fumes, but the color of the impure acid (or the pure acid after leaving for a period of time) is yellow due to containing soluble nitrogen oxides (especially NO_2). The acid is completely dissolving in water forming a mixture of (68%) and it boils at 120.5 °C.

7-4 PHOSPHORUS

Shell symbol	(Shell number	Electron number
K	1	2
L	2	8
M	3	5

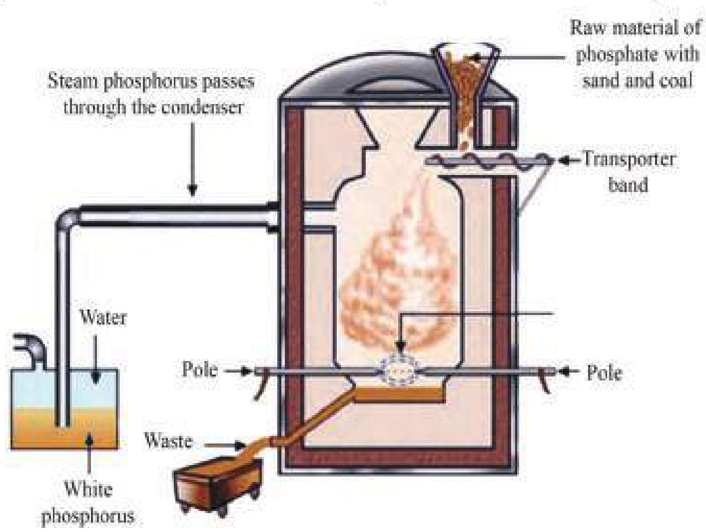
7-4-1 Existence of Phosphorus:

This element is an essential component in living things, it is found in nerve cells, bones and cell cytoplasm. It is not found freely in nature, yet, it is extensively found various minerals. Apatite ores (apatite: impure form of calcium phosphate) are important source of this element. Huge deposits of this mineral are found in different parts of the world including Iraq.

Figure 7-8
Preparation of phosphorous in industry

7-4-2 Industrial Production of Phosphorous:

Phosphate ores contain high ratio of phosphorous, therefore, these ores represent the basic source for commercial phosphorous production with high purity, therefore, there is no need to prepare it in laboratory. Phosphorous is normally produced by heating Calcium Phosphate $Ca_3(PO_4)_2$ with the sand (SiO_2) and carbon C in an electrical oven at high temperature, air-tight, as in the following equation:



$$2Ca_3(PO_4)_2 + 6SiO_2 + 10C \xrightarrow{1500\ ^\circ C} 6CaSiO_3 + 10CO + P_4$$

The resulting phosphorous is white, sometimes called yellow phosphorous it is cast in the form of cylinder bars. The casting process and preservation is done underwater because of the low temperature of flammability, fast integration with oxygen, high flammability in air. The figure 7-8 illustrates industrial production of phosphorous.

White phosphorus

Red phosphorus

7-4-3 Properties of Phosphorous:

Phosphorous is normally white (yellowish) having a waxy form. As for pure Phosphorous, it is solid colorless and transparent. There are other types of it, red or black (or purple), the most common is white and red phosphorous. These forms of phosphorous differ in their properties, see table 7-1.

White Phosphorous is more active than red phosphorous under normal temperatures, because atoms of these two forms of phosphorous differ in the way that they bind. Properties of white phosphorous are:

1-White phosphorous glows in the dark, looking pale green when exposed to damp air, this process is called chemical luminance or "glitter", accompanied by garlic-like odor.

2-It burns spontaneously "automatically" in air at room temperature due to enough oxidation, releasing phosphorous pentoxide (P_2O_5), see the following equation: $P_4 + 5O_2 \longrightarrow 2P_2O_5$

Under other conditions, (limited amount of oxygen) white phosphorous oxidizes to form phosphorous trioxide P_2O_3 as in the following equation:

$$P_4 + 3O_2 \longrightarrow 2P_2O_3$$

3-White Phosphorous is a poisonous for cells of living things whereby it penetrates into the digestive system and dissolves in the digestive juices , turning into a poison, unlike red phosphorous which doesn't dissolve in the juices

White phosphorous	Red phosphorous
1. Translucent, white to yellowish color	1.Its external surface is red to violet color.
2. Produced in the rod form and stored under water because of its activity.	2. Produced in powder form it is not effected by air at ordinary condition.
3. Lower density than the red.	3. Higher density than the white.
4. Soluble in some organic solvents such as carbon disulfide but insoluble in water.	4. Insoluble in organic solvents and water.
5. Its melting point is low.	5. Sublimates by heating.
6. Its flash point is low so it burns easily.	6. Its flash point is high.
7. It is poisonous.	7. It is not poisonous.

Table 7-1
Comparison of white and red phosphorous

7-4-4 Some Phosphorous Compounds:

Phosphoric Acid (H_3PO_4)

A densely formed ,colorless and odorless liquid. This acid is weak non oxidative acid. It reacts with bases forming phosphorous salts, such as sodium phosphate Na_3PO_4 which is used as preservative for some food products, meat and many other usees.

Matchsticks:

Use of Fertilizers

which have major importance in manufacturing phosphate fertilizers.

7-4-5 Industrial Uses of some Phosphorous compounds:

1- Matchsticks:

Matchsticks are processed by Ammonium Phosphate solution $(NH_4)_3PO_4$. This material helps burn the matchstick in a smokeless flame. It also helps keep the flame burning completely. It also ensures the stick put off when the flame goes off, therefore, no hazard of fires when the matchstick is thrown away. The top of the stick is covered by a paste made of :

a- Flammable material like antimony sulfide Sb_2S_3.

b- An oxidant, like Potassium Chlorate, $KCIO_3$.

c- Friction material like glass powder.

d- Glue material to bind the ingredients of the paste when the top of the matchstick is rubbed against the side of the box which contains red phosphorous, a sufficient heat is generated to ignite the side of the box then this ignition transfer to the top of the matchstick and it burns.

2- Phosphate Fertilizers:

Phosphorous is an essential element in the growth of plants, it plays a vital role in the life of living beings and the development of the skeletal structure of animals and humans. Therefore, it is important for plants to make use of this element in the soil in the form of soluble compounds. Since calcium phosphate (the original source of phosphate in nature), which is a salt that is fairly insoluble in water, therefore, it is necessary to transform it into a salt easily soluble in water to be used as a fertilizer. When calcium phosphate (naturally found in rocks) is processed with sulfuric acid, it changes into another chemical formula known commercially as super-phosphate fertilizer. It is soluble in water, so that the plant can make use of it, as in the following equation:

$$\mathbf{Ca_3(PO_4)_2 + 2H_2SO_4 \rightarrow Ca(H_2PO_4)_2 + 2CaSO_4}$$

This fertilizer is used to increase soil fertility, other kinds of phosphate fertilizers can be prepared through the reaction of phosphoric acid with calcium phosphate to form a fertilizer commercially called triple super-phosphate $\mathbf{Ca(H_2PO_4)_2}$ which is far much better than ordinary phosphate because it doesn't contain calcium sulfate.

It is worth noting that Iraq is an important source of natural calcium phosphate whereby large amounts are found in Rutba region, in Akashat at Anbar province.

CHAPTER QUESTIONS 07

7.1 Complete the following statements;

1- Atomic number of nitrogen is…………….......... therefore its nucleus contains...................... proton which………………electrons rotate around of nucleus.

2- Atomic number of phosphorus is…………….. therefore it nucleus contains proton,…………….. which………………electrons rotate around of nucleus.

3- A match's tip is coated with a paste,which consist of the following substance .

a) Inflammable material such as……………

b) An oxidizing material such as………………..

c) A material that increases the friction force such as............................

4- Nitrogen has …………………in nature. Chemical symbol of nitrogen………………

5- NH_3 is symbol of …………………………… molecule. This molecule consists of 1 atom …..….. and three atoms……………………

6- What is the benefits of fertilizer of phosphate?

7.2 Choose the correct answer.

1) Which one of the following percentage of nitrogen in earth's atmosphere?

a) 21% b) 78% c) 50%

2) Which of the following compounds is used in preparation of nitrogen gas in laboratory?

a) Copper oxide
b) Calcium Chloride
c) Ammonium Chloride and sodium nitrate in the presente of water.

3) Among those substances, where as phosphorus enters their structure a substance directly used as phosphate fertilizer; this substance is……………………………….

a) bones
b) natural calcium phosphate
c) super phosphate

4) Which one of the following can be a proof that shows presence of ammonia in a solution?

a) It turns red litmus to blue.
b) It turns blue litmus to red.
c) It turns red litmus to yellow.

5) Heat of your hand is sufficient to ignite one form of phosphorus element, thus it should not be handle with hand when it is used in experiments for studying the phosphorus properties. This form is……………………..

a) Red phosphorus b) White phosphorus

6) Which method is used to preparation of Nitric acid in industry?

a) Heating of Potassium nitrate salt and concentrated Sulfuric acid mixtures;

b) Oxidizing of ammonia by using catalyst platinum in atmospheric pressure.

c) Separation of ammonia molecule in aqueous. solution Dissociation

7) When phosphorous burns in enough of air, mostly produces…………………

a) Phosphorous trioxide
b) phosphorous pentaoxide
c) phosphorous nitrate

7.3 Complete the following reactions equations then balance them and write name of reactants and products.

a) $2NH_4Cl + Ca(OH)_2 \xrightarrow{\Delta}$ ....

b) $Ca_3(PO_4)_2 + H_2SO_4 \longrightarrow$ ....

c) $Ca_3(PO_4)_2 + SiO_2 + C \xrightarrow{1500^\circ}$ ....

7.4 Mark the following sentences as true (T) or false (F) after that correct the false sentences.

a) Phosphorous element exists compound form in the nature.

b)Highly tempretures are used in preparation of ammonia in industry.

c) Nitrogen has five electrons in outermost energy level. It can be composed single or multiple covalent bond.

d) Compounds which are called "phosphate" are salt of common phosphoric acid H_3PO_4.

e) White phosphorus is poisonous material thus it is stored under water.

f) Red phosphorus is stored in the water container bottles.

g) White phosphorus is more reactive than red phosphorus, where as they are two forms for same element.

h) The color of pure Nitric acid after a while becomes yellow after a while.

CHAPTER 08

GROUP VIA

After completing this chapter, students will be able to:

1-Identify names and symbols of group VIA elements.
2-Understand general properties for group VIA elements.
3-Express electron configuration for group VIA elements.
4-Know whereabouts of sulfur and its forms in nature.
5-Be familiar with some important and common sulfuric compounds

8-1 INTRODUCTION

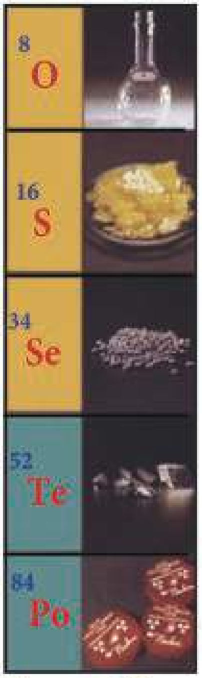


Figure 8-1
Place of group VI A elements on the periodic table

Group VI A elements appear on the right side of the periodic table. They include five elements: Oxygen (O), Sulfur (S), Selenium (Se), Tellurium (Te), Polonium (Po). Figure 8-1 illustrates the location of this group on the periodic table.

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						

8-2 GENERAL PROPERTIES OF GROUP VIA

Elements of this group are characterized by gradual increase in their atomic numbers ,whereby oxygen and sulfur are considered as non-metal while selenium and tellurium have non-metalic properties, as for polonium, it has pure metal properties. All elements of the group VIA has six electrons in the outer shell which make them "hunt" two electrons from other elements in order to have a stable electron configuration similar to that of noble elements.

Tellurim

Cesium

Sulfur

8-3 SULFUR

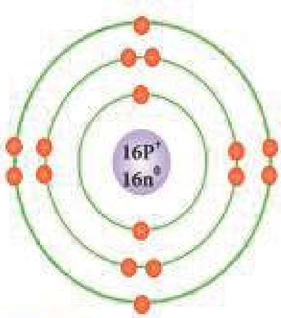


Figure 8-2
Electron configuration of sulfur atom

Symbol of shell	(Shell number (n)	Number of electron
K	1	2
L	2	8
M	3	6

Chemical symbol: S
Atomic number : 16
Mass number : 32

8-3-1 Occurrence of Sulfur:

Sulfur is found in nature freely in special sulfur mines in Mosul city, Mishraq region, Northern Iraq. It is also found in volcanic regions in large quantities in the form of compounds such as hydrogen sulfide, H_2S, and sulfur dioxide, SO_2, which evaporate with other volcanic gases.

8-3-2 Preparation of Sulfur:

a- Preparation of sulfur in laboratory:

Sulfur can be prepared in laboratory by adding concentrated hydrochloric acid to sodium thiosulfate, $Na_2S_2O_3$, (at -10°C). Sulfur precipitates and collected through filtration according to the following reaction equation:

$$\underset{\text{Concentrated hydrochloric acid}}{2HCl} + \underset{\text{Sodium thiosulfate}}{Na_2S_2O_3} \xrightarrow{-10^{\circ}C} \underset{\text{Sulfur}}{S\downarrow} + \underset{\text{Sulfur dioxide}}{SO_2\uparrow} + \underset{\text{Sodium chloride}}{2NaCl} + \underset{\text{Water}}{H_2O}$$

$(CuFeS_2)$

b- Extraction of Sulfur:

Sulfur is extracted freely in the form of underground deposits by using Frasch Process. This process is done by melting sulfur underground by means of special equipments, (Figure 8-3) consisting of three overlapping tubes pivotally centered. Pressurized and superheated to 170°C water vapor is pushed into the outer tube (A) to where sulfur converges, this pressure melts sulfur underground. Pressurized air from tube B lifts up molten sulfur through tube C, the middle tube. Sulfur comes out to the surface from this tube mixed with some air bubbles. On the surface, molten sulfur is cast in large basins and left to cool down and solidify. Much of the sulfur produced by using this process is 99.5%-99.9% pure, therefore in needs no further re-purification.

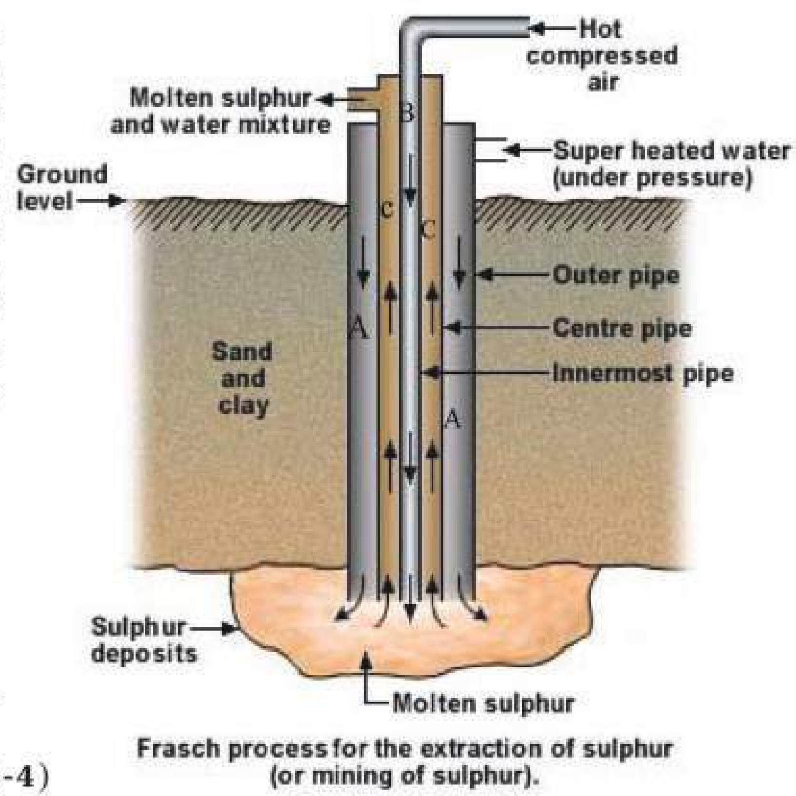


Figure 8-3
Extraction of sulfur by Frasch Process

8-3-3 General Properties of Sulfur:

1- Physical Properties:

Sulfur has the following physical properties:

a- It is yellow solid substance at (Figure **8-4**)

b- Tasteless, with distinctive odor.

c- Insoluble in water, yet dissolves in some inorganic solvents like carbon disulfide, CS_2. If carbon disulfide is evaporated, sulfur with 8 atoms (S_8) deposits gradually in the form of crystals.


Figure 8-4

d- Non-conductor of electricity.

e- Has various forms in nature with variant physical properties. Sulfur and other elements have many forms (allotropes) which vary in physical form, color despite belonging to the same element. These elements are called as allotropic elements. Sulfur has two main allotropes:

1- Crystalline sulfur . Rhombic sulfur is the most common type it is a yellow crystal (like lemon), stable at room temperature. It is the most stable form of sulfur. It is found as cyclic S_8 molecule in volcanic areas. There is another type of crystal sulfur, called the prismatic, because its crystals look like prism.

Rhombic sulfur

Prismatic sulfur

2- It is non-crystalline sulfur, like rubber or plastic sulfur. It is called amorphous sulfur. It can be prepared by heating sulfur to 1500 °C and pouring the liquid sulfur into cold water, whereby spiral chains are formed. It is less stable than crystal sulfur, it turns to crystal sulfur gradually.

Sulfur has the formulas; S_8 and S_6, the first form is more active than the latter due to the high tension of the rhombic ring as in figure 8-5.

Exercise 8-1

write Sulfur reaction eqution with copper and Zinc.

2- Chemical Properties of Sulfur :

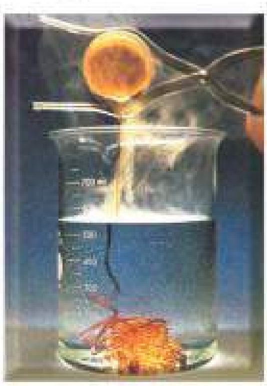
Sulfur is not reactive under normal temperatures, but when heated it gets active and reacts chemically, reacts with almost all elements directly under the appropriate temperature. As follows:

a- Reaction with non-metals: Sulfur burns easily in air producing blue flame, reacts with oxygen gas and releases a huge amount heat and sulfur dioxide as in the following reaction:

$$S + O_2 \xrightarrow{\Delta} SO_2$$

Sulfur reacts with carbon to produce carbon disulfide, CS_2

$$2S + C \xrightarrow{\Delta} CS_2$$



b- Reaction with metals: Sulfur reacts with metals like iron, copper and zinc to produce metal sulfides:

$$S + Fe \xrightarrow{\Delta} \underset{\text{Iron (II) sulfide}}{FeS}$$

c- Reaction with concentrated and oxidized acids:

Sulfur is not affected by dilute acids while it is oxidized with concentrated acids such as hot sulfuric acid, producing non-metallic oxides.

$$S + \underset{\text{Concentrated and hot}}{2H_2SO_4} \xrightarrow{\Delta} 3SO_2 + 2H_2O$$

With hot concentrated nitric acid, it produces non-metal oxides of NO_2:

$$S + 6HNO_3 \longrightarrow H_2SO_4 + 6NO_2 + 2H_2O$$

Figure 8-5

Three-dimensional shape of the S_8 molecule

8-3-4 Uses of Sulfur:

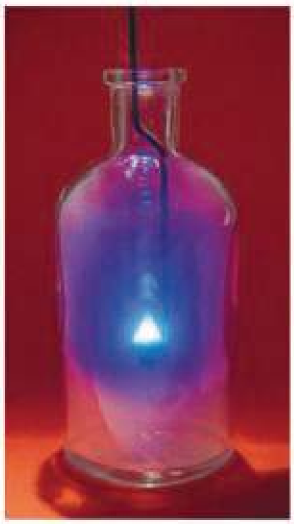
Sulfur has many uses in industrial and agricultural fields, it is used in

1 –matchsticks and black gunpowder and fireworks because of high flammability.

2 –It is used in agriculture to balance earth alkaline as well as a fertilizer.

3 –It is used to produce sulfuric acid, paints.

4 –It is used mining metals and oil refinery, films, drug industry.



8-3-5 Some Sulfur Compounds:

a- Sulfur Dioxide (SO_2):

Sulfur dioxide, SO_2, is produced mainly by burning sulfur with oxygen gas. This gas naturally evaporates in large quantities from volcanic activities. It is also generated from some industrial processes during mining of some substances and burning of petroleum derivatives and briquette.

Sulfur dioxide is prepared at laboratory by adding dilute sulfuric acid to sodium sulfite, (Na_2SO_3)(Figure 8-6). It can be collected by pumping air out from above because it is heavier than air. As in the following equation:

$$H_2SO_4 + Na_2SO_3 \longrightarrow SO_2\uparrow + Na_2SO_4 + H_2O$$

Sulfur dioxide is a colorless gas with a strong characteristic smell. It is heavier than air. It does not dissolve much in water producing a weak solution of sulfurous acid:

$$SO_2 + H_2O \rightleftharpoons \underset{\text{Sulfurous acid}}{H_2SO_3}$$

For this reason, the color of the blue litmus paper is turned to red when it is put in the gas collecting bottles used in the laboratory preparation of sulfur dioxide because of the effect of the sulfurous acid which results according to the above mentioned equation. Large quantities of sulfur dioxide can be

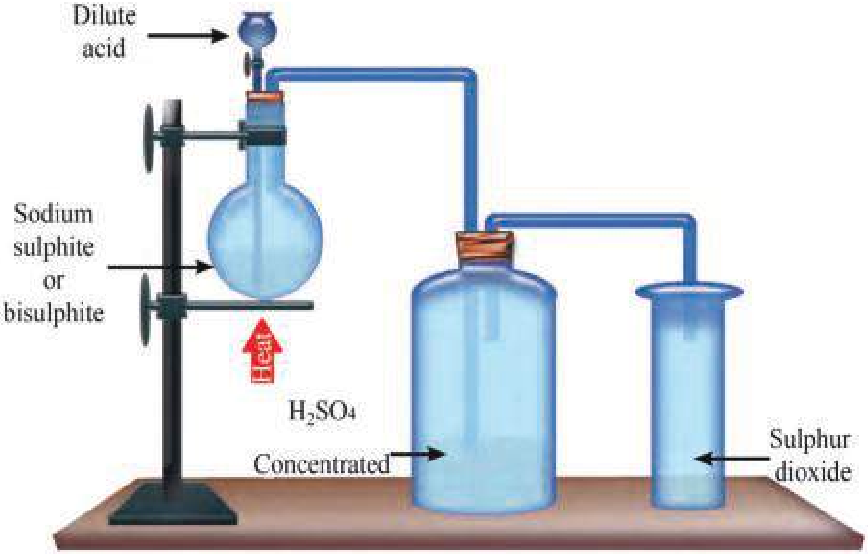


Figure 8-6
Preparation of sulfur dioxide in laboratory

industrially produced by the combustion of sulfur in air. The molten sulfur is pumped in special combustion towers. The resultant gas contains some impurities which need to be removed:

$$S + O_2 \xrightarrow{\Delta} SO_2$$

Sulfur dioxide is commercially used in decolorizing the delicate organic substances such as paper, straw, artificial silk and wool which changed when they are bleached with gas chlorine. However, this bleaching effect does not normally last for a long time.

Most of the SO_2 bleached materials recover their colors as soon as they are exposed to air. This gas can also be used for sterilizing purposes by the process of combustion some quantities inside the places that need to be sterilized. It is, in addition, used as a preservative agent in food industries. Sulfur can burn spontaneously in air at (400°C) with the existence of oxygen. The combustion releases sulfur dioxide which has an odor smell. This gas is bad for health and the increasing release of sulfur dioxide in air because of the fossil coal combustion and other industrial activities causes serious damages to the health of humans, animals and plants. It is also the main cause of acid rains.

b- Hydrogen Sulfide (H_2S)

Hydrogen sulfide is a colorless gas with a characteristic foul odor of rotten eggs. It occurs in nature as a result from: the bacterial breakdown of the organic matters, underground water that contains sulfur as in the mineral water wells in Hammam Al-Aleel in Nineveh Province north of Iraq or from the biological activity of some kinds of bacteria that rely of iron and manganese as part of their food sources. Hydrogen sulfide also occurs in almost all the natural and petroleum gases. Natural gas contains 28% of hydrogen sulfide and it may, because of this, cause air pollution in the regions where it is produced and in refineries. There may also be gas emissions in the industries that use sulfur compounds. Gas hydrogen sulfide gas can be produced in laboratories using the same device used to produce SO_2. The device is based on the reaction of the diluted acids such as sulfuric acid with metal sulfides such as iron (II) sulfide as in the following equation:

$$\underset{\text{Iron (II) sulfide}}{FeS} + \underset{\text{Sulfuric acid}}{H_2SO_4} \longrightarrow \underset{\text{Hydrogen sulfide}}{H_2S\uparrow} + \underset{\text{Iron (II) sulfate}}{FeSO_4}$$

Passing hydrogen sulfide gas through in the solutions of metal ions like copper (II) sulfate results in a black precipitate of copper (II) sulfide according to the following equation:

$$\underset{\text{Hydrogen sulfide}}{H_2S} + \underset{\text{Copper (II) sulfate}}{CuSO_4} \longrightarrow \underset{\text{Sulfuric acid}}{H_2SO_4} + \underset{\text{Copper (II) sulfide}}{CuS\downarrow}$$

c- Sulfuric Acid (H_2SO_4)

Sulfuric Acid (H_2SO_4) is one of the earliest acids identified by Arabs in early eighth century .

Sulfuric acid is a colorless oily liquid with high density and has no characteristic smell when it is pure. It is a highly corrosive strong acid. It is soluble in water at all concentrations and its solutions have high electrical conductivity.

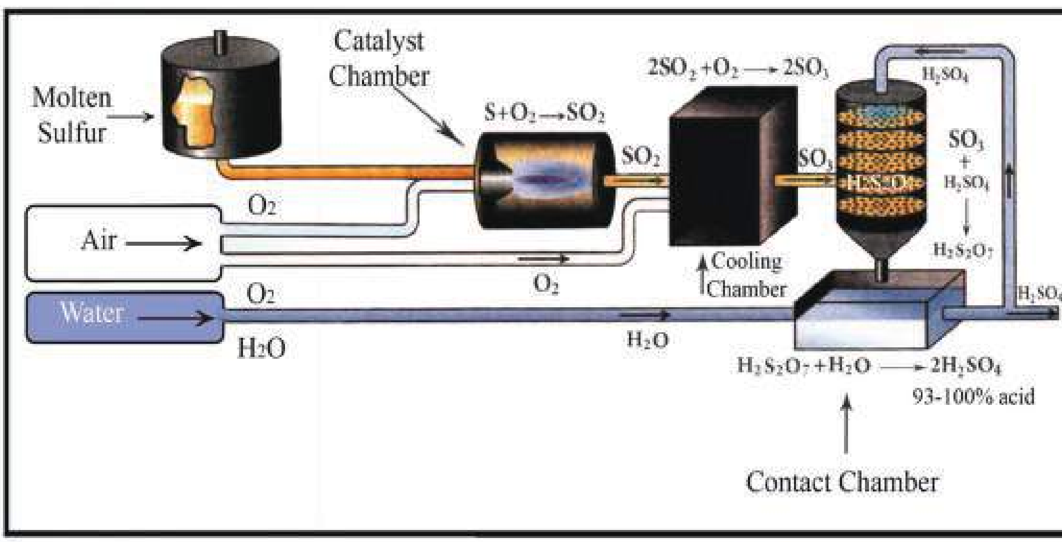
1- Industrial Manufacturing of Sulfuric Acid

Sulfuric acid can be industrially manufactured by contact process which simply involves the reaction between sulfur and oxygen to produce sulfur dioxide:

$$S + O_2 \xrightarrow{V_2O_5} SO_2$$

Sulfur dioxide is pumped into chamber which contains catalyst to obtain sulfur trioxide. $\underset{\text{Sulfur dioxide}}{2SO_2} + O_2 \longrightarrow \underset{\text{sulfur trioxide}}{2SO_3}$

After that sulfur trioxide is dissolved in water. $SO_3 + H_2O \longrightarrow \underset{\text{Sulfuric acid}}{H_2SO_4}$



Sulfuric acid is a colorless oily liquid with a high density of (1.84 g/cm^3). It has no characteristic smell and it dissolves in water at all concentrations generating high temperature. For this reason, cautions must be taken when reducing its concentration.

Sulfuric acid is usually used as a drying agent because of its high ability to absorb water from the organic compounds. This can be shown when we put a spoonful sugar in a bowel full of concentrated sulfuric acid. We see that a black carbonic substance results from the reaction in the bowel as in the following equation:

$$\underset{\text{Sugar cane}}{C_{12}H_{22}O_{11}} \xrightarrow{\text{Concentrated } H_2SO_4} \underset{\text{Carbon}}{12C} + \underset{\text{Water}}{11H_2O}$$

Sulfuric acid

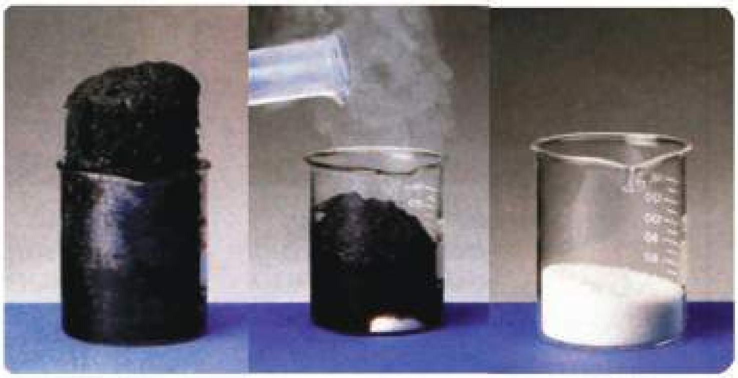


Figure 8-7
Addition of sulfuric acid into beaker which contains sugar cane.

2- Uses of Sulfuric Acid
Every year, large quantities of sulfuric acid are being produced more than any other chemical substances. The acid is used for many purposes:

1- It is used in the production of other acids such as nitric and hydrochloric acids because of its high boiling point.

2- It is used as a drying agent especially with the gases which do not react with it because of its high ability to react with water.

3- It is used to refine crude oil and remove impurities.

4- It is used in the production of explosives like nitroglycerin nitrates and cellulose nitrates.

5- It is used as a cleaning agent to remove rust from the iron tools before being painted with zinc.

6- It is widely used in the production of batteries (lead storage batteries) and also in the electrical coating because of its high electrical conductivity.

7- It is used in the production of chemical fertilizers such as ammonium sulfates and phosphate fertilizers.

Name of Zinc Compounds

ZnO: Zinc oxide

$ZnSO_4$: Zinc sulfate

$Zn(OH)_2$: Zinc hydroxide

$ZnCO_3$: Zinc carbonate

8-4 SULFATES

Sulfates are sulfuric acid salts which are derived from the reaction of sulfuric acid with the metals or with their oxides, hydroxides or carbonates. The result of such a reaction is the formation of metal sulfate salts as in the case of metal of zinc, zinc oxide, zinc hydroxide and zinc carbonates as in the equations below.

$$\mathbf{ZnO + H_2SO_4 \rightarrow ZnSO_4 + H_2O}$$

$$\mathbf{Zn(OH)_2 + H_2SO_4 \rightarrow ZnSO_4 + 2H_2O}$$

$$\mathbf{ZnCO_3 + H_2SO_4 \rightarrow ZnSO_4 + CO_2 \uparrow + H_2O}$$

8-4-1 Test of Sulfate Ion (SO_4)$^{2-}$

Sulfate ions can be identified in their aqueous solutions by adding the solution which contains barium ions such as barium chloride. The result is a white precipitate of barium sulfate:

$$\underset{\text{Barium chloride}}{BaCl_2} + \underset{\text{Sulfate ion}}{SO_4^{2-}} \rightarrow \underset{\substack{\text{Barium sulfate}\\\text{White precipitate}}}{BaSO_4 \downarrow} + \underset{\text{Chloride ion}}{2Cl^-}$$

CHAPTER QUESTIONS 08

8.1 Physical Properties of VIA group elements are arranged from oxygen to polonium. Write the properties.

8.2 Write the common electron configuration of VIA group elements.

8.3 Choose the correct anwser :

1- Sulfur element occurs, in nature, in form ....

a) Free only
b) Combined only
c) Free and combined

2- Some elements such as sulfur, phosphorous and carbon, occur in their solid states in different forms; they are characterized by these forms each other in some physical properties, these forms are called;

a) Allotropes of element b) Elements shape
c) Elements forms d) Elements types

3- One of the following free solid molecules contains eight atoms, that is...........

a) White phosphorus b) Iodine
c) Sulfur d) Carbon

8.4 What happens when hydrogen sulfide gas is passed in zinc sulfate ,lead acetate, copper sulfate solutions, explain these using equations.

8.5 The underground deposit of sulfur is extracted in the Mishraq fields, according to Frasch process which three concentric pipes extended to different deep. Answer the following questions according to figure 8-3.

a) What is the role of the pipe (B) in this process?
b) Which material passes through the outer pipe (A)?
c) Explain how you could get water 170^0C while it boils at 100^0C.

8.6 If you have a mixture of very fine table salt, chalk and sulfur, describe an experimental method to separate these materials in dry and pure form.

8.7 Write the reaction of sulfur with metal and non-metal.

8.8 Explain the preparation of Sulfuric Acid with industrial method.

8.9 Complete the following reaction;

$FeS + H_2SO_4 \rightarrow$ ....

$SO_3 + H_2O \rightarrow$ ....

$BaCl_2 + SO_4^{2-} \rightarrow$ ....

CHAPTER 09

GROUP VIIA

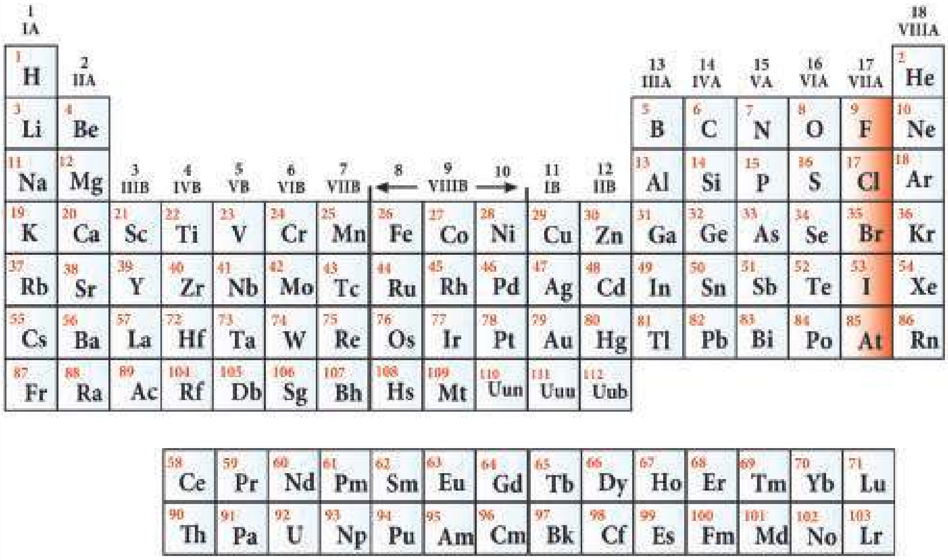
After completing this chapter, students will be able to:

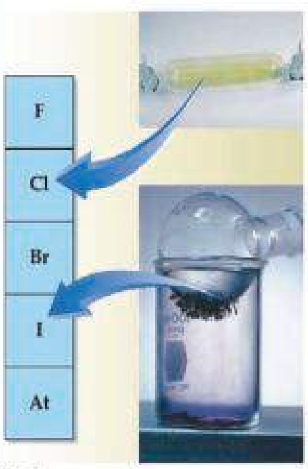
1-Find the location of VIIA group elements in the periodic table.
2-Identify names and symbols of seventh group (VIIA) elements.
3-Understand general properties for seventh group (VIIA) elements.
4-Realize importance of chlorine and some of its compounds.
5-Detect and discover chlorine and Hydrogen Chloride gas.

9-1 INTRODUCTION

Elements of 7A group are fluorine (F), chlorine (Cl), bromine (Br), iodine (I), astatine (At). Elements of this group are called as halogens, having extremely non-metallic properties and highly active, therefore, they are not found freely in nature but combined with other elements. They have similar physical and chemical properties with a gradual shift in these properties. There is also a difference in other properties. Figure 9-1 illustrates the location of this group on the periodic table.

Figure 9-1
Location of group VIIA elements





Halogens

9-2 GENERAL PROPERTIES OF GROUP VIIA (HALOGENS)

1- All elements of this group has seven electrons in the outer shell and tend to gain one electron during reactions to fill its outer shell. Electron gaining differs gradually from Fluorine to Iodine.

2- Halogens are found in normal temperatures in various physical forms, fluorine F_2 and chlorine Cl_2 are gases, as for bromine Br_2 is a liquid, iodine I_2 is a solid. (Figure 9-2)

3- Halogens are colorful substances because they absorb some of the visible rays. (Figure 9-2)

4- Boiling and melting points for halogens increase with the increase in atomic number.

Figure 9-2
Chlorine is gas.
Bromine is liquid.
Iodine is solid.

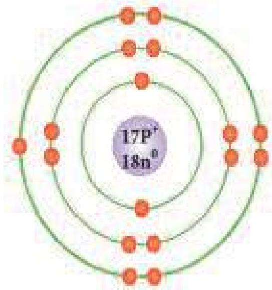
9-3 CHLORINE

It was first introduced in the nineteenth century by the well known scientist Scheele, from the reaction between manganese (IV) oxide, MnO_2, with concentrated hydrochloric acid.

Shell symbol	Shell number	Electron Number
K	1	2
L	2	8
M	3	7

Chemical symbol: Cl
Atomic number : 17
Mass number : 35

Electron configuration shows that chlorine atom tends to gain one electron to fill the outer shell (third shell), therefore, it is monovalent and its oxidation number is (-1) in compounds because it tends to gain one electron to form a negative chlorine ion (Cl^-).



Electron configuration of chlorine atom

9-3-1 Existence of Chlorine:

Chlorine is not found freely in nature due to high chemical reactivity and readily interaction with other elements to form many of the chlorine compounds. Sodium chloride NaCl (table salt) is the most common chlorine compound found in nature. It is found in sea water and saline sediments underground; Figure 9-3 illustrates the crystal network of sodium chloride molecule (NaCl).

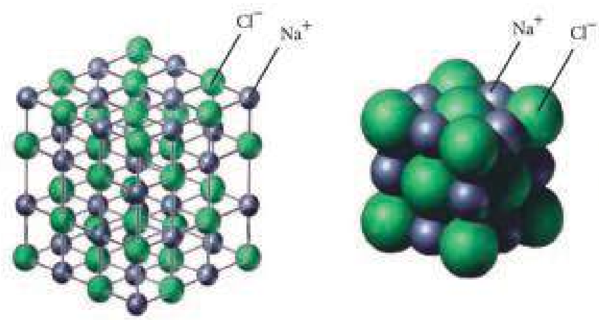


Figure 9-3
Crystal network of sodium chloride

9-3-2 Preparation of Chlorine:

A- Laboratory Preparation:

Chlorine is prepared in laboratory (Figure 9-4) by oxidizing concentrated hydrochloric acid with manganese (IV) dioxide as shown in the following equation:

$$4HCl + MnO_2 \xrightarrow{\Delta} MnCl_2 + 2H_2O + Cl_2\uparrow$$

The resulting gas is refined from HCl and water by passing it through bottles containing water and sulfuric acid consecutively. It is observed that manganese (IV) dioxide does not act as a catalyst but it is consumed after the reaction as an oxidizing agente .

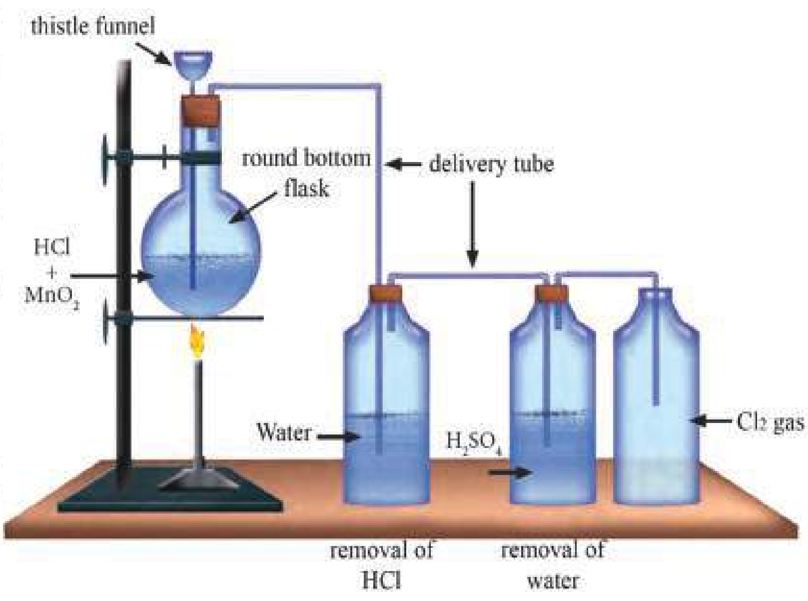


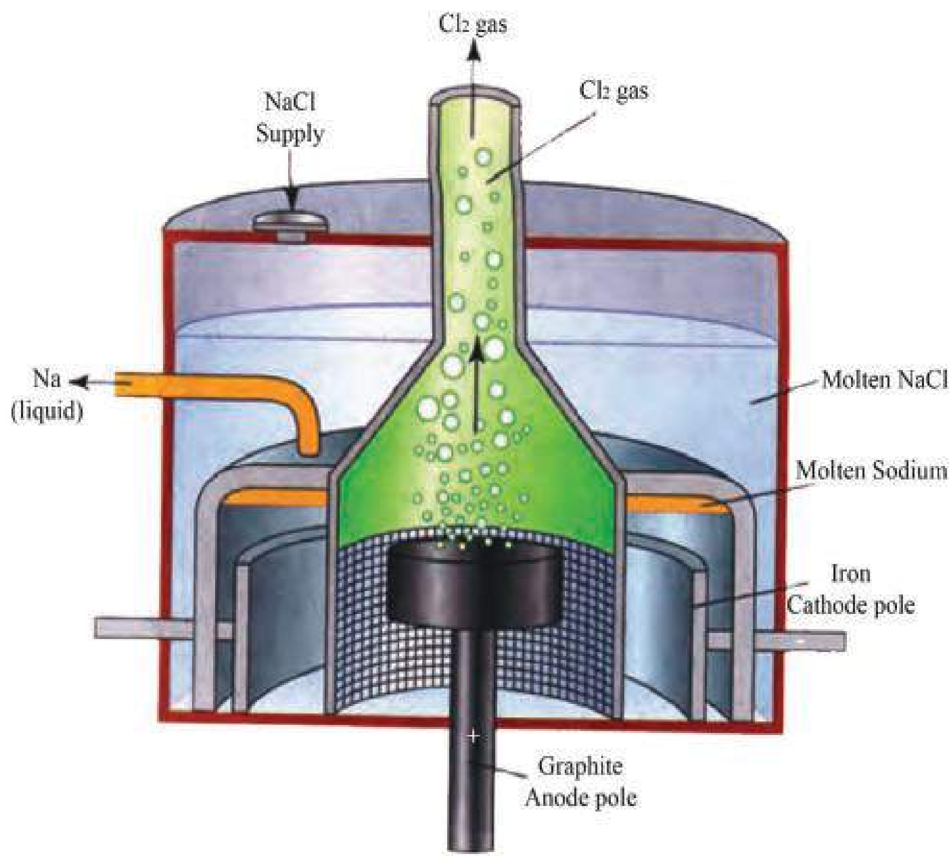
Figure 9-4
Preparation of chlorine gas in laboratory

B- Industrial Preparation of Chlorine Gas:

Chlorine is prepared industrially through electrolysis of sodium chloride in water or molten sodium chloride in the electrolytic cell, see figure 9-5.

$$\underset{}{2NaCl} \xrightarrow{\text{electric current}} \underset{\text{Negative pole}}{2Na} + \underset{\text{Positive pole}}{Cl_2\uparrow}$$

Figure 9-5
Electrolysis device for preparation of chlorine gas from molten NaCl in industry



9-3-3 Properties of Chlorine Gas:


Chlorine gas

1- It has greenish yellow color.
2- Chlorine gas is collected by pushing air upward. This indicates that chlorine gas is heavier than air.
3- It is less soluble in water under normal temperature.
4- It has suffocating odor, it attacks mucous membranes of the nose, throat and when inhaled in large quantities, it causes death.
5- It reacts with highly active metals like heated sodium forming Sodium Chloride, an ionic compound.

$$2Na + Cl_2 \xrightarrow{\Delta} 2NaCl$$

6- Chlorine gas reacts strongly with non-metals like phosphorous, forming phosphorous chlorides which are covalent compounds:

$$2P + 3Cl_2 \longrightarrow \underset{\text{Phosphorus trichloride}}{2PCl_3}$$

$$2P + 5Cl_2 \longrightarrow \underset{\text{Phosphorus pentachloride}}{2PCl_5}$$

7- Chlorine gas reacts with hydrogen to form hydrogen chloride, as in the following equation:

$$H_2 + Cl_2 \longrightarrow \underset{\text{Hydrogen chloride gas}}{2HCl}$$

9-3-4 Uses of Chlorine gas:

Chlorine gas is used in many areas:

1- Used to sterilize drinking water and swimming pools.

2- Chlorine compounds are used in the preparation of some medical drugs.

3- Chlorine gas is used in the combination of many industrial organic solvents like chloroform, $CHCl_3$, methyl dichloride, CH_2Cl_2 and carbon tetrachloride CCl_4

4- Chlorine is used in bleaching and sterilization of tissues of vegetable colors. Chlorine reacts with water when dissolve slowly under normal temperatures and reacts quickly in sunlight. It reacts with water to produce oxygen in its atomic state; this is why it is called atomic oxygen. A highly active substance which removes vegetable colors (bleach them), killing germ and sterilize. As shown in the following equation:

$$H_2O + Cl_2 \longrightarrow \underset{\text{Hydrogen chloride solution}}{2HCl} + \underset{\text{Oxygen in atomic form}}{[O]}$$

5- Chlorine is used to bleach the colors of clothes, especially cotton clothes. But, it should not be used to bleach natural silk and wool, because it damages them. Try to put a colorful flower or a plant leave in a bottle of dry chlorine gas. You cannot see a clear change. However, make the flower or the leave wet, then put them in the gas bottle and leave them there for some time. You can see that their colors fade away which in turn signal the ability of chlorine to bleach colors of plants and that water is so essential to the process of bleaching. The atomic oxygen forms during the process which bleaches the colors as we mentioned earlier.

Calcium hypochlorite $Ca(OCl)_2$ is one of chlorine compounds which is the active substance for the bleaching powder used for bleaching and purification.

9-4 HYDROGEN CHLORIDE GAS (HCl)

Hydrogen chloride gas is not found freely in nature. But, it is found in gastric juice as a hydrochloric acid solution which helps digestion of proteins.

9-4-1 Preparation of Hydrogen Chloride Gas in Laboratory:

HCl gas can be prepared in the laboratory by the reaction of concentrated sulfuric acid (H_2SO_4) with sodium chloride (NaCl) (Figure 9-6) as in the following equation:

$$NaCl + H_2SO_4 \xrightarrow{\Delta} 2NaHSO_4 + HCl \uparrow$$

Sodium chloride — Concentrated Sulfuric acid — Sodium bisulfate — Hydrogen chloride gas

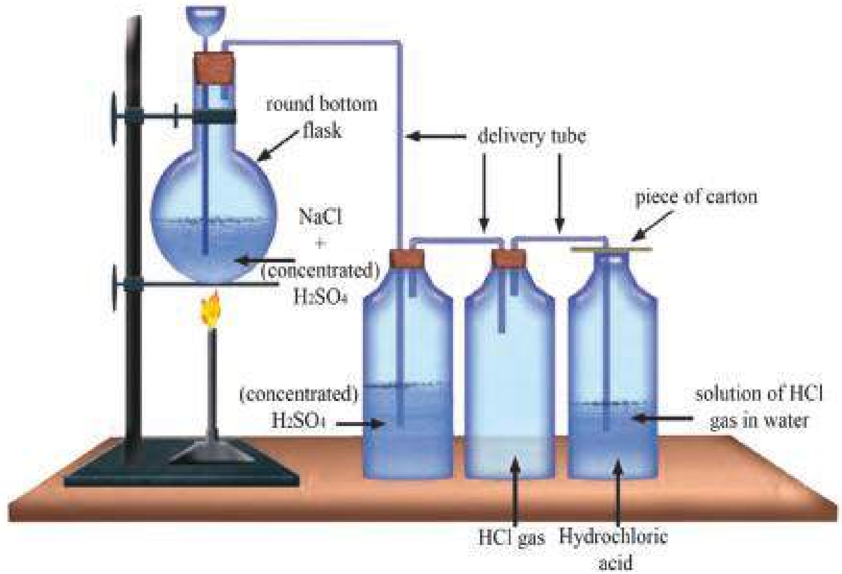


Figure 9-6
Apparatus to produce hydrogen chloride gas in the laboratory

An appropriate amount of approximately (10 mg) of pure sodium chloride is put in a glass flask. The cover of the flask has two tubes, one goes down to the bottom of the flask and the other goes to a glass bottle. Concentrated sulfuric acid is put in the glass bottle and the connecting tube goes down the acid. Another connecting tube connects the glass bottle with a dry gas collecting bottle. Concentrated sulfuric acid is added to the flask through the tube as to cover the salt. Heating the flask slowly causes a reaction that releases hydrogen chloride gas. Several gas bottles are collected and then sealed with glass covers in order for the properties of the gas to be studied.

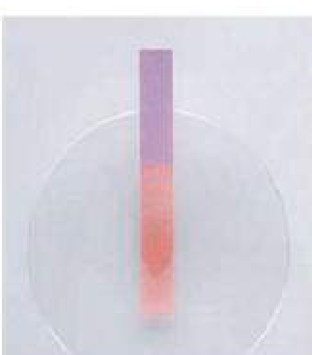
9-4-2 Properties of Hydrogen Chloride:

Properties of hydrogen chloride can be tested by using one of the gas-full bottles that have been collected during the process of preparation. The most important properties of hydrogen chloride are:

1- It is a colorless gas of suffocating odor.

2- It is heavier than air and can be collected by removing air upward.

3- The aqueous solution of hydrogen chloride is acidic in effect and it is called "Hydrochloric Acid". It changes the blue color of litmus paper into red.



Acids turn blue litmus to red.

4- It is highly soluble in water and for this property to be attested, the following experiment is made.

A gas bottle is sealed with a rubber cover with two holes, a dropper full of water goes through one of the holes and a glass tube goes through the other hole to the bottom of the gas bottle. The outer end of the tube is put a water-full bowel with little orange methylene. By squeezing the dropper, the water gushes into the bottle through the bottom-reaching glass tube as a red fountain because of the gas dissolution in the water of the dropper. This disturbs the pressure inside the gas bottle which is a clear indication of the high solubility of gas in water as shown in the figure 9-7 below:

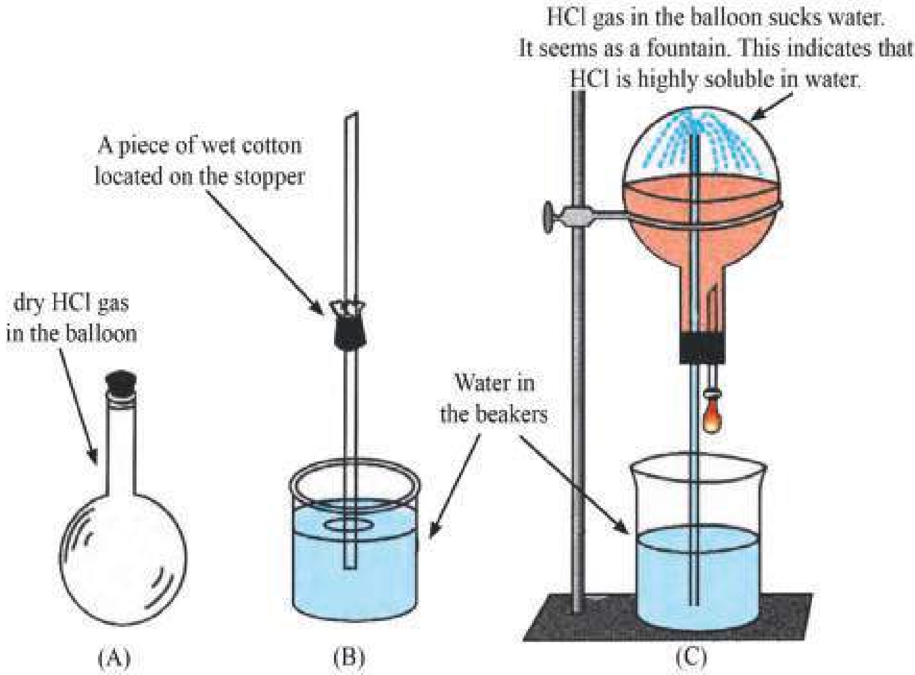


Figure 9-7
Preparation of HCl fountain in the laboratory

5- Hydrochloric acid reacts with iron fillings to form iron (II) chloride and release hydrogen gas according to the following equation:

$$\underset{\text{Iron}}{Fe} + \underset{\text{Hydrochloric acid}}{2HCl} \longrightarrow \underset{\text{Iron (II) Chloride}}{FeCl_2} + \underset{\text{Hydrogen gas}}{H_2\uparrow}$$

6- It is nonflammable and does not instigate combustion.

9-4-3 Test of hydrogen chloride gas:

A glass tube is put in the solution of ammonia. Then taken out and put again close to a bottle of hydrogen chloride gas. A white foggy substance of ammonium chloride forms as a result of the direct union of hydrogen chloride gas with ammonia solution:

$$\underset{\text{Ammonia}}{NH_3} + \underset{\text{Hydrogen chloride gas}}{HCl\uparrow} \rightarrow \underset{\text{Ammonium chloride (White foggy substance)}}{NH_4Cl}$$

Figure 9-8 Test of hydrogen chloride gas.

This reaction is considered to be one of the examination means of hydrogen chloride gas. Similarly, the same means can be used to examine ammonia gas.

It is worth mentioning here that dissolving hydrogen chloride gas in water produces a solution called "Hydrochloric acid" (HCl) which can be test by adding silver nitrate, $AgNO_3$. A white precipitate of silver chloride, AgCl, results from the reaction as will be shown in the test of chlorides.

9-5 CHLORIDES

Chlorides are salts of hydrochloric acid. They are formed when a metal or root such as ammonium replaces the hydrogen in the acid as in the equations below:

$$\underset{\text{Magnesium}}{Mg} + \underset{\text{Hydrochloric acid}}{2HCl} \longrightarrow \underset{\text{Magnesium chloride}}{MgCl_2} + \underset{\text{Hydrogen}}{H_2}$$

$$\underset{\text{Ammonium hydroxide}}{NH_4OH} + \underset{\text{Hydrochloric acid}}{HCl} \rightarrow \underset{\text{Ammonium chloride}}{NH_4Cl} + \underset{\text{Water}}{H_2O}$$

It is also possible to obtain chlorides from the direct reaction of gas chlorine with metals as in sodium chloride (NaCl) and potassium chloride (KCl). All chlorides are soluble in water except for silver chloride (AgCl) and mercury (II) chloride ($HgCl_2$). Lead (II) chloride ($PbCl_2$) is soluble only in hot water. It does not dissolve in cold water.

9-5-1 Test of Chlorides:

The insolubility of silver chloride, AgCl, in water is a very useful ways of testing chlorides. The process involves adding silver nitrate ($AgNO_3$) to its solutions such as sodium chloride solution and hydrogen chloride solution. A white precipitate of insoluble silver chloride is formed in the ammonia solution as in the equations below:

$$\underset{\text{Silver Nitrate}}{AgNO_3} + \underset{\text{Sodium Chloride}}{NaCl} \rightarrow \underset{\text{Silver Chloride (White precipitate)}}{AgCl \downarrow} + \underset{\text{Sodium Nitrate}}{NaNO_3}$$

$$\underset{\text{Silver Nitrate}}{AgNO_3} + \underset{\text{Hydrochloric acid}}{HCl} \rightarrow \underset{\text{Silver Chloride (White precipitate)}}{AgCl \downarrow} + \underset{\text{Nitric acid}}{HNO_3}$$

CHAPTER QUESTIONS 09

9.1 How many electrons are there in VIIA group elements on the outermost energy level?

9.2 Do VIIA group elements gain or lose electrons to make their outer shell full?

9.3 What the most important reactions of chlorine gas?

9.4 Choose the correct answer.

1) Which compound is important for human life and found abundantly in the nature?

a) Calcium Chloride b) Sodium Chloride
c) Potassium Chloride d) Magnesium Chloride

2) Which color differs chlorine gas from other gases?

a) Red b) green
c) Yellow d) greenish yellow

3) When chlorine atom combines with sodium atom, how many electrons are gained?

a) 1 b) 2 c) 3 d) 4

4) Which one of following gas is used to bleach herbal colors?

a) Hydrogen b) Ammonia
c) Nitrogen d) Chlorine

9.5 Complete the following reactions.

MnO_2 + HCl → ……………………..

$NaCl_{(l)}$ → ………………………….

Fe + HCl →…………………………….

Mg + HCl →…………………………..

$H_2 + Cl_2$ →…………………………..

NH_4OH + HCl →………………………

9.6 Explain the reasons of the following.

1) Chlorine gas has Mono Valent as NaCl.

2) Chlorine gas bleaches herbal textile product only in water.

3) When concentrated hydrogen chloride is approached to a bottle of ammonia solution, a foggy substance is formed.

4) Chlorine is not found freely in nature.

9.7 Which methods are used to determine the following substances?

a) Hydrochloric acid
b) Hydrogen chloride gas

9.8 What are chlorides? Write down necessary reactions to obtain magnesium chloride and ammonium chloride.

9.9 Write important usages of chlorine gas.

9.10 Explain the preparation of chlorine gas in laboratory by writing chemical equation and drawing its figure.

Electron Configuration of Element																			
Elements	sublevels																		
	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	6d	7s	7p
1-Hydrogen	1																		
2-Helium	2																		
3-Lithium	2	1																	
4-Berylium	2	2																	
5-Boron	2	2	1																
6-Carbon	2	2	2																
7-Nitrogen	2	2	3																
8-Oxygen	2	2	4																
9-Fluorine	2	2	5																
10-Neon	2	2	6																
11-Sodium	2	2	6	1															
12-Magnesium	2	2	6	2															
13-Aluminum	2	2	6	2	1														
14-Silicon	2	2	6	2	2														
15-Phosphorus	2	2	6	2	3														
16-Sulfur	2	2	6	2	4														
17-Chlorine	2	2	6	2	5														
18-Argon	2	2	6	2	6														
19-Potassium	2	2	6	2	6		1												
20-Calcium	2	2	6	2	6		2												
21-Scandium	2	2	6	2	6	1	2												
22-Titanium	2	2	6	2	6	2	2												
23-Vanadium	2	2	6	2	6	3	2												
24-Chromium	2	2	6	2	6	5	1												
25-Manganese	2	2	6	2	6	5	2												
26-Iron	2	2	6	2	6	6	2												
27-Cobalt	2	2	6	2	6	7	2												
28-Nickle	2	2	6	2	6	8	2												
29-Copper	2	2	6	2	6	10	1												
30-Zinc	2	2	6	2	6	10	2												
31-Gallium	2	2	6	2	6	10	2	1											
32-Germanium	2	2	6	2	6	10	2	2											
33-Arsenic	2	2	6	2	6	10	2	3											
34-Selenium	2	2	6	2	6	10	2	4											
35-Bromium	2	2	6	2	6	10	2	5											
36-Krypton	2	2	6	2	6	10	2	6											
37-Rubidium	2	2	6	2	6	10	2	6			1								
38-Strontium	2	2	6	2	6	10	2	6			2								
39-Yttrium	2	2	6	2	6	10	2	6	1		2								
40-Zirconium	2	2	6	2	6	10	2	6	2		2								

Electron Configuration of Element																			
Elements	sublevels																		
	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	6d	7s	7p
41-Niobium	2	2	6	2	6	10	2	6	4		1								
42-Molybdenum	2	2	6	2	6	10	2	6	5		1								
43-Technetium	2	2	6	2	6	10	2	6	5		2								
44-Ruthenum	2	2	6	2	6	10	2	6	7		1								
45-Rhodium	2	2	6	2	6	10	2	6	8		1								
46-Palladium	2	2	6	2	6	10	2	6	10										
47-Silver	2	2	6	2	6	10	2	6	10		1								
48-Cadmium	2	2	6	2	6	10	2	6	10		2								
49-Indium	2	2	6	2	6	10	2	6	10		2	1							
50-Tin	2	2	6	2	6	10	2	6	10		2	2							
51-Antimony	2	2	6	2	6	10	2	6	10		2	3							
52-Tellurium	2	2	6	2	6	10	2	6	10		2	4							
53-Iodine	2	2	6	2	6	10	2	6	10		2	5							
54-Xenon	2	2	6	2	6	10	2	6	10		2	6							
55-Cesium	2	2	6	2	6	10	2	6	10		2	6			1				
56-Barium	2	2	6	2	6	10	2	6	10		2	6			2				
57-Lanthanum	2	2	6	2	6	10	2	6	10		2	6	1		2				
58-Cerium	2	2	6	2	6	10	2	6	10	1	2	6	1		2				
59-Prasedoymium	2	2	6	2	6	10	2	6	10	3	2	6			2				
60-Neodymium	2	2	6	2	6	10	2	6	10	4	2	6			2				
61-Promethium	2	2	6	2	6	10	2	6	10	5	2	6			2				
62-Samarium	2	2	6	2	6	10	2	6	10	6	2	6			2				
63-Europium	2	2	6	2	6	10	2	6	10	7	2	6			2				
64-Gadolinum	2	2	6	2	6	10	2	6	10	7	2	6	1		2				
65-Terbium	2	2	6	2	6	10	2	6	10	9	2	6			2				
66-Dysprosium	2	2	6	2	6	10	2	6	10	10	2	6			2				
67-Holmium	2	2	6	2	6	10	2	6	10	11	2	6			2				
68-Erbium	2	2	6	2	6	10	2	6	10	12	2	6			2				
69-Thulium	2	2	6	2	6	10	2	6	10	13	2	6			2				
70-Yetterbium	2	2	6	2	6	10	2	6	10	14	2	6			2				
71-Luteium	2	2	6	2	6	10	2	6	10	14	2	6	1		2				
72-Hafanium	2	2	6	2	6	10	2	6	10	14	2	6	2		2				
73-Tantalium	2	2	6	2	6	10	2	6	10	14	2	6	3		2				
74-Tungesten	2	2	6	2	6	10	2	6	10	14	2	6	4		2				
75-Rhenium	2	2	6	2	6	10	2	6	10	14	2	6	5		2				
76-Osmium	2	2	6	2	6	10	2	6	10	14	2	6	6		2				
77-Iridium	2	2	6	2	6	10	2	6	10	14	2	6	7		2				
78-Platinum	2	2	6	2	6	10	2	6	10	14	2	6	9		1				
79-Gold	2	2	6	2	6	10	2	6	10	14	2	6	10		1				
80-Mercury	2	2	6	2	6	10	2	6	10	14	2	6	10		2				

Electron Configuration of Element

Elements	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	6d	7s	7p
81-Thalium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	1			
82-Lead	2	2	6	2	6	10	2	6	10	14	2	6	10		2	2			
83-Bismuth	2	2	6	2	6	10	2	6	10	14	2	6	10		2	3			
84-Polonium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	4			
85-Astatine	2	2	6	2	6	10	2	6	10	14	2	6	10		2	5			
86-Radon	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6			
87-Francium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6		1	
88-Radium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6		2	
89-Actinium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6	1	2	
90-Thorium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6	2	2	
91-Protactinum	2	2	6	2	6	10	2	6	10	14	2	6	10	2	2	6	1	2	
92-Uranium	2	2	6	2	6	10	2	6	10	14	2	6	10	3	2	6	1	2	
93-Neptonium	2	2	6	2	6	10	2	6	10	14	2	6	10	4	2	6	1	2	
94-Plutonium	2	2	6	2	6	10	2	6	10	14	2	6	10	6	2	6		2	
95-Amerecium	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6		2	
96-Curium	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6	1	2	
97-Berkelium	2	2	6	2	6	10	2	6	10	14	2	6	10	9	2	6		2	
98-Californium	2	2	6	2	6	10	2	6	10	14	2	6	10	10	2	6		2	
99-Einestanium	2	2	6	2	6	10	2	6	10	14	2	6	10	11	2	6		2	
100-Fermium	2	2	6	2	6	10	2	6	10	14	2	6	10	12	2	6		2	
101-Mendelevium	2	2	6	2	6	10	2	6	10	14	2	6	10	13	2	6		2	
102-Nobelium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6		2	
103-Lawrencium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	1	2	
104-Rutherium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	2	2	
105-Dubinum	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	3	2	
106-Seaborgium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	4	2	
107-Bohrium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	5	2	
108-Hassium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	6	2	
109-Meitnerium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	7	2	
110-Darmstadium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	9	1	
111-Unununium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	10	1	
112-Unubium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	10	2	
113- Ununquadium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	10	2	2

SI Units and Conversion Factors الوحدات وعوامل التحويل الجدول (1)

الطول (Length) SI Unit: meter (m) المتر

1 kilometer(km) =1000 meter(m)

1 mile = 1.61 kilometer (km)

1 meter(m)=100 centimeter (cm)

الحجم (Volume) SI Unit: cubic meter المكعب(m^3) المتر

1 liter (L) = 10^{-3} meter^3 (m^3)

1 liter(L) =1000 milliliter(mL)

1 liter(L)= 1000 centimeter^3 (cm^3)

1 milliliter (mL) =1centimeter^3 (cm^3)

درجة الحرارة (Temperature) SI Unit: Kelvin (K)

T Kelvin(K) =t Celsius (°C) +273

°F Fahrenheit = $\frac{9}{5}$ × t Celsius (°C) +32

الكتلة (Mass) SI Unit: kilogram (kg)

1 kilogram =1000 grams (1 kg = 1000 g)

1 amu(وكذ) = 1.66×10^{-27} kg

amu (وحدة كتلة ذرية)

الزمن (Time) SI Unit: second (s)

1 hour (h) = 60 minutes (min)

1 hour (h)= 3600 seconds (s)

الطاقة (Energy) SI Unit : Joule(J)

1 Joule (J) = 1 kg . m^2/s^2 (exact)

1 calorie (cal)= 4.184 Joules (J)

الضغط (Pressure) SI Unit: Pascal (Pa)

1 atmosphere (atm) = 101.325 Pascal (Pa)

1 atmosphere(atm) = 760 mm Hg = 760 Torr

1 mmHg =1 Torr

Oher Symbols and abbreviations (المختصرات العلمية)

α alpha particals (دقائق الفا)	h hour (ساعة)	mL milliter (volume) ملتر (حجم)
β beta particals (دقائق بيتا)	J Joule(energy)(جول (وحدة طاقة)	mm millimeter (length) ملمتر (طول)
γ gamma rays (اشعة كاما)	K Kelvin (temperature) (حرارة)	mole (amount) مول(كمية)
atomic mass unit (amu) (وحدة كتلة ذرية)	kg kilogram (mass) كيلو غرام (كتلة)	(mp) melting point نقطة انصهار
(aq) aqueous solution (محلول مائي)	kPa kilopascal (pressure) كيلو باسكال (ضغط)	n° neutron نيوترون
(atm) atmosphere (pressure)(وحدة ضغط)	L liter (volume) لتر (حجم	n number of moles عدد المولات
bp boiling point(نقطة الغليان)	(l) liquid (سائل)	n principal quantum number عدد الكم الرئيسي
°C degree Celsius (temperature)(درجة سيليزية)	M molar mass الكتلة المولية	P pressure ضغط
C Speed of light in vacunm (سرعة الضوء)	m meter (length) (متر(طول	p^+ proton بروتون
cm centimeter (lenght)(سنتيمتر وحدة الطول)	m mass كتلة	Pa pascal (pressure) باسكال ضغط
E energy(الطاقة)	V volume حجم	R ideal gas constant ثابت الغاز المثالي
e^- electron(الكترون)	$t_{1/2}$ half– life time زمن عمر النصف	s second ثانية
g gram (mass)(غرام (وحدة الكتلة	T temperature درجة حرارة	(s) solid صلب
(g) gas (غاز)	STP Standard Temperature and Pressure الظروف القياسية	SI international System of Units النظام الدولي للوحدات

List of Elements

ATOMIC NUMBER	NAME	SYMBOL	RELATIVE ATOMIC MASS	GROUP	PERIOD
1	Hydrogen	H	1.00794	1 / IA	1
2	Helium	He	4.002602	18 / VIIIA	1
3	Lithium	Li	6.941	1 / IA	2
4	Beryllium	Be	9.012182	2 / IIA	2
5	Boron	B	10.811	13 / IIIA	2
6	Carbon	C	12.0107	14 / IVA	2
7	Nitrogen	N	14.0067	15 / VA	2
8	Oxygen	O	15.9994	16 / VIA	2
9	Fluorine	F	18.9984032	17 / VIIA	2
10	Neon	Ne	20.1797	18 / VIIIA	2
11	Sodium (Natrium)	Na	22.98976928	1 / IA	3
12	Magnesium	Mg	24.3050	2 / IIA	3
13	Aluminium (Aluminum)	Al	26.9815386	13 / IIIA	3
14	Silicon	Si	28.0855	14 / IVA	3
15	Phosphorus	P	30.973762	15 / VA	3
16	Sulfur	S	32.065	16 / VIA	3
17	Chlorine	Cl	35.453	17 / VIIA	3
18	Argon	Ar	39.948	18 / VIIIA	3
19	Potassium (Kalium)	K	39.0983	1 / IA	4
20	Calcium	Ca	40.078	2 / IIA	4
21	Scandium	Sc	44.955912	3 / IIIB	4
22	Titanium	Ti	47.867	4 / IVB	4
23	Vanadium	V	50.9415	5 / VB	4
24	Chromium	Cr	51.9961	6 / VIB	4
25	Manganese	Mn	54.938045	7 / VIIB	4
26	Iron (Ferrum)	Fe	55.845	8 / VIII	4
27	Cobalt	Co	58.933195	9 / VIII	4
28	Nickel	Ni	58.6934	10 / VIII	4
29	Copper (Cuprum)	Cu	63.546	11 / IB	4
30	Zinc	Zn	65.39	12 / IIB	4
31	Gallium	Ga	69.723	13 / IIIA	4
32	Germanium	Ge	72.64	14 / IVA	4
33	Arsenic	As	74.92160	15 / VA	4
34	Selenium	Se	78.96	16 / VIA	4
35	Bromine	Br	79.904	17 / VIIA	4
36	Krypton	Kr	83.798	18 / VIIIA	4
37	Rubidium	Rb	85.4678	1 / IA	5
38	Strontium	Sr	87.62	2 / IIA	5
39	Yttrium	Y	88.90585	3 / IIIB	5
40	Zirconium	Zr	91.224	4 / IVB	5
41	Niobium	Nb	92.906 38	5 / VB	5
42	Molybdenum	Mo	95.94	6 / VIB	5
43	Technetium	Tc	97.9072*	7 / VIIB	5
44	Ruthenium	Ru	101.07	8 / VIII	5

45	Rhodium	Rh	102.905 50	9 / VIII	5
46	Palladium	Pd	106.42	10 / VIII	5
47	Silver (Argentum)	Ag	107.8682	11 / IB	5
48	Cadmium	Cd	112.411	12 / IIB	5
49	Indium	In	114.818	13 / IIIA	5
50	Tin (Stannum)	Sn	118.710	14 / IVA	5
51	Antimony (Stibium)	Sb	121.760	15 / VA	5
52	Tellurium	Te	127.60	16 / VIA	5
53	Iodine	I	126.904 47	17 / VIIA	5
54	Xenon	Xe	131.293	18 / VIIIA	5
55	Caesium (Cesium)	Cs	132.9054519	1 / IA	6
56	Barium	Ba	137.327	2 / IIA	6
57	Lanthanum	La	138.90547 -		6
58	Cerium	Ce	140.116 -		6
59	Praseodymium	Pr	140.90765 -		6
60	Neodymium	Nd	144.242 -		6
61	Promethium	Pm	144.9127 -		6
62	Samarium	Sm	150.36		6
63	Europium	Eu	151.964 -		6
64	Gadolinium	Gd	157.25		6
65	Terbium	Tb	158.92535 -		6
66	Dysprosium	Dy	162.500		6
67	Holmium	Ho	164.930 32 -		6
68	Erbium	Er	167.259 -		6
69	Thulium	Tm	168.93421 -		6
70	Ytterbium	Yb	173.04 -		6
71	Lutetium	Lu	174.967	3 / IIIB	6
72	Hafnium	Hf	178.49	4 / IVB	6
73	Tantalum	Ta	180.94788	5 / VB	6
74	Tungsten (Wolfram)	W	183.84	6 / VIB	6
75	Rhenium	Re	186.207	7 / VIIB	6
76	Osmium	Os	190.23	8 / VIII	6
77	Iridium	Ir	192.217	9 / VIII	6
78	Platinum	Pt	195.084	10 / VIII	6
79	Gold (Aurum)	Au	196.966569	11 / IB	6
80	Mercury (Hydrargy rum)	Hg	200.59	12 / IIB	6
81	Thallium	Tl	204.3833	13 / IIIA	6
82	Lead (Plumbum)	Pb	207.2	14 / IVA	6
83	Bismuth	Bi	208.98040	15 / VA	6
84	Polonium	Po	208.9824*	16 / VIA	6
85	Astatine	At	209.9871*	17 / VIIA	6
86	Radon	Rn	222.0176*	18 / VIIIA	6
87	Francium	Fr	223.0197*	1 / IA	7
88	Radium	Ra	226.0254*	2 / IIA	7
89	Actinium	Ac	227.0277* -		7
90	Thorium	Th	232.03806* -		7
91	Protactinium	Pa	231.03588* -		7
92	Uranium	U	238.02891		7

93	Neptunium	Np	237.0482*		7
94	Plutonium	Pu	244.0642*		7
95	Americium	Am	243.0614*	-	7
96	Curium	Cm	247.0704*	-	7
97	Berkelium	Bk	247.0703*	-	7
98	Californium	Cf	251.0796*	-	7
99	Einsteinium	Es	252.0830*		7
100	Fermium	Fm	257.0951*	-	7
101	Mendelevium	Md	258.0984*		7
102	Nobelium	No	259.1010*	-	7
103	Lawrencium	Lr	262.1097*	3 / IIIB	7
104	Rutherfordium	Rf	261.1088*	4 / IVB	7
105	Dubnium	Db	262	5 / VB	7
106	Seaborgium	Sg	266	6 / VIB	7
107	Bohrium	Bh	264	7 / VIIB	7
108	Hassium	Hs	277	8 / VIII	7
109	Meitnerium	Mt	268	9 / VIII	7
110	Darmstadtium	Ds	271	10 / VIII	7
111	Roentgenium	Rg	272	11 / IB	7
112	Ununbium	Uub	285	12 / IIB	7
113	Ununtrium	Uut	284	13 / IIIA	7
114	Ununquadium	Uuq	289	14 / IVA	7
115	Ununpentium	Uup	288	15 / VA	7
116	Ununhexium	Uuh	292	16 / VIA	7
117	Ununseptium	Uus		17 / VIIA	7
118	Ununoctium	Uuo	294	18 / VIIIA	7
			-		

*Relative atomic mass of the isotope of the element with the longest known half-life.

Periodic Table of the Elements

Atomic Number	6
Symbol	C
Name	Carbon
Average Atomic Mass	12.0107

- Hydrogen
- Semiconductors (also known as metalloids)

Metals
- Alkali metals
- Alkaline-earth metals
- Transition metals
- Other metals

Nonmetals
- Halogens
- Noble gases
- Other nonmetals

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
1	1 H Hydrogen 1.007 94																	2 He Helium 4.002 60
2	3 Li Lithium 6.941	4 Be Beryllium 9.012 182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.998 4032	10 Ne Neon 20.1797
3	11 Na Sodium 22.989 769 28	12 Mg Magnesium 24.3050											13 Al Aluminum 26.981 5386	14 Si Silicon 28.0855	15 P Phosphorus 30.973 762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955 912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938 045	26 Fe Iron 55.845	27 Co Cobalt 58.933 195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.409	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.921 60	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.905 85	40 Zr Zirconium 91.224	41 Nb Niobium 92.906 38	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.905 50	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.904 47	54 Xe Xenon 131.293
6	55 Cs Cesium 132.905 4519	56 Ba Barium 137.327	57 La Lanthanum 138.905 47	72 Hf Hafnium 178.49	73 Ta Tantalum 180.947 88	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966 569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.980 40	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub* Ununbium (285)		114 Uuq* Ununquadium (289)		116 Uuh* Ununhexium (292)		

* The systematic names and symbols for elements greater than 111 will be used until the approval of trivial names by the IUPAC.

The discoveries of elements with atomic numbers 112, 114, and 116 have been reported but not fully confirmed.

58 Ce Cerium 140.116	59 Pr Praseodymium 140.907 65	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925 35	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930 32	68 Er Erbium 167.259	69 Tm Thulium 168.934 21	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
90 Th Thorium 232.038 06	91 Pa Protactinium 231.035 88	92 U Uranium 238.028 91	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

The atomic masses listed in this table reflect the precision of current measurements. (Each value listed in parentheses is the mass number of that radioactive element's most stable or most common isotope.)