Atomic Structure of Matter:

Atoms:- Tiny particles which form the basic unit of the substances in the universe.
***atom means indivisible in Latin.**

Evolution of the concept of the atomic structure:

1-Dalton's Model:

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

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) "The atom is positively charged sphere on which negatively charged electrons are attached to balance the charge". Therefore the atom has a neutral charge.

3-Rutherford Model:

In the early 20th century after discovering of (the proton a positively charged particle, its mass greater than the mass of the electron). Rutherford said that the 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 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.

This model is called "The Planetary Astral Model", Why ?

A/ The electrons rotate around the nucleus in various orbits with varying distances from the nucleus as in the case of planets rotating around the sun.

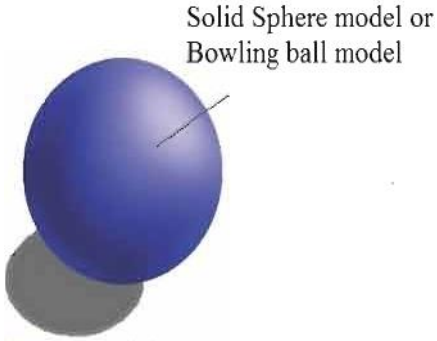


Figure 1-1
Dalton's Atomic Model

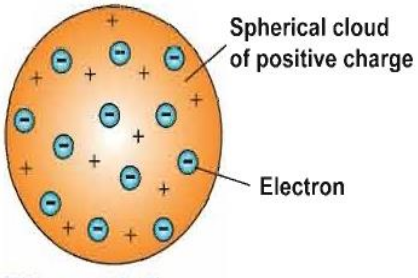


Figure 1-2
Thomson's Atomic Model

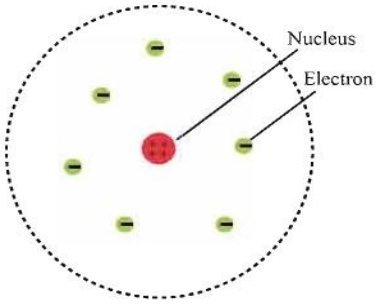


Figure 1-3
Rutherford's Atomic Model

Q:What are the problems with Rutherford's model? (The reasons of fail)

A/There are two assumptions:

No.1 Assumption:The negative electrons(e^-) are static these electrons will be drawn to (magnetized) nucleus with the positive charge.

No.2 Assumption:Electrons must be in constant motion, 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 moving around in a circular motion and finally falls into the nucleus.

In both assumptions, the atom must collapse and atoms don't.

(1) Bohr's Model:

The Danish scientist proposed in 1913 that:-

1- electrons rotate around the nucleus in a fixed energy levels.

2- Each energy level has a distinctive number describing its energy, this number is called principal quantum number.

***electron in 1st energy level has a principal quantum number 1**

***electron in 2nd energy level has a principal quantum number 2**

3- The farther from the nucleus the more the level of energy.

4- An electron may travel within energy levels through gaining

or losing energy.

Q: Why Bohr's model based on Hydrogen atom?

A/ it's the simplest atomic structure because it contains one proton (p^+) and one electron (e^-).

***This model failed to explain for some natural phenomena of other elements containing more electrons.**

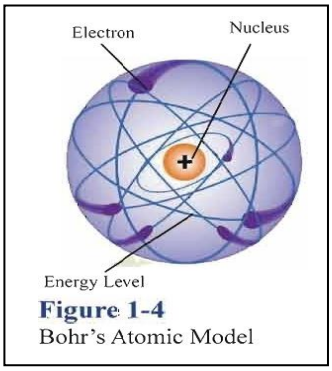


Figure 1-4
Bohr's Atomic Model

(2)Modern Atomic Theory: **Scientists 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**

Orbital:- can be expressed as the electron cloud surrounding the nucleus.
***This atomic cloud has different shapes and sizes.**

Q: What are the hypothesis of modern atomic theory?

A/ (1) The atoms consist 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 atom) in energy levels these levels represented by

Principal quantum numbers (positive integers with n symbol)

(3) The nucleus at the center of the atom and consists of the proton (P^+) and neutron (n^0).

Energy levels: **Electrons rotating continuously around the nucleus on different orbitals with different energy, the rotate in a different distances. Scientists used numbers called Secondary quantum numbers which describe fairly all features of the orbital as well as the electrons in this orbital.**

[1] Primary energy levels:represented by principal quantum number (n), it holds a positive value equals 1,2,3,4,5,6,7… Each indicates a particular energy level. (n) Cannot be zero

***greatest (n) → greatest energy**

Higher (n) value farther distance of electron from the nucleus and having more energy.

Table 1-1

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

Energy increasing

***(n=1) the nearest to the nucleus → has the lowest energy**

***(n=7) the farthest to the nucleus → has the highest energy**

This energy level (n =7 Q) is the farthest from nucleus and less attached to nucleus therefore, it's easy to be removed.

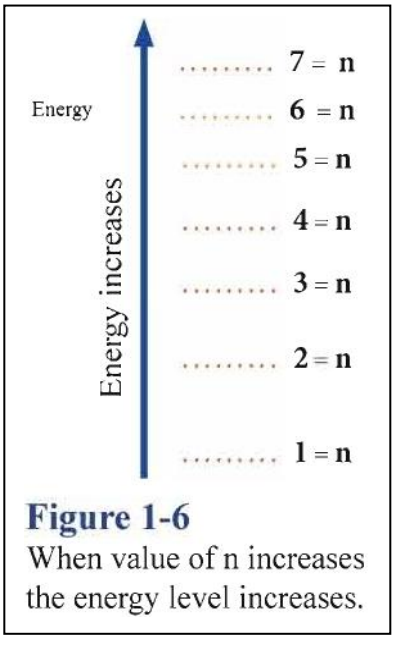


Figure 1-6
When value of n increases the energy level increases.

[2] Secondary energy levels: Are four levels (s,p,d,f) found in the primary energy levels. And differ in shape and number of electrons.

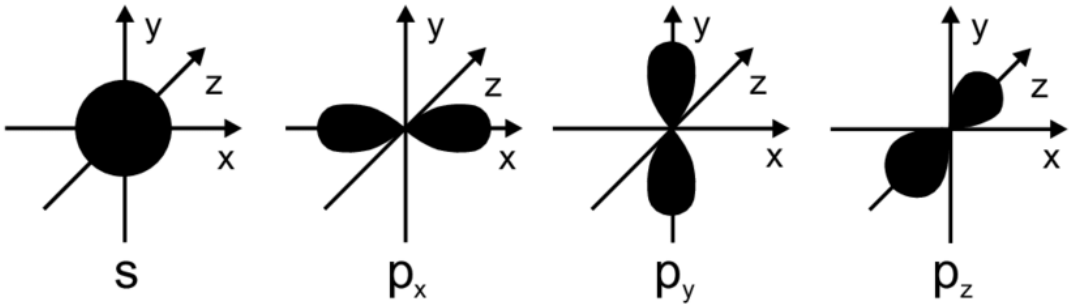
(1) Orbital S : one orbital, it has a spherical shape can hold up 2 electrons S^2.

(2) Orbital P : three orbitals, each orbital consist of two equivalent sides distributed in three vertical directions (Px, Py, Pz) can hold up 6 electrons P^6 .

(3) Orbital d : five orbitals, can hold up 10 electrons d^{10} .

(4) Orbital f : Seven orbitals, can hold up 14 electrons f^{14}.

***Both d and f have more complicated interstitial forms.**

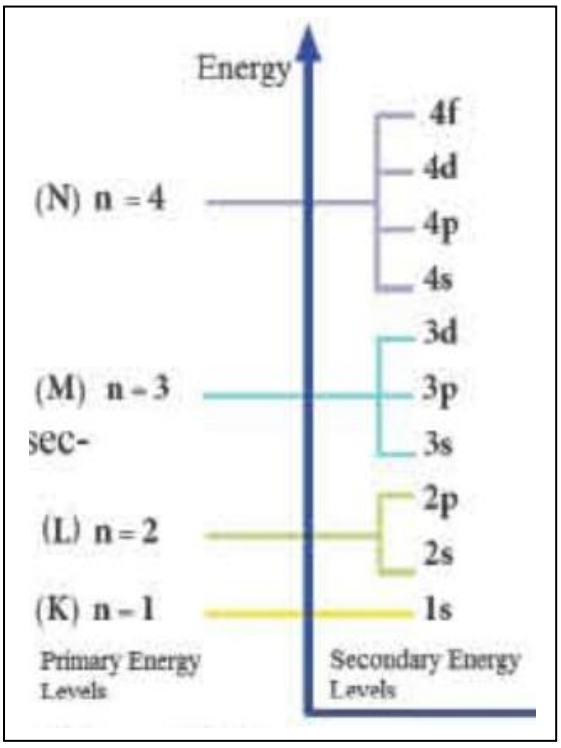


First Primary energy level n=1 (K) $1s^2$ (1 orbital) ($2\ e^-$)

Second Primary energy level n=2 (L) $2s^2$ $2p^6$ (4 orbitals) ($8\ e^-$)

Third Primary energy level n=3 (M) $3s^2$ $3p^6$ $3d^{10}$ (9 orbitals) ($18\ e^-$)

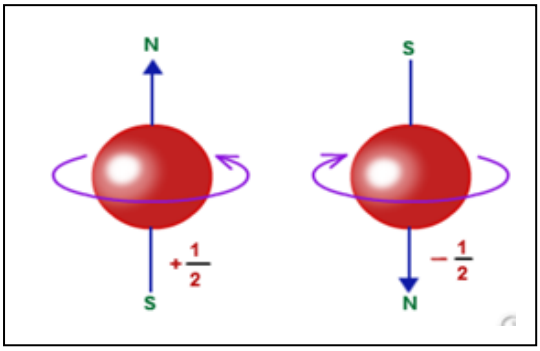
Fourth Primary energy level n=4 (N) $4s^2$ $4p^6$ $4d^{10}$ $4f^{14}$ (16 orbitals) ($32\ e^-$)



*Orbital indicated by ☐

Q: Why electrons don't repel each other in an orbital?

A/ When two electrons are coupled in one orbital one would spin clockwise ↑ and the other would spin anticlockwise ↓ they cancel repulsion in this way.



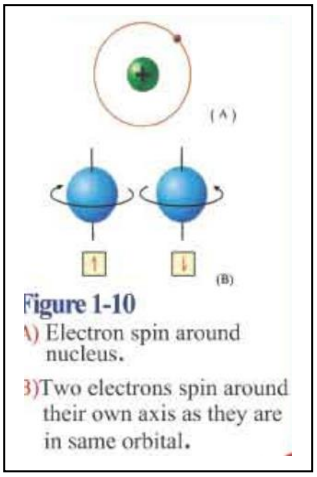


Figure 1-10
A) Electron spin around nucleus.
B)Two electrons spin around their own axis as they are in same orbital.

Q:How many spins (motion) of electron? -2 spins

A-Electron spins around itself at the same time as it spins around the nucleus.

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

Exercise 1-3:(A) What is the number of orbitals in the first and third primary energy levels?

Answer- First primary energy level n=1 (K) 1s [one orbital].

Third primary energy level n=3 (M) 3s 3p 3d

One s orbital + three p orbitals + five d orbitals= [nine orbitals].

(B)What is the number of electrons of second and third primary energy levels?

Answer-Second primary energy level n=2 (L) $2s^2$ $2p^6$

[2+6 = 8 electrons]

Third primary energy level n=3 (M) $3s^2$ $3p^6$ $3d^{10}$

[2 + 6 +10 =18 electrons]

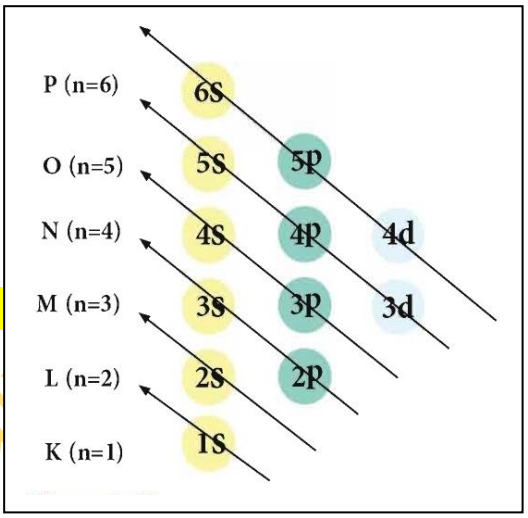
Electron Configuration:- **The configuration of electrons of the atom around the nucleus.**

***Electrons are ordered in the atoms in a way that the total energy is at the minimum.**

Rules of Configuration:

(1) Aufbau principle:-Shows that" secondary energy levels are filled with electrons according to their energy level, from the lowest to the highest".

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



***The number of electrons of the electrically balanced neutral atom must be equal its atomic number.**

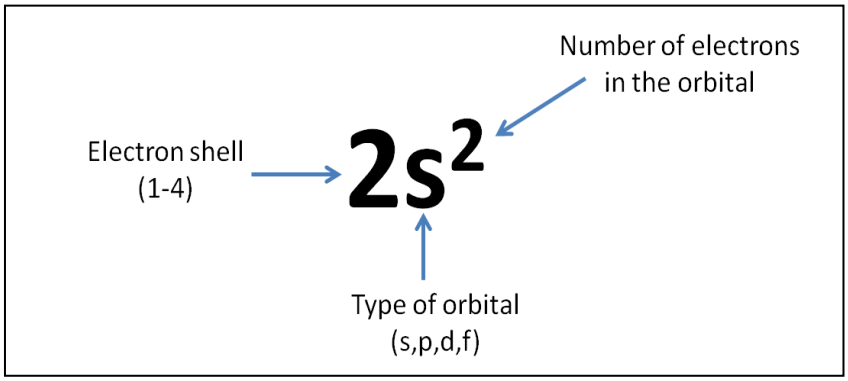
Q: There's an overlap between secondary shells which belong to various primary shells. Why?

A-Higher number of the primary shell, higher energy of electrons and less distance between shells.

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

(2) Hund's Rule:- Shows that "no electrons are doubly occupied in the subshell (secondary level) unless its orbitals are singly filled".

***This rule applies to atoms whose electron configuration ends with secondary energy levels p, d, f.**



Example 1-1: **Write the electron configuration for the following subshells?**
p^3, d^4, f^6, p^4,d^7 ,f^{11} ,p^5 .

Solution: p^3 ↑ ↑ ↑

d^4 ↑ ↑ ↑ ↑ | f^6 ↑ ↑ ↑ ↑ ↑ ↑ | p^4 ↑↓ ↑ ↑

d^7 ↑↓ ↑↓ ↑ ↑ ↑ | f^{11} ↑↓ ↑↓ ↑↓ ↑↓ ↑ ↑ ↑ | p^5 ↑↓ ↑↓ ↑

Exercise 1-4: **Write the electron configuration for the following subshells?**
p^2, d^6, d^3, p^5

Solution:

p^2 1 1 | d^3 1 1 1

d^6 1↓ 1 1 1 1 | p^5 1↓ 1↓ 1

Example 1-2

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

Solution:

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

Exercise 1-5

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

Solution :-

$_9F$: $\underset{K}{1s^2}\ \underset{L}{2s^2\ 2p^5}$

$_{14}Si$: $\underset{K}{1s^2}\ \underset{L}{2s^2\ 2p^6}\ \underset{M}{3s^2\ 3p^2}$

$_{18}Ar$: $\underset{K}{1s^2}\ \underset{L}{2s^2\ 2p^6}\ \underset{M}{3s^2\ 3p^6}$

Example 1-3: **Write the electron configuration and order of electrons in the primary energy level for each of the following elements:**

$_{15}P$, $_{13}Al$, $_{12}Mg$, $_{10}Ne$, $_{8}O$, $_{5}B$

Solution:

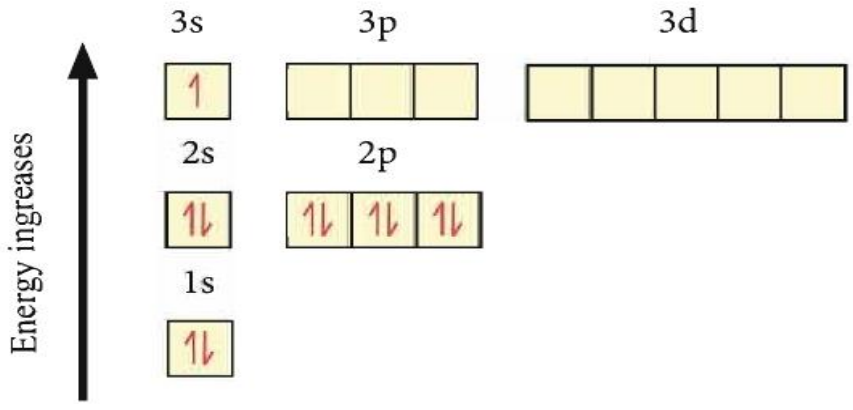
Element	Electron configuration	Outermost energy level
$_5B$	$1s^2\ 2s^2\ 2p^1$	$2s^2\ 2p^1$
$_8O$	$1s^2\ 2s^2\ 2p^4$	$2s^2\ 2p^4$
$_{10}Ne$	$1s^2\ 2s^2\ 2p^6$	$2s^2\ 2p^6$
$_{12}Mg$	$1s^2\ 2s^2\ 2p^6\ 3s^2$	$3s^2$
$_{13}Al$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$	$3s^2\ 3p^1$
$_{15}P$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$	$3s^2\ 3p^3$

Example 1-4

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

Solution:

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



Exercise 1-6

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

Solution:-

$_{3}Li$ $1s^2$ $2s^1$

K L

increase energy

2(L) $2s^1$ 1 $2p^0$

1(K) $1s^2$ ↿⇂

$_{15}P$ $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^3$

K L M

increase energy

3(M) $3s^2$ ↿⇂ $3p^3$ 1 1 1 $3d^0$

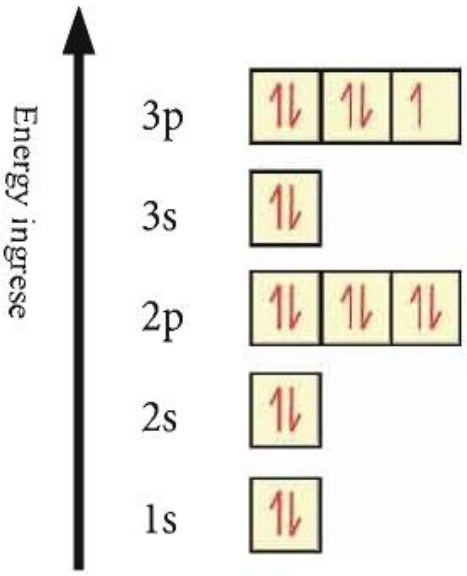
2(L) $2s^2$ ↿⇂ $2p^6$ ↿⇂ ↿⇂ ↿⇂

1(K) $1s^2$ ↿⇂

Example 1-5: Write the electron configuration of chlorine 17Cl then indicate the order of secondary energy levels from lowest to the highest.

Solution:

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

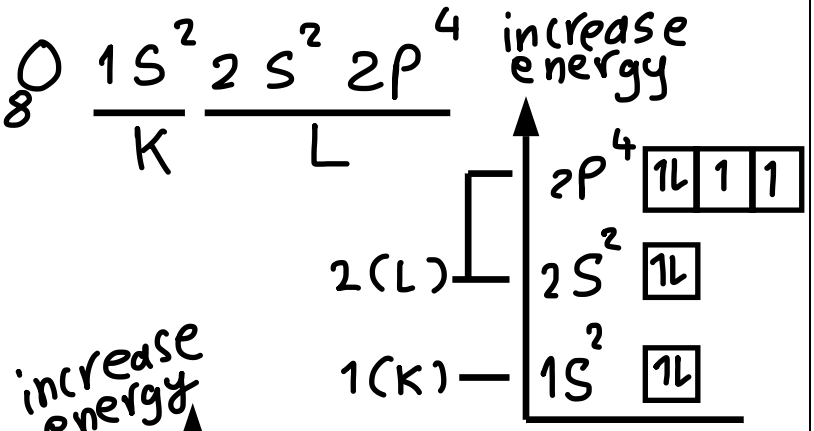


Exercise 1-7

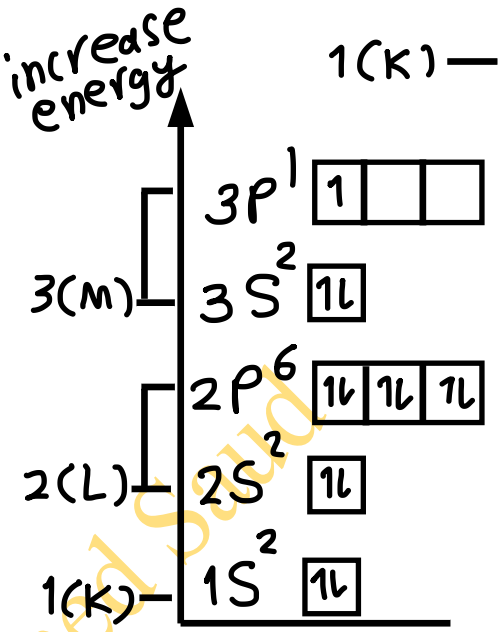
Write the electron configuration the for following atoms then indicate the gradual energy according to the secondary energy levels.
$_{13}Al$, $_{8}O$

Solution:

$_{8}O$: $1s^2$ $2s^2$ $2p^4$ — K, L



$_{13}Al$: $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^1$ — K, L, M



Example 1-6

State the number of electrons in each primary energy level around the nucleus.
$_{5}B$, $_{10}Ne$, $_{12}Mg$

Solution:

$_{5}B = 1s^2\ \ 2s^2\ 2p^1$

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

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

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

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

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: $_{2}He$, $_{7}N$

Solution:

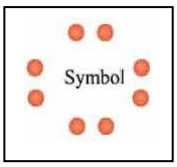
$_{2}He$: $1s^2$ — K

1(K): $2e^-$

$_{7}N$: $1s^2$ $2s^2$ $2p^3$ — K, L

1(K): $2e^-$
2(L): $5e^-$

Lewis order (Lewis symbol):-Electrons of the outer shell of the atom are ordered in a symbolic way.



Lewis's symbol depends on the number of electrons on the last shell (external energy level) which is called valence shell.

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 distributed in four directions in such a way that it has two dots on the right and two on the left, two dots above and two dots below.

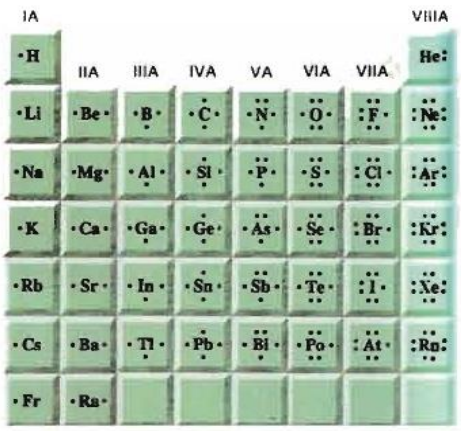


Figure 1-13
Some elements from periodic table with Lewis order.

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
$_1H$	$1s^1$	1	H·
$_5B$	$1s^2$ $2s^2\ 2p^1$	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.
$_{20}Ca$, $_{18}Ar$, $_{13}Al$

Solution:

$_{13}Al : 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ ·Al·

$_{18}Ar : 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$:Ar:

$_{20}Ca : 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ ·Ca·

Example 1-8

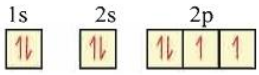
An atom, the electrons of which are ordered as follows.

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

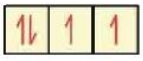
1- What is the total number of electrons in this atom?
2- What is the atomic number ?
3- How many secondary energy level filled with electrons?
4- What is the number of single electrons?
5- Write Lewis symbol for this atom?

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 

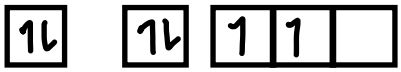
Exercise 1-10

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?

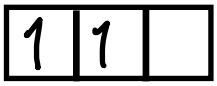
Solution:

① $1s^2\ 2s^2\ 2p^2$ (K, L)



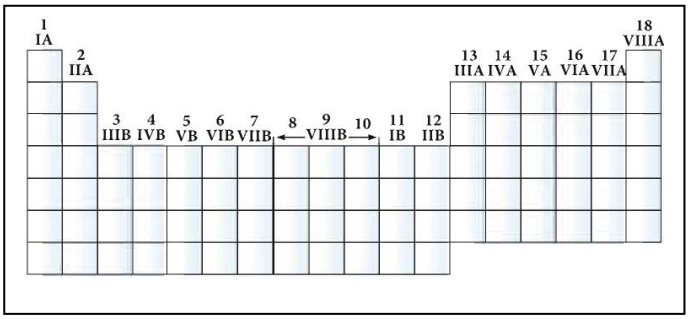
② two secondary energy levels are full filled with electrons ($1s^2, 2s^2$)

③ two Singles electrons ($2p^2$)



④ Symbol

Periodic table:- **Is considered the most 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.**



Classification of Elements in the Periodic Table According to the 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 energy level with which the electron configuration of the elements ends with (s, p, d, f)

(1)S-Block Elements:

The elements on the far left of the periodic table including two groups IA and IIA, whose electron configuration ends with s, except for Helium ($_2$He) it is added to the noble elements at the far right of the periodic table. Group IA include elements whose last secondary energy level s has one electron (s^1), group IIA includes elements whose last secondary energy level s has two electrons (s^2).

(2)P-Block Elements:

These elements are located on the right side of the periodic table, 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 called the noble gases group.

Represented Elements:- Elements partly filled with electrons at the secondary shells S and P , and noble elements.

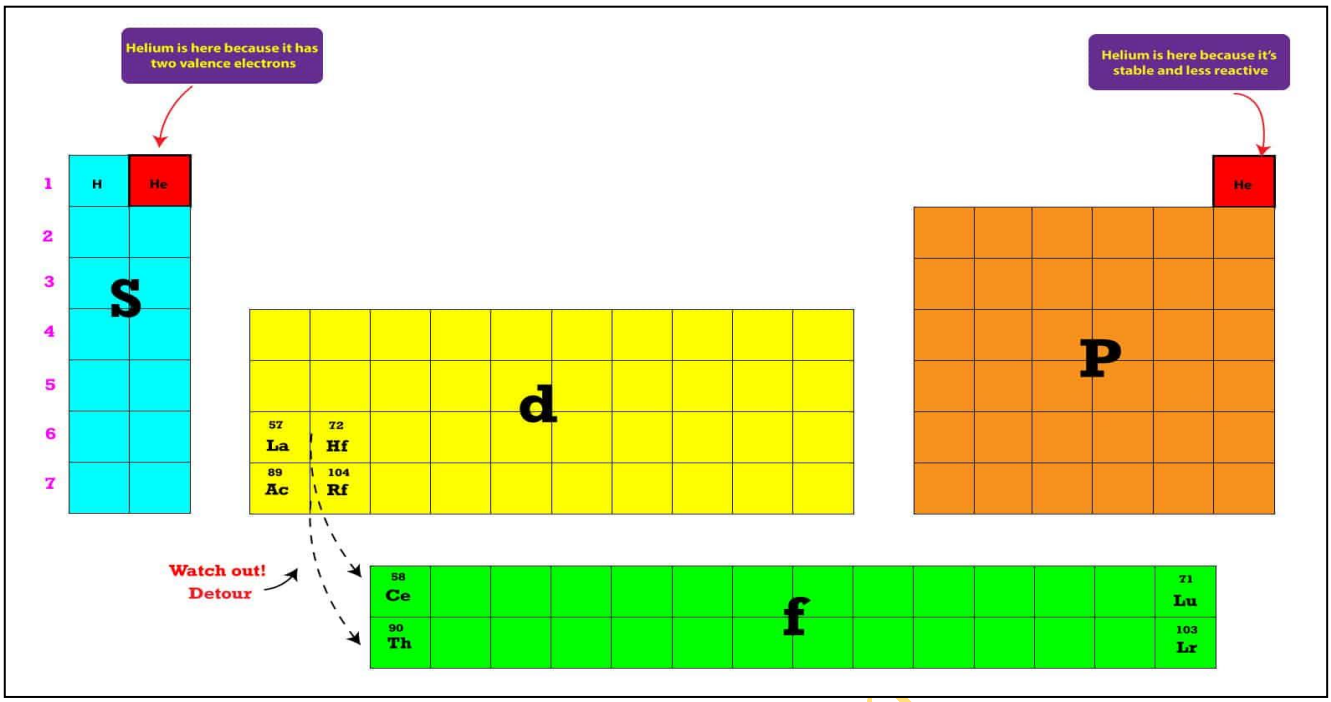
IA: alkaline metals IIA: Alkaline Earth metals VIIA: Halogens

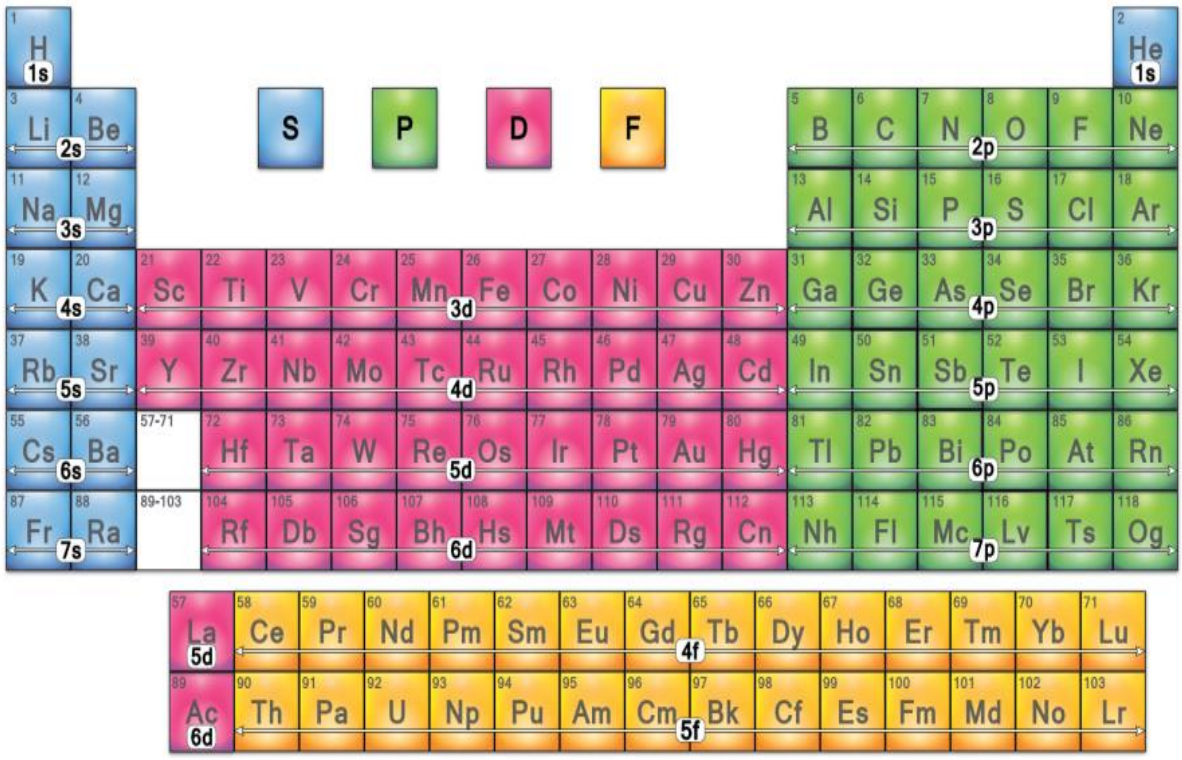
(3)d-Block Elements:

These are metal elements whose electron configuration ends with s and d , they are called Transition Elements or B – block elements , at the center of the periodic table.

(4)f-Block Elements:

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


Helium is here because it has two valence electrons
Helium is here because it's stable and less reactive
H
He
S
d
P
57 La
72 Hf
89 Ac
104 Rf
Watch out! Detour
58 Ce
90 Th
f
71 Lu
103 Lr


S
P
D
F
1s
2s
3s
4s
3d
5s
4d
6s
5d
7s
6d
2p
3p
4p
5p
6p
7p
4f
5f

Finding period and group number of any element in group A :

1-Write the electron configuration of the element.
2- The number of the period is the highest number of the n, with 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. *s = group

b) If the electron configuration ends with 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. *(s+p) = group

If the total number of electron is 8 then it means that this element is in the noble gases group. Except for helium $_2$He 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?
$_{19}K$, $_{10}Ne$, $_{17}Cl$, $_8O$

Solution:

$_8$O: $1s^2$ $\underline{2s^2\ 2p^4}$ 2^{nd} period , 6^{th} group (VIA)

$_{17}$Cl: $1s^2\ 2s^2\ 2p^6$ $\underline{3s^2\ 3p^5}$ 3^{rd} period , 7^{th} group (VIIA)

$_{10}$Ne: $1s^2$ $\underline{2s^2\ 2p^6}$ 2^{nd} period , 8^{th} group (zero group) (VIIIA)

$_{19}$K: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ $\underline{4s^1}$ 4^{th} period , 1^{st} group (IA)

Exercise 1-11: What are the period and group for the following elements? $_{13}$Al, $_6$C, $_3$Li

Solution: $_3$Li : $1s^2$ $\underline{2s^1}$ 2^{nd} period, 1^{st} group (IA)

$_6$C : $1s^2$ $\underline{2s^2\ 2p^2}$ 2^{nd} period, 4^{th} group (IVA)

$_{13}$Al : $1s^2\ 2s^2\ 2p^6$ $\underline{3s^2\ 3p^1}$ 3^{rd} period, 3^{rd} group (IIIA)

Example 1-10 : **What is the common property between the locations of the following elements in the periodic table ?** $_{12}Mg$, $_{11}Na$, $_{3}Li$

Solution: $_{3}Li : 1s^2 \underline{2s^1}$ — 2nd period, 1st group (IA)

$_{11}Na : 1s^2\ 2s^2\ 2p^6\ \underline{3s^1}$ — 3rd period, 1st group (IA)

$_{12}Mg : 1s^2\ 2s^2\ 2p^6\ \underline{3s^2}$ — 3rd period, 2nd group (IIA)

The common property between $_{3}Li$ and $_{11}Na$ is that they both located in same group (first group) (IA).
The common property between $_{11}Na$ and $_{12}Mg$ is that they both located in the same period (third period).

Example 1-11: **What is the common property between the locations of the following elements in the periodic table ?** $_{4}Be$, $_{5}B$, $_{7}N$

Solution: $_{4}Be: 1s^2 \underline{2s^2}$ — 2nd period, 2nd group (IIA)

$_{5}B : 1s^2\ \underline{2s^2\ 2p^1}$ — 2nd period, 3rd group (IIIA)

$_{7}N : 1s^2\ \underline{2s^2\ 2p^3}$ — 2nd period, 5th group (VA)

The common property between $_{4}Be$, $_{5}B$ and $_{7}N$ is that they all located in same period (second period).
They differ from each other with respect to groups. Each element belongs to a different group ($_{4}Be$) in the second group , ($_{5}B$) in the third group , ($_{7}N$) in the fifth group.

Exercise 1-12: **What is the common property between the locations of the following elements in the periodic table?** $_{15}P$, $_{6}C$, $_{14}Si$

Solution: $_{14}Si : 1s^2\ 2s^2\ 2p^6\ \underline{3s^2\ 3p^2}$ — 3rd period, 4th group (IVA)

$_{6}C : 1s^2\ \underline{2s^2\ 2p^2}$ — 2nd period, 4th group (IVA)

$_{15}P : 1s^2\ 2s^2\ 2p^6\ \underline{3s^2\ 3p^3}$ — 3rd period, 5th group (VA)

The common property between $_{14}Si$ and $_{6}C$ is that they both located in same group (fourth group) (IVA).

The common property between $_{14}Si$ and $_{15}P$ is that they both located in same period (third period).

Periodic Properties:

The physical and chemical characteristics of the elements in the groups and periods of the periodic table vary according to their:- (1)Atomic radius (2)Ionization energy (3)Electron affinity (4)Electronegativity (5)Metallic and non-metallic properties

[1] Atomic Radius:- Half of the minimum distance between two identical and chemically-combined nuclei of the element.

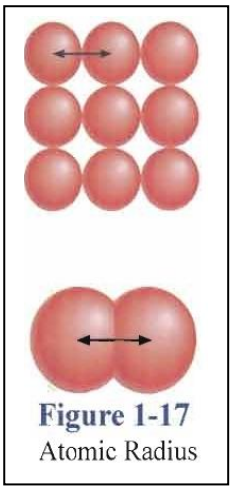


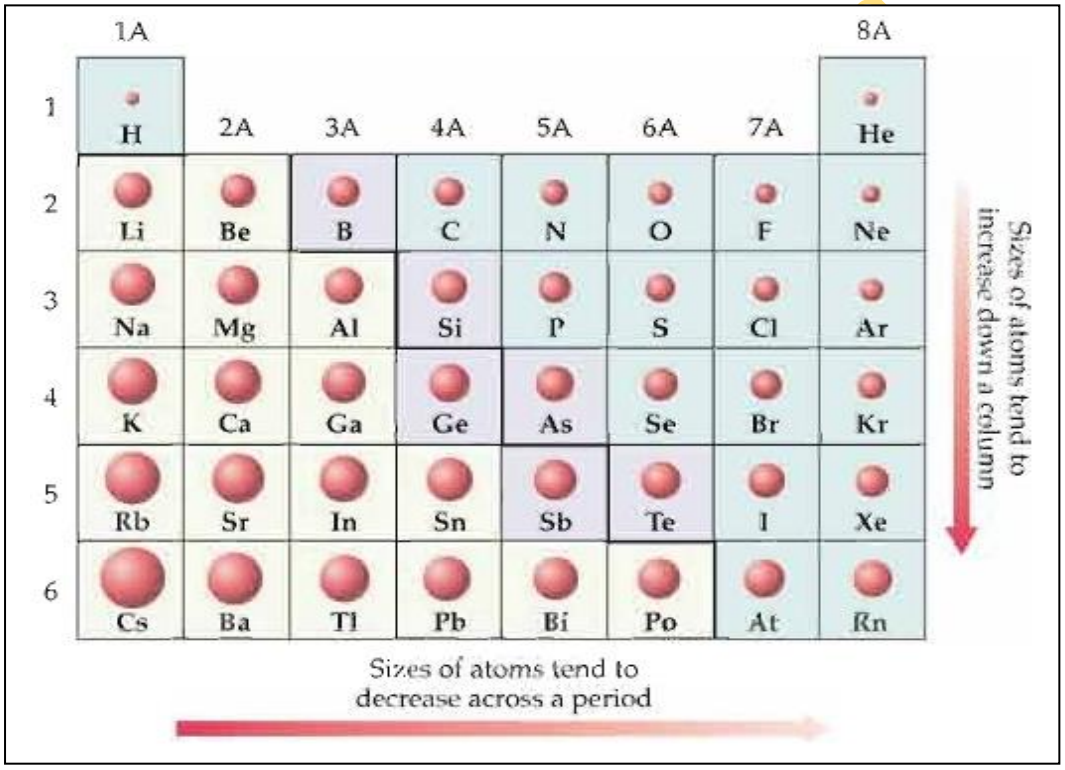
Figure 1-17
Atomic Radius

The radius of the atom determines its volume .

Theoretically, atom radius can be calculated by?

A- 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.



In one period, The Radius of the element decreases as we move from left to right as their atomic number increases?

A- Because the attraction energy between the electrons with in one main level and the positive charge of the nucleus increases with increasing in the number of electrons in it.

In one group, the elements Radius increases as their atomic number increases from top to bottom? A- Because the outer electrons keep distance from the nucleus.

Example 1-12 : **Arrange the following elements according to increasing in their atomic radius $_9F$, $_6C$, $_8O$, $_3Li$**

Solution:

$_3Li : 1s^2 \underline{2s^1}$ — 2nd period, 1st group (IA)

$_6C : 1s^2 \underline{2s^2\ 2p^2}$ — 2nd period, 4th group (IVA)

$_8O : 1s^2 \underline{2s^2\ 2p^4}$ — 2nd period, 6th group (VIA)

$_9F : 1s^2 \underline{2s^2\ 2p^5}$ — 2nd period, 7th group (VIIA)

All these elements are located in the same period (second period):

$$_3Li > {}_6C > {}_8O > {}_9F$$

Exercise 1-13 : **Arrange the following elements according to increasing in their atomic radius. $_{20}Ca$, $_{12}Mg$, $_4Be$**

Solution:

$_4Be : 1s^2 \underline{2s^2}$ — 2nd period, 2nd group (IIA)

$_{12}Mg : 1s^2\ 2s^2\ 2p^6 \underline{3s^2}$ — 3rd period, 2nd group (IIA)

$_{20}Ca : 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 \underline{4s^2}$ — 4th period, 2nd group (IIA)

All these elements are located in the same group (second group IIA)

$$_{20}Ca > {}_{12}Mg > {}_4Be$$

Q1-6 : **Arrange elements by decreasing in their atomic size. $_2He$, $_{10}Ne$, $_{18}Ar$**

Solution:

$_2He : \underline{1s^2}$ — 1st period, 8th group (zero group) noble elements

$_{10}Ne : 1s^2 \underline{2s^2\ 2p^6}$ — 2nd period, 8th group (zero group)

$_{18}Ar : 1s^2\ 2s^2\ 2p^6 \underline{3s^2\ 3p^6}$ — 3rd period, 8th group (zero group)

All these elements are located in the same group (eighth group VIIIA) which called moble elements.

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

[2] Ionization Energy :- **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.**

$Na + ionization\ energy \rightarrow Na^{+} + 1e^{-}$

In one group: Ionization energy of the element decreases from top to bottom as the atomic number becomes greater (increases)?

A-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

In one period: As the atomic number increase from left to right the ionization energy increases?

A- Because of the increase in 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.

There's an exception of this: If an element has a secondary saturated shell (ns^2) or half saturated (np^3), its ionization energy is greater than the ionization energy of the following atom.

Q: Show cause $_7N$ which has greater ionization energy than ionization energy of $_8O$ in spite of the fact that Oxygen atom has a bigger atomic number than the atomic number of Nitrogen & that they both belong to the same period?

A- $_7N : 1s^2\ 2s^2\ \underline{2p^3}$  **half saturated shell (p^3) more ionization energy.**

$_8O: 1s^2\ 2s^2\ \underline{2p^4}$  **not saturated shell (p^4) less ionization energy.**

$_7N$ has a half saturated energy level (np^3), its ionization energy is greater than the ionization energy of the following atom which is $_8O$.

Q:Nobel gases have the greatest ionization energy?

A- They do not lose electrons easily.

---

[3] Electron Affinity :- **The amount of energy released when a neutral gaseous atom acquires on electron as in Fluoride atom** $F + e^{-} \longrightarrow F^{-} + energy$

In Periods: Electron affinity increases from top to bottom as the atomic number increases.

left to right

In Groups: the elements in the same group face more difficulty to acquire an electron as their atomic number increases. The bigger the atomic number of an element the more difficult it is for the elements to acquire an electron.

Q: Noble elements are known to have the lowest electron affinity?

A- Because it is very hard to add electrons to them.

---

[4]Electronegativity:- The tendency of an atom to attract bonded electrons towards itself in any chemical compound,

$_9$F fluoride of all other elements has the greatest electronegativity and thus , is given number (4) as measure for its electronegativity, this number fluoride electronegativity is used as measurement for all other elements.

In many chemical compounds , the negative charge of the bounded electrons in centered near a certain atom. This greatly affects the chemical properties of the compound.

In periods: electronegativity increases as the atomic number increases with some exceptions.

In groups: electronegativity decreases from top to bottom as the atomic number increases.

Q:Nobel gases considered exceptional?

A- 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.

---

[5] Metallic and Non-Metallic properties:-

The Metallic and Non-Metallic 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 decrease and the nonmetallic properties increase on the other hand.

Lithium Li and Beryllium Be in the second period show metallic, Boron B and Silicon Si came after with properties of metalloid. The rest of the elements in the period such as Nitrogen N, Oxygen O and Fluoride F came at the end with non-metallic properties.

2nd Period: Li , Be,	**B, Si**	**N, O, F**
metals	metalloids	Non-metals

In one group the metallic properties increase and nonmetallic properties decrease as the atomic number increases.

All elements in group IA and IIA are Metals

The elements in group VIA and VIIA are Non-metals

The elements in the rest of the groups are not of the same type.

Group VA

Nitrogen (N) → nonmetal

Arsenic (As) and Antimony (Sb) →metalloid

Bismoth (Bi) → metal [is the last element in the group]

As far as the periods are concerned,

The two elements in the first period (Hydrogen H and Helium He) → nonmetals

In the following four periods, there is a gradual change from metallic to nonmetallic properties.

All 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.

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) Bor

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) $5p^3$

a) $3p^3$

18- Which of the following elements has highest electronegativity?

a) Fluorine.

b) Chlorine

a) 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) •Ar• b) :Ar: c) •Ar•

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 impor tant characteristic of these elements ?

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

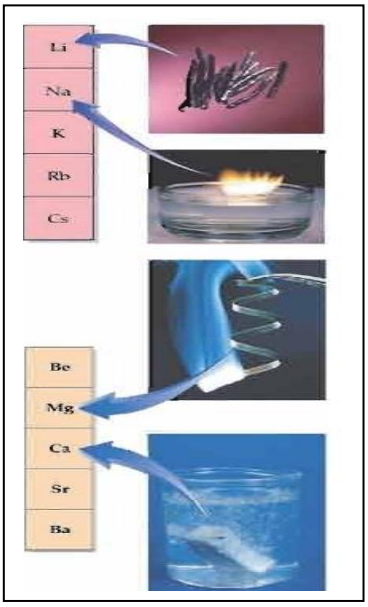
1.12 How many secondary levels and orbitals and electrons in each of primary energy level (second ، third)?

1.13 Answer the following questions accord ing 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)

Group IA and IIA Elements:

Elements of group IA and IIA are found on the left side of the periodic table.



Q:What are the first group IA consist of ?

A/ (IA), It consists of the alkali metals:Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Cesium (Cs) and Francium (Fr).

***Francium (Fr) is only element in this group prepared industrially.**

Q:What are the second group IIA consist of ?

A/(IIA), It consists of the alkali earth metals: Beryllium (Be), Magnesium (Mg), Calcium (Ca) , Strontium (Sr), Barium (Ba), Radium (Ra).

These elements are arranged according to the increase in their atomic numbers.

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												5 B	6 C	7 N	8 O	9 F	2 He
3 Li	4 Be											13 Al	14 Si	15 P	16 S	17 Cl	10 Ne
11 Na	12 Mg											31 Ga	32 Ge	33 As	34 Se	35 Br	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	49 In	50 Sn	51 Sb	52 Te	53 I	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	81 Tl	82 Pb	83 Bi	84 Po	85 At	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						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						

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Qوزاري:What are the general properties of group (IA) and (IIA) elements?

Answer:

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

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

3-They cannot occur in the free form in nature? –Because of their reactivity.

There is a very small difference in the general properties between IA and IIA groups:-

4-The metallic properties of the elements in group IIA are lower than those of group IA.

5-The ionization energy of the elements in group IIA is greater than those of group IA?

A/ Because of the decrease in the atomic volume.

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

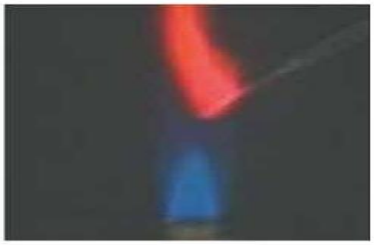
1-Melting and boiling points decrease when the atomic numbers of the elements increase.

2-The compounds of these metals such as NaCl, KCl, …, give different colors distinguish each metal individually.

Group IA	Group IIA	
Lithium → scarlet	Calcium → dark red	Strontium → scarlet
Sodium → shiny yellow	Barium → yellowish green	

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

(A)



(B)

(C)

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

Sodium (Na)

Lithium (Li)

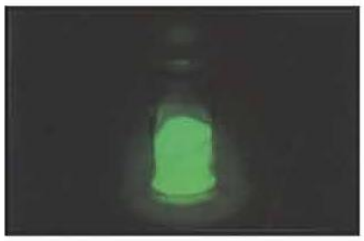
Cessium (Cs)

Magnesium (Mg)

Beryillium (Be)

Strontium (Sr)

Calcium (Ca)



Radium (Ra)

Barium (Ba)

Some chemical properties:-

1-Elements of group 1A have one valence electron and elements of group IIA have two valence electrons. They have the tendency to lose their valence electrons when they enter into a chemical reaction

Group IA elements form positively charged ion M^+ **[$M - 1e^- \longrightarrow M^+$]**

Group IIA elements form positively charged ion M^{++} **[$M - 2e^- \longrightarrow M^{+2}$]**

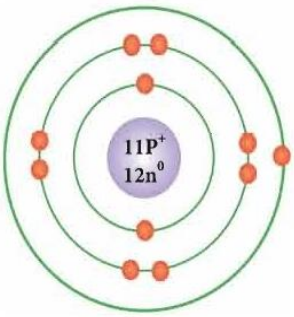
2-They combine with nonmetals to form stable salts with high solubility except lithium(Li) which is less soluble in water? -Because Li has a small volume and the great attraction energy of its nucleus to electrons.

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.

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

Natrium in Latin "Na"

Chemical symbol: Na

Atomic number: 11

Mass number: 23

Occurrence:

1-Sodium does not occur as a free element in nature? –Due to its high reactivity.
2-It occurs in nature combined with other elements forming stable compounds such as sodium chloride NaCl, sodium sulfates Na_2SO_4 and sodium silicates Na_2SiO_3
3-It is preserved in liquids, with which does not react like pure benzene and kerosene ? -Because it burns when exposed to air.

Properties of sodium:

A-Physical Properties:

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

B-Chemical Properties:

Free sodium (Na) is a very active element. It combines directly with nonmetals to form ionized compounds as it forms a positively charged sodium ion (Na^+).

Most important chemical properties of sodium are:-

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 color?

$$4Na + O_2 \longrightarrow 2Na_2O$$

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

$2Na + Cl_2 \longrightarrow 2NaCl$

sodium chlorine gas sodium chloride

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

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

sodium water sodium hydroxide Hydrogen gas

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

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

sodium Hydrochloric acid sodium chloride Hydrogen gas

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

$2Na + MgO \longrightarrow Na_2O + Mg$

sodium magnesium oxide sodium oxide magnesium

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

sodium Aluminum chloride sodium chloride Aluminum

Question وزاري:How can you test (detect) of sodium ion in its compounds?

Answer: By using Flame test (dry detection) sodium from group IA gives the flame the yellow color.

lame of sodium yellow color

Reverse Sodium in the white gas

Sodium has bright color

Reaction of sodium with water

Uses of Sodium:-

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

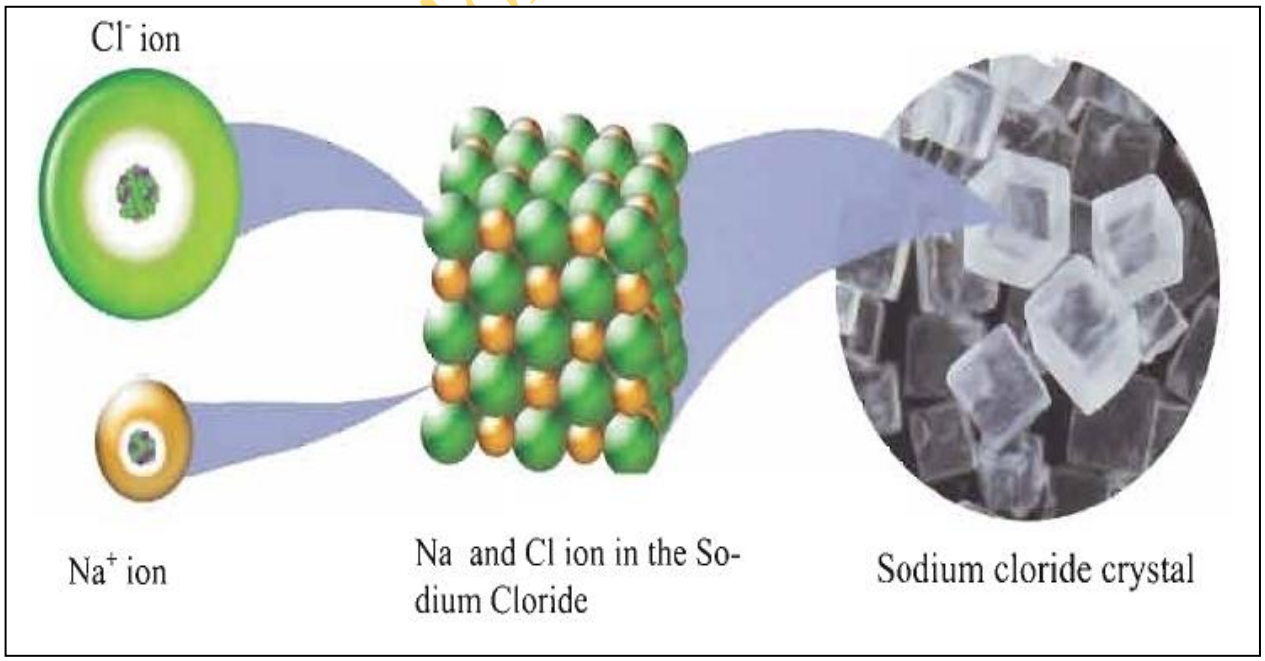
2-It is used in the production of sodium cyanide (NaCN) which is used in purifying gold and in many other industrial applications.

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.

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) NaCl:

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 the salt(NaCl): **Q- How can you extract table salt?**

A/-If salts exist 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.

Uses of Sodium Salt: 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.

Properties of Sodium Chloride:

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

1-Put some crystals of pure sodium chloride in a glass bowel and put some salt (table salt) in another.
2-Put the two glasses bowels in humid air and label the bowels individually.
3-After one or two days, check the salt in the bowels.
4-You notice that the regular salt becomes humidified and the pure salt stays unaffected.
5-This indicates that sodium chloride does not absorb water from air (it doesn't hydrate).
6-Regular salt has the property of absorbing water (humidity) from air. (it is hydrated)

Hydrolysis:-The process of absorbing of absorbing water from air being wet such as table salt.

Q/ What is the reason of hydration? (Why table salt is a hydrated substance)?

A-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).

Q 2-5: What is the difference between pure salt NaCl and impure NaCl?

A/ Pure salt NaCl	Impure salt NaCl
1-pure doesn't contain impurities.	1-impure contains impurities ($CaCl_2$,$MgCl_2$) or both.
2-non-hydrated substance.	2-hydrated substance.
(Can't absorb water)	(Can absorb water)

Exercise 2-1: What is the difference between pure sodium chloride and sugar? When they affected by heat?

A- pure sodium chloride doesn't affect by heat (its ions combined), Sugar get burns by heating.

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 (CO_2) in air to form a layer of sodium carbonates Na_2CO_3 which is insoluble in concentrated NaOH solution. A dry layer is formed on sodium hydroxide grains.

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

sodium hydroxide carbon dioxide sodium carbonate water

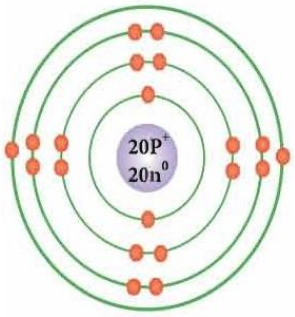
***Sodium hydroxide (NaOH) is a base with a great tendency to dissolve in water.**

It is used in many industrial fields such as:

1-Soap and detergents industries.
2-Textile and paper manufacturing.
3-An essential raw material in the preparation of many chemical compounds used in various industries.

Sodium Hydroxide

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

Occurrence:

1-Calcium does not occur as a free element in nature? -Because of its high activity.
2-It occurs in combination of other elements as in the forms of carbonates (alabaster and limestone), Sulfates (plaster), Phosphate (Calcium phosphate) or silicates.
3-Calcium is obtained by the method of electrolyzes of molten calcium chloride ($CaCl_2$) and calcium fluoride (CaF_2).
4-It occurs in some kinds of food such as milk and fish.


Some food that contain calcium.

Some Calcium Compounds:

1-Calcium hydroxide ($Ca(OH)_2$):

It is preparing 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 ".

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

calcium oxide water calcium hydroxide

Quick lime Hydrated lime

***Quick lime:- It is calcium oxide CaO.**

***Hydrated lime:- It is calcium hydroxide $Ca(OH)_2$ pure lime water.**

***Hydrating lime:- It is the process of adding water to calcium oxide CaO to produce calcium hydroxide $Ca(OH)_2$ pure lime water.**

Q/Pure lime water ($Ca(OH)_2$) when exposed to carbon dioxide CO_2 becomes impure?

A-Because of calcium carbonate $CaCO_3$ formation.

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

solution	carbon dioxide	calcium carbonate	water
(lime water)		(white precipitate)	
pure solution		turbid solution	

2-Calcium Sulfates:

Occur in the form of plaster $CaSO_4.2H_2O$. whereby two molecules of water (crystallization water) combine with solid calcium sulfate.

Q/ How can you prepare Paris plaster?

A-Normal plaster $CaSO_4.2H_2O$ by heating gradually removes crystallization water turns into Paris plaster $(CaSO_4)_2.H_2O$.

Q2-2: What is the difference between Normal plaster and Paris plaster?

A- Normal plaster	Paris plaster
1-Two molecules of crystallization water combine with one molecule of plaster. $CaSO_4.2H_2O$	1-Two molecules of plaster combine with One molecule of crystallization. $(CaSO_4)_2.H_2O$
2-Used for building.	2-Used for building, casting, statue making

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) Mg^{2+}

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

2.2 $Li - 1e^- \longrightarrow Li^+$

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

2-2: 2/ Why sodium chloride is important for industry?

A-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.

3/ Barium (Ba) has more metallic property than Beryllium?

A- ($_4$Be , $_{56}$Ba) Both of them located in group IIA, metallic properties are increased from top to bottom in the same group.[The attraction between the valence electrons and the nucleus is weaker].

2-3: (1) $_{13}$Al: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ It has 3 electrons valence electrons in the outermost shell, so it belongs to group IIIA.

(2) -Because Na burns when exposed to air.

(3) –Because their solutions are highly basic.

(4) 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 color

$$4Na + O_2 \longrightarrow 2Na_2O$$

(5) NaOH is hydrated when exposed to humid air. The hydrated layer of sodium hydroxide reacts with carbon dioxide (CO_2) in air to form a layer of sodium carbonates Na_2CO_3 which is insoluble in concentrated NaOH solution. A dry layer is formed on sodium hydroxide grains.

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

2-4: (1) $_{20}$Ca: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ Calcium has $2e^-$ in its valence shell (these e^- are farther from the nucleus and less attract to nucleus compared to inner electrons). Easily oxidized.

(2) $_3$Li: $1s^2\ 2s^1$, ^{11}Na: $1s^2\ 2s^2\ 2p^6\ 3s^1$, $_{19}$K: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$, When we make the electron configuration all these elements are end with S^1 they have one valence electrons.

Group IIIA Elements:

Q-What is the main reason behind putting the elements of group IIIA in one group?

A-The reason is that the outer shell in 3A group atoms contains same number of electrons despite they are different in their atomic numbers.

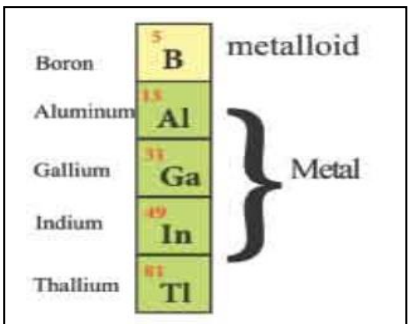
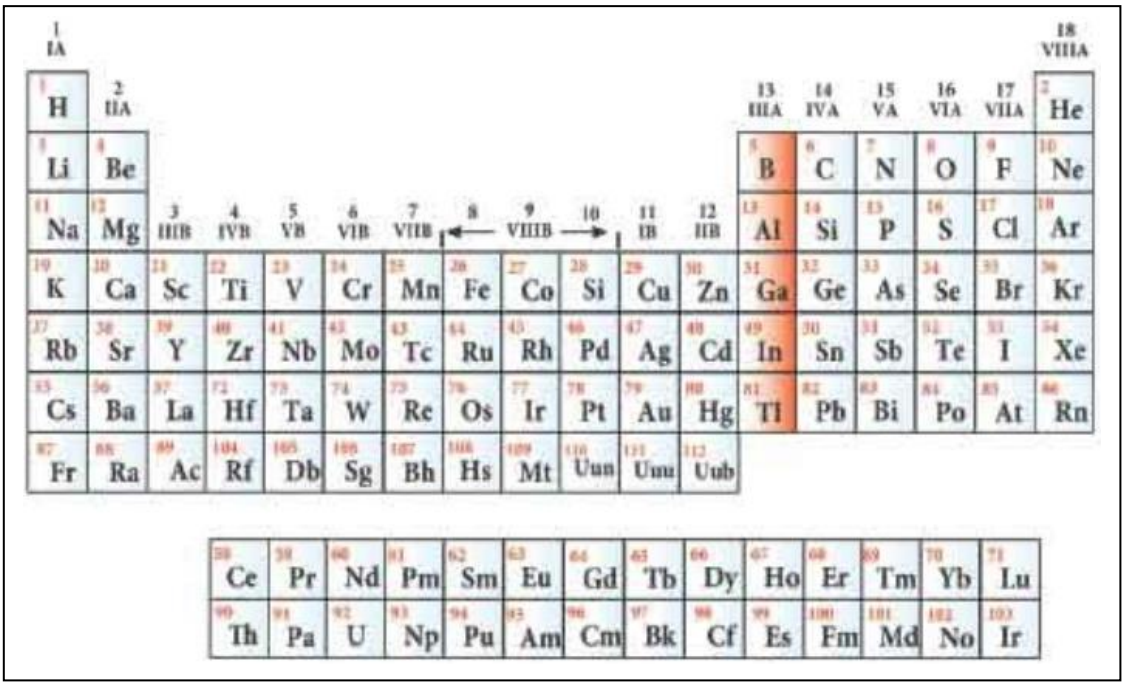


Figure 3-1
Place of element of group III in the periodic table

Q-What are the elements of IIIA group?

A-They are: Boron (B), Aluminum (Al), Gallium (Ga), Indium (In), Thallium (Tl).



Q: What are the general characteristic properties of group IIIA elements?

A- (1)The elements of these groups are metals except Boron which is metalloid.
(2)The ionization energy of these elements (IIIA) is less than the ionization energy of group IIA elements? –Elements of group IIIA contain one group in the secondary shell (p) following a saturated secondary shell (whether s or p).The outer shell of group IIA elements is the saturated secondary shell ns^2
*The increase in the atomic number of group3A elements (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), 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 characteristic as the atomic number increases. Thus, the aqueous solutions of boron oxides are acidic whereas aluminum oxides are amphoteric.

Boron (B)

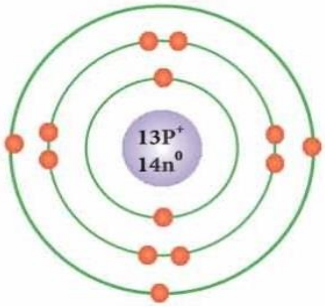
Aluminum (Al)

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:

Occurrence:

1-Aluminum metal is too reactive chemically to occur natively. Instead, it is found combined in a great number of different compounds.

2-Aluminum metal is the most abundant metal in earth's crust it makes up 8% by weight of the earth solid surface.

3-The row materials of aluminum are:-

A-Bauxite:- It is the aqueous aluminum oxide, $Al_2O_3.2H_2O$ the main source for aluminum extraction.

B-Cryolite:- It is a fluoride of sodium and aluminum (Na_3AlF_6) (Sodium hexafluoroaluminate), one of the most important sources used in aluminum extraction.

Extraction of Aluminum:

The Hall process is the major industrial process for aluminum extraction?- It is the best and reliable process and widely used in industry.

It involves:- (1) Electrolyzing pure alumina (Al_2O_3) in molten cryolite bath at a temperature of (1000℃) by using carbon electrodes.

(2) Alumina (Al_2O_3) does not occur naturally, it exist 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).

(3) Alumina has a high melting point and being melted in molten cryolite ? –The molten cryolite decreases the melting point of alumina.

(4) The molten, then is poured in an electrolytic cell. As the current passes through .

(5) Aluminum accumulates at the bottom of the cell, then molten aluminum is pulled gradually.

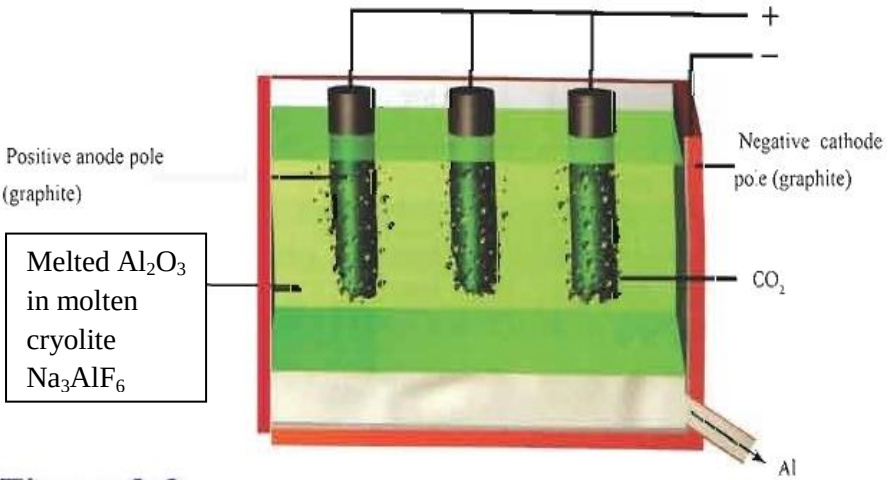
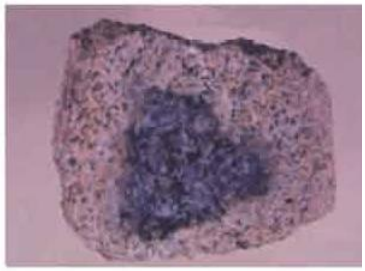


Figure 3-2 Hall cell which is used to obtain aluminum.



Bauxite

Molten aluminum

Properties of Aluminum:

Aluminum Oxide

Land is natural staple of Aluminum

A-Physical properties:

1-Aluminum is a fine silvery metal with remarkable low density.

2-It is a good conductor for heat and electricity.

B-Chemical properties:

1-Oxygen effect on aluminum:

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.

2-Aluminum powder burns vigorously with a bright flame releasing great energy.

$$4Al + 3O_2 \longrightarrow 2Al_2O_3 + \text{Energy}$$

Aluminum powder

3-Aluminum is a reducing agent:

Put a mixture of Aluminum powder [Al] 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 "

$$2Al + Fe_2O_3 \longrightarrow Al_2O_3 + 2Fe + \text{high temperature}$$

Aluminum powder Iron(III) Oxide Aluminum oxide Iron

**Thermite Process:-It is a reaction between aluminum powder and iron (III) oxide, vigorous with shiny flame, results in molten iron and great amount of heat.
(as aluminum is reducing agent)**

Thermite Reaction

The important of Thermite Process:

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

جهد اختزال

4-Reaction of Aluminum with acids and bases:

Aluminum reacts with dilute hydrochloric acid (HCl) easily to produce hydrogen gas (H_2) and aluminum chloride ($AlCl_3$) component. $2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2\uparrow$

Aluminum — Dilute hydrochloric acid — Aluminum chloride — hydrogen gas

Q-Aluminum does not react with both concentrated and dilute nitric acid (HNO_3) continually ?

Answer- 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.

Aluminum reacts with basic solutions like sodium hydroxide (NaOH) or potassium hydroxide (KOH) to release hydrogen gas and aluminum salt.

Amphoteric behavior :-The reaction of aluminum once with acids (HCl) and another with bases (NaOH) releasing hydrogen gas (H_2) in both and forming aluminum salt.

Uses of Aluminum:

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

Aluminum and its alloy have a very high mass.

1-Aluminum is a metal with 'self-protection' against erosion?

A- Aluminum when exposed to air, it forms a thin but firm layer of aluminum oxide (Al_2O_3) which sticks to the metal and protects it from oxidation.

Q-This is not the case with iron (Fe)?

A-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.

2-Aluminum can be used in electrical wires whereby its connectivity is twice as much of that of copper (Cu), considering the mass of both elements, the diameter of aluminum wires is larger than that of copper , *Q-Aluminum is in electrical wires in on a limited level? A- because it is expands and shrinks 39% more than copper when exposed to the same heat.

3-Thin layers of aluminum are used to food, medications and other household appliances as well as various shapes and sizes of cans.

4-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

5-Aluminum alloys are used to make cans and containers to preserve liquids at very at a very low temperature such as oxygen, argon and nitrogen ? –This is because the fact that the lower temperature the harder aluminum gets.

The elements mixed with aluminum in making alloys lead (Pb), Copper (Cu), Zinc (Zn) and Magnesium (Mg)

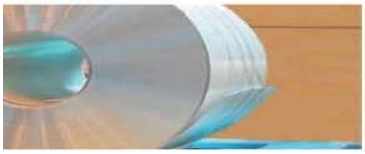
Q: Compare between aluminum alloys?

A- Duralumin alloy	Bronze aluminum alloy
1-Consists of high percentage of aluminum and small amount ratio of copper and magnesium it might contain manganese. 2-It is light and hard, so it is used for building aircraft parts.	1- Consist of small percentage of aluminum and a high ratio of copper and other metals. 2-It characterized by resistance to erosion. its color changes according to the color of its component parts, ranging from copper color to gold color and silver color. Therefore, it is used to make decoration materials.

Aluminum alloy

Aluminum oxide in the precious stones

Manufactured window from Aluminum



Jsages of aluminum

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:-

$$\underset{\text{aluminum hydroxide}}{2Al(OH)_3} \xrightarrow{\Delta} \underset{\text{aluminum oxide}}{Al_2O_3} + \underset{\text{water}}{3H_2O}$$

2-Alum:

A salt crystals containing aluminum sulfate and potassium sulfate along with crystallized water molecules in a fixed mass ratio. The general formula of alum is **$KAl(SO_4)_2.12H_2O$** it also called Potassium 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 called Alum.

The Uses of Alum:

1-Normal alum used as 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.

2-It used to make dye permanent on textiles.

3-In purifying drinking water.

Test of Aluminum ion (Al^{3+}) in solution of Aluminum compounds:

Aluminum ion is identified in its compounds by basic solution such as sodium hydroxide(NaOH) or potassium hydroxide (KOH), they react with aluminum to form a white gelatin precipitate aluminum hydroxide $Al(OH)_3$

$$\underset{\text{Aluminum ion}}{Al^{3+}} + \underset{\text{sodium hydroxide}}{3NaOH} \longrightarrow \underset{\substack{\text{aluminum hydroxide}\\ \text{white gelatin precipitate}}}{Al(OH)_3\downarrow} + \underset{\text{sodium ion}}{3Na^+}$$

For example: $\underset{\text{aluminum chloride}}{AlCl_3} + \underset{\text{sodium hydroxide}}{3NaOH} \longrightarrow \underset{\text{aluminum hydroxide}}{Al(OH)_3\downarrow} + \underset{\text{sodium chloride}}{3NaCl}$

Q-The precipitate $Al(OH)_3$ dissolves when sodium hydroxide NaOH is added?

A-Because dissolved sodium aluminate is formed ($NaAlO_2$).

Q-$Al(OH)_3$ also dissolves when an acid is added?

A-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 H_2 gas, while when reacts with bases it release H_2, because the amphoteric behavior

2- The effect of oxygen in air on Aluminum don't lead to corrosion as in the case of iron because of framing a layer of its oxide Al_2O_3 which sticks firmly to the metal and prevent corrosion

3- Heavy heating of Aluminum hydroxide gives Al_2O_3, H_2O

4- Salt composed from potassium and aluminum elements called Alum or (Potassium Alum)

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

3.4 Explain the extraction of aluminum and draw the figure.

by Hall Process طريقة هول

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

list A

1- An element with amphoteric behavior. Aluminum (Al)

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

3-Aluminum oxide (Alumina)

4-Double salt of potassium sulphate and aluminum (Alum)

5-One element of group IIIA which is semi-metal (Boron)

list B

1-Thermite 2

2-Alum 4

3-Alumina 3

4-Aluminum 1

5-Indium X

6-Boron 5

Teacher: Mohamed Saud

محمد سعود . م.م

Solutions and Expressions for Concentrations

Solution is important in chemistry science with a great extent. Especially liquid solutions?
A/ Because they are the medium for chemical reaction, whereby they help to happen interaction among reacting substances.

Solution:- is a homogenous mixture composed of two or more pure substance, having no chemical reaction between them.

The substance with majority in the solution is called the (Solvent).
The material with less existence in the solution is called the (Solute).

Solute + Solvent = Solution

Types of solutions:

There are several kinds of solutions, the most important and most common are liquid solutions when the Solvent is liquid.

1-dissolving a sold material in a liquid, as in the case of dissolving salt (NaCl) in water to get the (saline solution) or dissolve sodium hydroxide (NaOH) in water (basic solution).

2-dissolving liquid in another liquid , like dissolving alcohol in water .

3-dissolving hydrogen chloride gas (HCl) in water. The resulting solution is called hydrochloric acid solution (acidic solution).

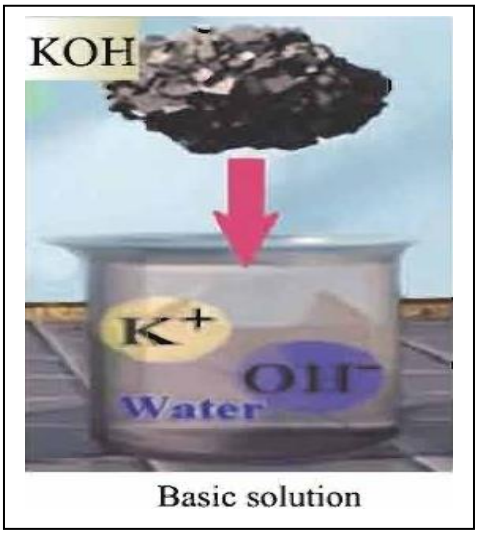
$$HCl_{(g)} \xrightarrow{H2O} HCl_{(l)}$$

hydrogen chloride gas — hydrochloric acid

4-dissolving gas in another gas like air.

5-dissolving solid solution in another like various alloys, mostly coins and gold alloys.

Salt solution



Basic solution

Acidic solution

Nature of solutions:

Names of solutions vary according to the amount of the solvent and the solute and also the nature of dissolving process.

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1-Saturated Solution: is the solution which contains a greater amount of the solute and solvent can dissolve no more of solute the given temperature and pressure.

2-Super Saturated Solution: When the amount of solute is greater in any solution that the solvent is able to dissolve it under normal conditions,

This kind of solution is not stable whereby it deposits the extra amount of solute, turning it into a saturated solution.

3-Unsaturated Solution: is the solution which contains less amount of the solute that is required for saturation at a particular temperature and pressure.

Q:What is the difference between Saturated Solution and Unsaturated Solution?

Electrolytic Solutions: When the solute molecules ionize in the solution.

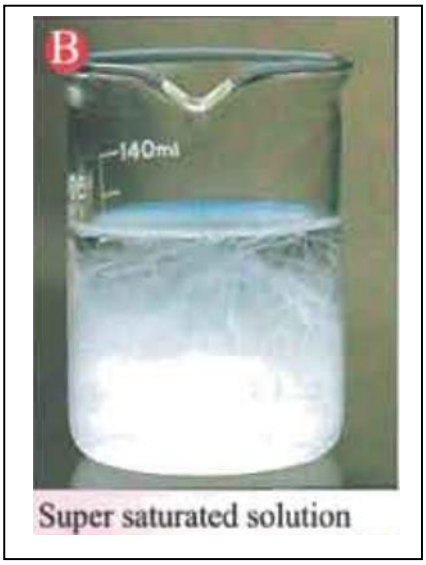
Non-electrolytic solutions: Are compounds whose molecules don't ionize in the solution at all such as sugar or ethyl alcohol in water.

Electrolytic Solutions can be Strong (HCl) or Weak (HF).

Q:Compare between strong electrolyte and weak electrolyte? وزاري

A/ Strong electrolyte	Weak electrolyte
1-Solute molecules ionize completely in the solution. (HCl) 2-HCl → $H^+ + Cl^-$ (1 arrow) 3-High electro conductivity.	1-Solute molecules ionize partially in the solution. (HF) 2- HF ↔ $H^+ + F^-$ (2 reverse arrows) 3-Low electro conductivity

Saturated solution



Super saturated solution

Unsaturated solution

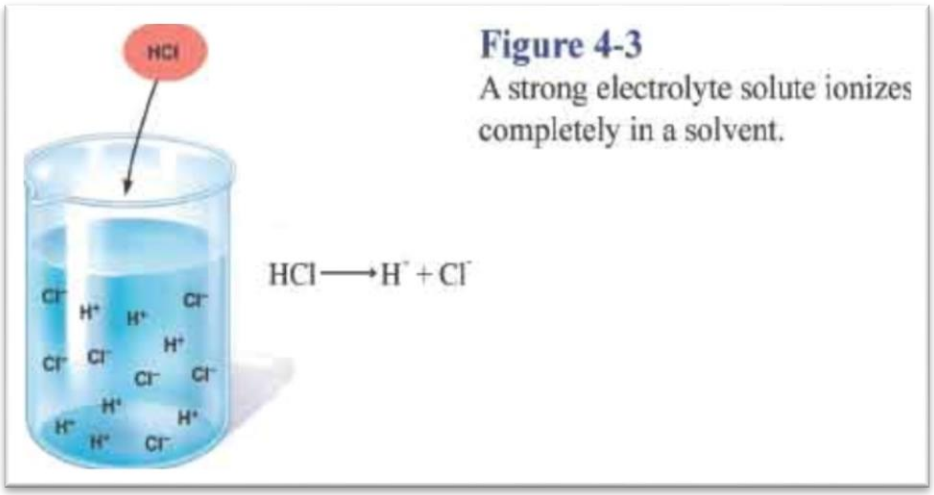
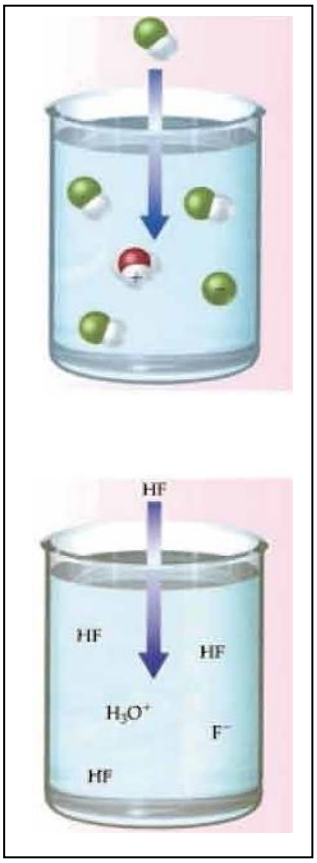


Figure 4-3
A strong electrolyte solute ionizes completely in a solvent.



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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.

Q: What are the factors that affected on solubility?

1-Nature of Solute and Solvent:

The Solute

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 the surface which are exposed to dissolution this is why we stirred tea with a spoon when sugar is added?.

وزاري

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 Solvent

For the solvent the nature of polarity determines its solubility. According to a rule which says" like dissolves like" 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.

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.

وزاري

Figure 4-5

Figure 4-6
A) Sugar dissolves in cold water slowly.
B) Sugar dissolves in hot water quickly.

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, concentration of dissolved carbon dioxide CO_2 in the liquid depends on the pressure of CO_2 on the surface of 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.

Q: Why bubbles are formed and move up when the cover of the beverages? وزاري

A/Because the pressure of CO_2 gas will decrease and making it less soluble, since solubility is directly proportional with pressure.

Concentration of Solution:

It has already been noted that a solution consists of two major parts.
The solute and the solvent. Solution 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".

Concentration:- It is the amount of solute in a particular solvent or solution.

The Concentration of the solution can be descriptively expressed the terms dilate and concentrated are used to describe concentration of the solution.

Dilute Solution:- Solution with relatively small amount of solute.

Concentrated Solution:- Solution with large amount of the solute.

Q: How can you convert (change) concentrated solution into dilute solution? وزاري

A/ By adding a large amounts of the solvent.

As high qualitative expression, concentration of the solution can be expressed in various ways.

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:

$$\text{perecntage concentration of solute} = \frac{\text{mass of solute (m1)}}{\text{mass of solution (m1+m2)}} \times 100\%$$

$$\text{Solute } \% = \frac{\text{m solute } (m1)}{\text{m solution (mT)}} \times 100\%$$

$$\text{perecntage concentration of solvent} = \frac{\text{mass of solvent (m2)}}{\text{mass of solution (m1+m2)}} \times 100\%$$

$$\text{Solvent } \% = \frac{\text{m solvent } (m2)}{\text{m solution (mT)}} \times 100\%$$

m1: mass of solute (g)
m2: mass of solvent (g)
mT = m1 + m2 **mass of solution (g)**

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

Solution:

m1= 20 g

m2= 80 g

mT= m1 + m2 → mT = 20 + 80 ∴ mT = 100 g

$$\%m1 = \frac{m1}{mT} \times 100\% \rightarrow \%m1 = \frac{20}{100} \times 100\% \therefore \%m1 = 20\%$$

$$\%m2 = \frac{m2}{mT} \times 100\% \rightarrow \%m2 = \frac{80}{100} \times 100\% \therefore \%m2 = 80\%$$

Example 4-1: **What is the mass ratio of the solute and solvent of a solution made of 15.3 g of salt dissolved in 155 g of water?**

Solution:

m1= 15.3 g
m2= 155 g
mT= m1 + m2 → mT = 15.3 + 155 ∴ mT = 170.3 g

$$\%m1 = \frac{m1}{mT} \times 100\% \rightarrow \%m1 = \frac{15.3}{170.3} \times 100\% \therefore \%m1 = 8.98\%$$

$$\%m2 = \frac{m2}{mT} \times 100\% \rightarrow \%m2 = \frac{155}{170.3} \times 100\% \therefore \%m2 = 91.02\%$$

Exercise 4-1: **A Solution is formed by dissolving 48.2 g sugar in 498 g of water what is the mass ratio of sugar and water in the solution?**

Solution:

m1= 48.2 g
m2= 498 g
mT= m1 + m2 → mT = 48.2 + 498 ∴ mT = 546.2 g

$$\%m1 = \frac{m1}{mT} \times 100\% \rightarrow \%m1 = \frac{48.2}{546.2} \times 100\% \therefore \%m1 = 8.82\%$$

$$\%m2 = \frac{m2}{mT} \times 100\% \rightarrow \%m2 = \frac{498}{546.2} \times 100\% \therefore \%m2 = 91.18\%$$

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:

%m1= 4%
m1= 20 g
mT = ? g

$$\%\, m1 = \frac{m1}{mT} \times 100\% \rightarrow 4\% = \frac{20}{mT} \times 100\% \therefore 4 = \frac{2000}{mT}$$

$$mT = \frac{2000}{4}$$

$$\therefore mT = 500\ g$$

Q-2014: A sample of vinegar contains 12% of acetic acid by mass. How many grams of vinegar is required to obtain 36 g of acetic acid.

Solution:

%m1= 12%
m1= 36 g
mT = ? g

$$\% \, m1 = \frac{m1}{mT} \times 100\% \quad \rightarrow \quad 12\% = \frac{36}{mT} \times 100\% \quad \therefore 12 = \frac{3600}{mT}$$

$$mT = \frac{3600}{12}$$

$$\therefore mT = 300 \text{ g}$$

Q-2013: Find the mass of potassium chloride in 19 g mass solution containing a 2.5% mass percentage potassium chloride.

Solution:

mT = 19 g
%m1 = 2.5 %
m1 = ? g

$$\% \, m1 = \frac{m1}{mT} \times 100\% \quad \rightarrow \quad 2.5\% = \frac{m1}{19} \times 100\% \quad \therefore 2.5 = \frac{100\, m1}{19}$$

$$100\, m1 = 2.5 \times 19 \quad \rightarrow \quad m1 = \frac{47.5}{100} \quad \therefore m1 = 0.475 \text{ g}$$

Q-2016: Find the mass of potassium chloride (KCl) in grams which found in 42 g of solution contains 8% by mass percentage of KCl?

Solution:

m1 = ? g
mT = 42 g
%m1 = 8 %

$$\% \, m1 = \frac{m1}{mT} \times 100\% \quad \rightarrow \quad 8\% = \frac{m1}{42} \times 100\% \quad \therefore 8 = \frac{100\, m1}{42}$$

$$100\, m1 = 8 \times 42 \quad m1 = \frac{336}{100} \quad \rightarrow m1 = 3.36 \text{ g}$$

The percentage of volume ratio of the solute and the solvent is calculated as follows:

$$\text{perecntage concentration of solute} = \frac{\text{volume of solute (v1)}}{\text{volume of solution (v1+v2)}} \times 100\%$$

$$\text{Solute \%} = \frac{\text{v solute (v1)}}{\text{v solution (vT)}} \times 100\%$$

$$\text{perecntage concentration of solvent} = \frac{\text{volumeof solvent (v2)}}{\text{volume of solution (v1+v2)}} \times 100\%$$

$$\text{Solvent \%} = \frac{\text{v solvent (v2)}}{\text{v solution (vT)}} \times 100\%$$

v1: volume of solute (ml)
v2: volume of solvent (ml)
vT = v1 + v2 volume of solution (ml)
***Units of Volume: Liter (L) , milliliter (mL) , cubic centimeter (cm^3).**

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

L → mL (×1000)
mL → L (÷ 1000)

Example 4-3: Calculate the percentage of volume for both acetic acid and water in a solution formed by mixing 20mL of acetic acid and 30mL of water.

Solution:

v1= 20 mL
v2= 30 mL
vT = v1 + v2 → vT= 20 + 30 ∴ vT= 50 mL

$$\%v1 = \frac{v1}{vT} \times 100\% \rightarrow \%v1 = \frac{20}{50} \times 100\% \therefore \%v1 = 40\%$$

$$\%v2 = \frac{v2}{vT} \times 100\% \rightarrow \%v2 = \frac{30}{50} \times 100\% \therefore \%v2 = 60\%$$

Exercise 4-3: **If 80mL of pure water is added to 20 mL of sulfuric acid what will be percentage of volume for both sulfuric acid and water?**

Solution:

v1= 20 mL
v2= 80 mL
vT = v1 + v2 → vT= 20 + 80 ∴ vT= 100 mL

$$\%v1 = \frac{v1}{vT} \times 100\% \rightarrow \%v1 = \frac{20}{100} \times 100\% \therefore \%v1 = 20\%$$

$$\%v2 = \frac{v2}{vT} \times 100\% \rightarrow \%v2 = \frac{80}{100} \times 100\% \therefore \%v2 = 80\%$$

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%.**

Solution:

v1= ?ml
vT= 50 ml
%v1= 80%

$$\%v1 = \frac{v1}{vT} \times 100\% \rightarrow 80\% = \frac{v1}{50} \times 100\% \rightarrow 80 = \frac{100v1}{50}$$

100v1= 80 × 50 → 100v1= 4000 ∴v1= 40 ml

Q-2015: **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 40 ml and its percentage of volume would be 80%.**

Solution:

v1= ?ml
vT= 40 ml
%v1= 80%

$$\%v1 = \frac{v1}{vT} \times 100\% \rightarrow 80\% = \frac{v1}{40} \times 100\% \rightarrow 80 = \frac{100v1}{40}$$

100v1= 80 × 40 → 100v1= 3200 (÷100) ∴v1= 32 ml

Expressing concentration by mass / volume:

Concentration is expressed by mass unit of the solute (gram) in given volume of the solution (liter).

***The unit of the concentration is (g/L)**

$$\text{Concentration} = \frac{\text{mass}}{\text{volume}} \quad \rightarrow \quad \text{Concentration (g/L)} = \frac{\text{m (g)}}{\text{v (L)}}$$

***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.**

$$\rho\ (g/L) = \frac{mass\ (g)}{Volume\ (L)}$$

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

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:

m = 5 g
V = 0.5 L
Concentration = ? g/L

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

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?

Solution:

m = ? g
V = 1 L
Concentration = 0.5 g/L

$$\text{Concentration (g/L)} = \frac{\text{m (g)}}{\text{V (L)}} \quad \rightarrow \quad 0.5 = \frac{m}{1} \qquad \therefore m = 0.5\ g$$

Q4-6:How many liters of water is needed to add 10 g of potassium hydroxide to obtain a solution with 2.5 g/L concentration?

Solution:

V= ?L
m= 10 g
Conc. =2.5 g/L $\quad$ **Concentration** $= \frac{m}{V} \rightarrow 2.5 = \frac{10}{V} \rightarrow V = \frac{10}{2.5} \quad \therefore V = 4L$

Q4-9: 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.

Solution:

m = 27.5 g

V = 175 mL $\rightarrow \quad V = \frac{175}{1000} \quad \therefore V = 0.175\ L$

Concentration $= \frac{m}{V} \rightarrow$ **Conc.** $= \frac{27.5}{0.175} \rightarrow$ **Conc.** $= \frac{27500}{175} \quad \therefore$ **Conc.= 157.142 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.

Solution:

m1=27.5 g , %m1 = ?%

V2= 175 mL , m2=? g

$\rho_{water} = 1.00\ g/mL \rightarrow \quad \rho 2 = \frac{m2}{v2} \rightarrow 1.00 = \frac{m2}{175} \rightarrow m2 = 1.00 \times 175 \quad \therefore m2 = 175\ g$

$mT = m1 + m2 \rightarrow \quad mT = 27.5 + 175 \quad \therefore mT = 202.5\ g$

$\%m1 = \frac{m1}{mT} \times 100\% \quad \rightarrow \%m1 = \frac{27.5}{202.5} \times 100\% \quad \therefore \%m1 = 13.58\ \%$

Exercise 4-5: **KCl is 5.80 % by mass in a solution. Calculate mass of KCl in 0.337L of the solution. (Suppose that density of the solution is 1.05 g/mL.)**

Solution:

%m1= 5.80 % , m1= ? g

VT= 0.337 L → VT = 0.337 × 1000 ∴VT=337 mL

$\rho_{solution}$ **= 1.05 g/mL →** $\rho T = \frac{mT}{vT} \rightarrow 1.05 = \frac{mT}{337} \rightarrow mT = 1.05 \times 337$ **∴mT =353.85 g**

$\% \, m1 = \frac{m1}{mT} \times 100\% \rightarrow 5.80\% = \frac{m1}{353.85} \times 100\% \therefore 5.80 = \frac{100\, m1}{353.85}$

$100\, m1 = 5.80 \times 353.85 \rightarrow 100\, m1 = 2052.33 \rightarrow m1 = \frac{2052.33}{100}$ **∴m1= 20.5233 g**

Q4-10: **A sample of water 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.)**

Solution:

%m1= 8.5 % , m1 = ? g

VT = 28.6 L → VT = 28.6 × 1000 ∴VT = 28600 mL

$\rho_{Lake\ water}$ **= 1.03 g/mL →** $\rho T = \frac{mT}{vT} \rightarrow 1.03 = \frac{mT}{28600} \rightarrow mT = 1.03 \times 28600$ **∴mT =29458 g**

$\% \, m1 = \frac{m1}{mT} \times 100\% \rightarrow 8.5\% = \frac{m1}{29458} \times 100\% \therefore 8.5 = \frac{100\, m1}{29458}$

$100\, m1 = 8.5 \times 29458 \rightarrow 100\, m1 = 250393 \rightarrow m1 = \frac{250393}{100}$ **∴m1= 2503.93 g**

Q4-11: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)

Solution:

%m1 = 11.5 %

m1 = 85.2 g , VT = ? mL

$\rho_{solution}$ = 1 g/mL

$$\%\,m1 = \frac{m1}{mT} \times 100\% \quad \rightarrow \quad 11.5\% = \frac{85.2}{mT} \times 100\% \quad \rightarrow \quad 11.5 = \frac{8520}{mT} \quad \rightarrow \quad mT = \frac{8520}{11.5}$$

$$\therefore mT = 740.869\ g$$

$$\rho_{solution} = \frac{mT}{vT} \quad \rightarrow \quad 1 = \frac{740.869}{VT} \quad \rightarrow \quad VT = \frac{740.869}{1} \qquad \therefore VT = 740.869\ mL$$

Q2018: A juice contains 11.5 % mass percentage of sugar. What is the volume of juice in mL if juice contain 28.2 g of sugar. (($\rho_{solution}$ = 1 g/mL)

Solution:

%m1 = 11.5 %

m1 = 28.2 g , VT = ? mL

$\rho_{solution}$ = 1 g/mL

$$\%\,m1 = \frac{m1}{mT} \times 100\% \quad \rightarrow \quad 11.5\% = \frac{28.2}{mT} \times 100\% \quad \rightarrow \quad 11.5 = \frac{2820}{mT} \quad \rightarrow \quad mT = \frac{2820}{11.5}$$

$$\therefore mT = 245.217\ g$$

$$\rho_{solution} = \frac{mT}{vT} \quad \rightarrow \quad 1 = \frac{245.217}{VT} \quad \rightarrow \quad VT = \frac{245.217}{1} \qquad \therefore VT = 245.217\ mL$$

Q2019: Calculate the mass percentage of methyl alcohol in a solution containing (26.5 g) of methyl alcohol and (173.5 mL) of water and assume that density of water (1 g/mL)

Solution:

m1=26.5 g , %m1 = ?%

V2= 173.5 mL , m2=? g

$\rho_{water} = 1\ g/mL \rightarrow \rho 2 = \frac{m2}{v2} \rightarrow 1 = \frac{m2}{173.5} \rightarrow m2 = 1 \times 173.5 \quad \therefore m2 = 173.5\ g$

$mT = m1 + m2 \rightarrow mT = 26.5 + 173.5 \quad \therefore mT = 200\ g$

$\%m1 = \frac{m1}{mT} \times 100\% \rightarrow \%m1 = \frac{26.5}{200} \times 100\% \quad \therefore \%m1 = 13.25\ \%$

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 %

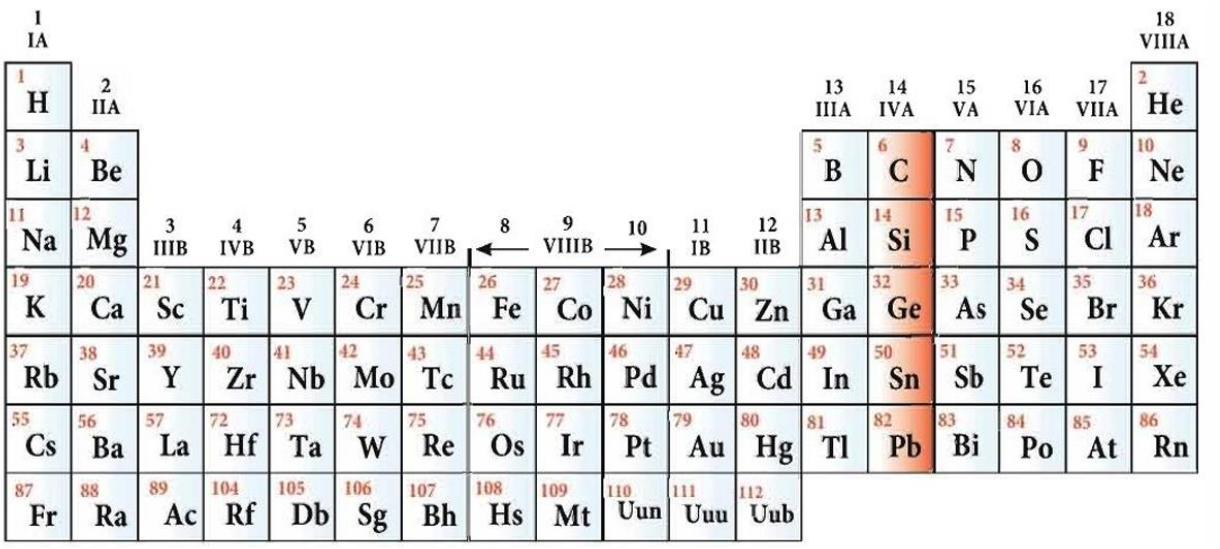
4.19 Fill in the blanks.

substance	vol. of solute	vol. of solvent	vol. of solution	percentagevol 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 %

Group IVA:

Q:What are group IVA consist of?

A/ It consists of Carbon (C), Silicon (Si), Germanium (Ge), Tin (Sn) and Lead (Pb).



Q:What are the general characteristics of group IVA?

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A/ Group IVA is more various and numerous in the characteristics of its members than other groups in the periodic table.

1-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.

Carbon (C) is nonferrous, silicon (Si) and germanium (Ge) are metalloid, tin (Sn) and lead (Pb) are pure metals. Thus, tin and lead have the physical characteristic of metals such as:

(1) high density.

(2) thermal and electro conductivity together.

(3) bright color and high malleable and ductile prone.

2-The melting and boiling points of group IVA also decrease as we go from the top to bottom.

3-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).

Q:Why group (IVA) tend to share 4 electrons and make covalent bonds?

4-In fact silicon and carbon compounds are actually covalent compounds of tetra-oxidation. (Si^{4+}, C^{4+}).
Germanium, tin and lead, on the other hand, combine to make ionic and covalent compounds. In ionic compounds, only two electrons are lost to make Ge^{2+} , Sn^{2+} , Pb^{2+}.

Ionic	Covalent
Ge^{2+}	Ge^{4+}
Sn^{2+}	Sn^{4+}
Pb^{2+}	Pb^{4+}
-	C^{4+}
-	Si^{4+}

5-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.

SILICON:

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 loss four electrons.
Silicon combines with its four electrons to form compounds, most of which are covalent silicon compounds.
Its valence electrons is four.

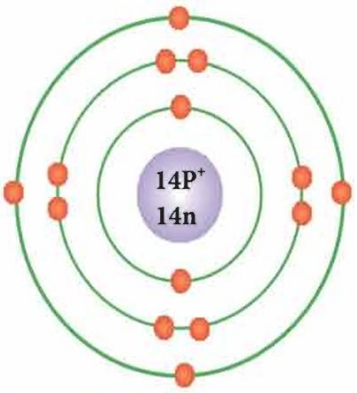

Figure 5-2
Electron configuration of silicon atom.
Chemical symbol: Si
Atomic number : 14
Mass number : 28

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

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%.

1-It occurs mostly in combination with oxygen in soil or as various forms of sand and clay deposits.
2-It does not occur as a pure free element in nature.
3-It is most widely distributed in rocks as silicon dioxide (SiO_2).
4-It is in the form of quartz and sand.
5-Silicon has two main forms crystallized silicon and non-crystallized Silicon. Both forms have a formula similar to diamonds.

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Crystallized silicon	Non-crystallized silicon
1-Dark brown color	1-Dark gray color
2-Less active	2-More active
3-Its formula similar to diamond	3-Its formula similar to diamond

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

Preparation In Laboratory:

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

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

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

Industrial preparation:

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

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

Properties of silicon:

A-Physical properties:

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1-Silicon is a metalloid.
2-It is a very rigid element, with a high melting point of approximately (1410°C).
3-It has a gray color and a metallic luster.

Q: Why Silicon is used in manufacturing of electrical devices?

4-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,
5-It is used in manufacturing solar cells. Which convert the solar energy into electricity.

B-Chemical properties:

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

$$Si + 2NaOH + H_2O \rightarrow \underset{\text{Sodium Silicates}}{Na_2SiO_3} + 2H_2$$

2-Silicon is very reactive with chlorine (Cl_2) as in the following equation.

$$Si + 2Cl_2 \rightarrow \underset{\text{Silicon tetrachloride}}{SiCl_4}$$

3-Silicon is not prone to react at room temperature. It reacts at (950°C).

4-Silicon and its natural compounds (silica and silicate) are not poisonous.

Silicon at high temperature

Uses of silicon:

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

1- Electronics industry, electrical appliances and in manufacturing solar cells.

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

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's prepared by the reaction of magnesium silicide Mg_2Si with the acids such as hydrochloric acid as in the following equation:

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

Magnesium silicide Silicon hydride

Hydrates are so active compounds. For example silicon (IV) hydride (SiH_4) burns spontaneously in atmosphere and forms silicon dioxide (SiO_2) and water (H_2O) as in the following reaction.

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

B-Silicon compounds with oxygen:

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1-Silicon Dioxide (Silica) SiO_2:

It occurs in nature as pure silica such as quartz and flints, 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.

Q:Why quartz and flints used in cutting glass and scratching steel?

Q:Why sand and clay have different colors?

Figure 5 - 6

Figure 5 - 5
A sample of pure silicon

Q:What are the most important properties of silica? **(2024 1st)**

A/

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

b- It reacts with hydrofluoric acid (HF) and bases.

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

d- Silica gel is mainly used as a drier due to its large surface and great ability to absorb water. **Q:Why silica gel is used as drier?**

Figure 5 - 7 Silica gel as a desiccant factor

2-Silicates $MSiO_3$:

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Silicates occur so widely in nature, among other types of silicates, sodium silicate Na_2SiO_3 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:

1- providing passive fire protection for textiles and papers.

2- used as a cheap adhesive.

3- Cement can be strengthened by mixing it with sodium silicate in order to be used in buildings.

Water glass:- Is the concentrated aqueous solution of sodium silicate after dissolving it in water, it has various industrial uses such as …..

Figure 5-8
Soil is one of natural silicates.

$Na_2O + SiO_2 \xrightarrow{\Delta} Na_2SiO_3$

$Na_2CO_3 + SiO_2 \xrightarrow{\Delta} Na_2SiO_3 + CO_2$

$CaO + SiO_2 \xrightarrow{\Delta} CaSiO_3$

$CaCO_3 + SiO_2 \xrightarrow{\Delta} CaSiO_3 + CO_2$

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C-Silicones:

These compounds are organic compounds of silicon. They are not poisonous and are very stable along a very wide range of temperature variation.

1-Silicon oils are the most important of these compounds. They make the surface anti- adhesive and moisture and are used to cover the roofs of buildings.

2-Silicone rubber, it 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.

3-Silicone resin is used in electrical insulation and in making construction materials. Water proof, too.

Q5-2:

$_{14}Si$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

$_{14}Si^{+4}$: $1s^2\ 2s^2\ 2p^6$ (lost 4 e^-)

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 quartz and flints and non-pure type such as Sand, and clay.

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

3- The elements of the fourth group have common oxidation (+4) , (+2)

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

5- The silicon reacts when it heated to (950 c°) with oxygen or aerated air to give Silica SiO_2

6- The more the characteristics in group IVA transfer from non-ferrous to metal when we move from the top of the group to the bottom in this group, also the elements of this group melting and boiling Points decrease as we move from the top to bottom.

7-Silicon has two main forms, the first form of silicon is Crystallized has dark brown color, the second form non-Crystallized and has dark gray color.

5-1:

① $2Mg + SiO_2 \longrightarrow Si + 2MgO$

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

③ $SiO_2 + 2C \longrightarrow Si + 2CO\uparrow$

$Si + O_2 \xrightarrow{950^\circ C} SiO_2$

Silicon dioxide (Silica)

Chapter-6 INTRODUCTION TO ORGANIC CHEMISTRY

Introduction:

We studied Carbon and some of its important compounds in our life, such as (carbon dioxide CO_2 and calcium carbonate $CaCO_3$). 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.

Organic Chemistry: Is a branch of chemistry that studied carbon element and the general properties of its important compounds like methane, ethylene and acetylene as well as ethyl alcohol, benzene, acetic acid and phenol.

Q:What is Importance of organic compound?

A/

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.

Exercise 6-1
How can you prove presence of carbon in organic compounds experimentally?

Existence of carbon in organic compounds:

Q:How can you prove the existence of carbon element in the 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.

GENERAL FEATURES OF ORGANIC COMPOUNDS:

Burning of sugar

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

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.

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.

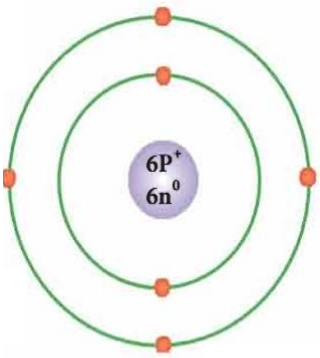
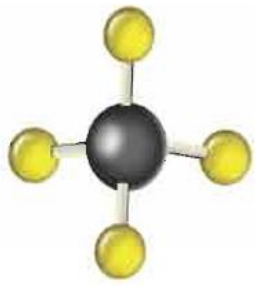
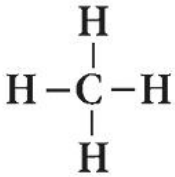


Figure 6-1
Electron configuration of carbon atom

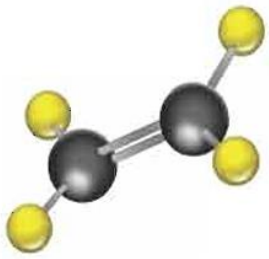
$_6C$: $1s^2$ $2s^2$ $2p^2$

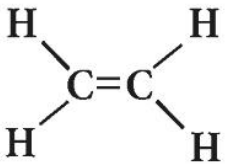
Each valence bond needs two electrons (one from each atom), therefore, carbon atoms bind in the following way by four single bonds with hydrogen in a methane molecule (CH_4)





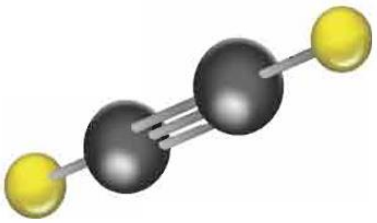
Methane (4 single bonds)

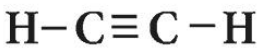




Ethylene: A double bond and 4 single bonds

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





Acetylene : One triple bond and two single bonds;

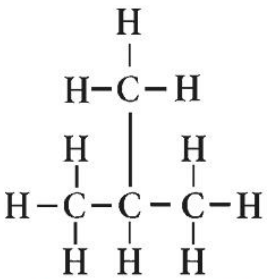
Such various bonding possibilities for carbon atom in compounds add versatility to this atom in having various valence bonds, not to mention carbon atoms' ability to bond with each other to form open or closed chains (rings).

These chains include single, double or triple bonds between carbon atoms or other atoms.

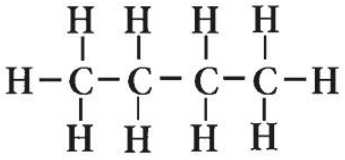
Therefore, there are thousands of organic compounds in nature and can also be synthesized as well.

Alkanes

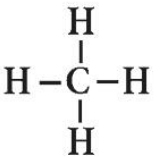
C_1H_4 methane
C_2H_6 ethane
C_3H_8 propane
C_4H_{10} butane
C_5H_{12} pentane
C_6H_{14} hexane
C_7H_{16} heptane
C_8H_{18} octane
C_9H_{20} nonane
$C_{10}H_{22}$ decane



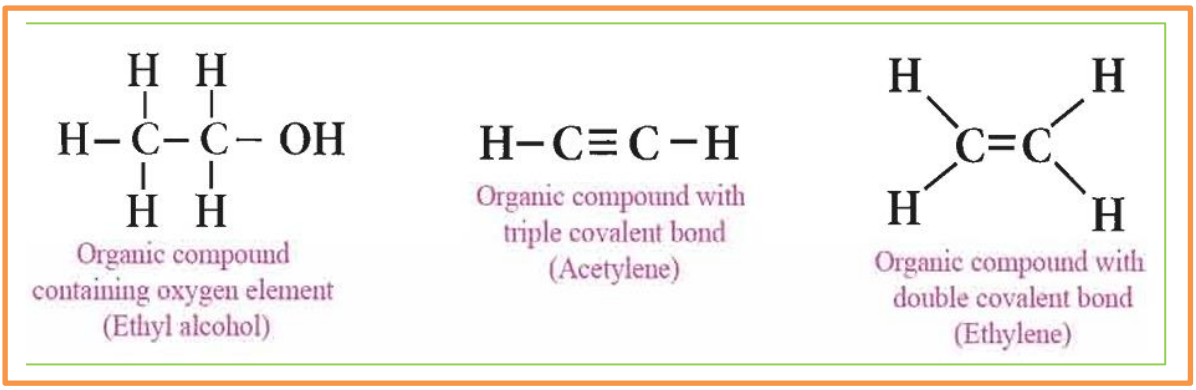
Organic compound (branched chain) Isobutane



Organic compound (unbranched chain) Butane



Organic compound with single covalent bond (Methane)



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.

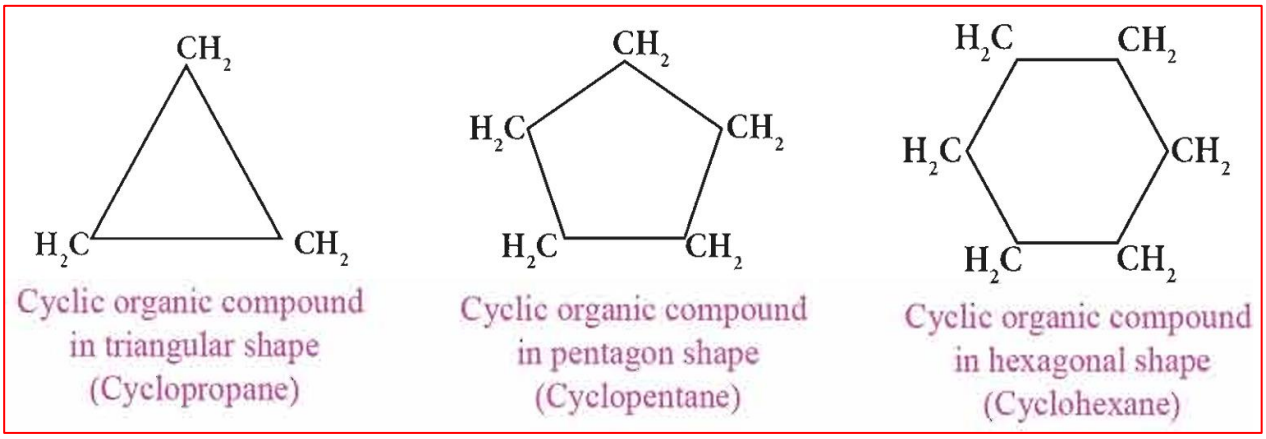
Methane represents an example of organic compounds which contain single valence bonds, this type of saturated hydrocarbon compounds is called (alkanes).

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.**

We will study organic compounds in which carbon atom bonds as well as hydrogen and oxygen. Ethyl alcohol, acetic acid in addition to benzene and phenol compounds which are examples of closed chain organic compounds.



Some Organic compounds:

We will study some organic compounds such as saturated and unsaturated hydrocarbons, alcohols and acids.

1-Hydrocarbons:

It contains only carbon and hydrogen, either saturated or unsaturated, these hydrocarbons include:

1-Methane (CH_4):

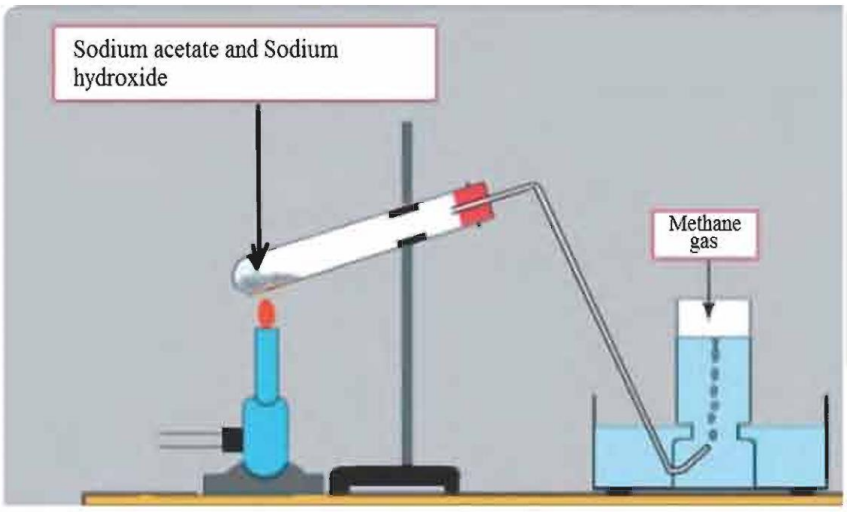
Its molecular formula is CH_4 whereby a carbon atom is bonded with 4 hydrogen atoms in a single bond.

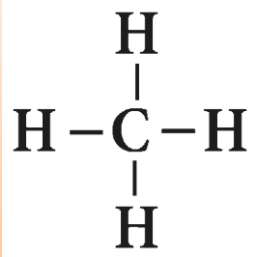
a) Existence in nature:

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, whereby sodium acetate CH_3COONa is heated at high temperature along with sodium hydroxide NaOH or calcium hydroxide $Ca(OH)_2$ (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.





Structure of Methane

$$CH_3COONa + NaOH \xrightarrow{\Delta} CH_4 \uparrow + Na_2CO_3$$

Sodium acetate Sodium hydroxide Methane Sodium carbonate

c)Physical and chemical properties of Methane gas:

1-Colorless and odorless.

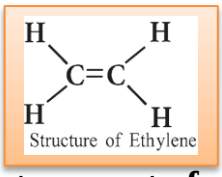
2-Highly insoluble in water.

3-Flammable, smokeless flame, releasing <u>carbon dioxide CO_2</u> and <u>water vapor</u> and <u>energy</u>, 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 <u>double</u> bond. It is one kind of unsaturated hydrocarbons which are called ''Alkenes''.

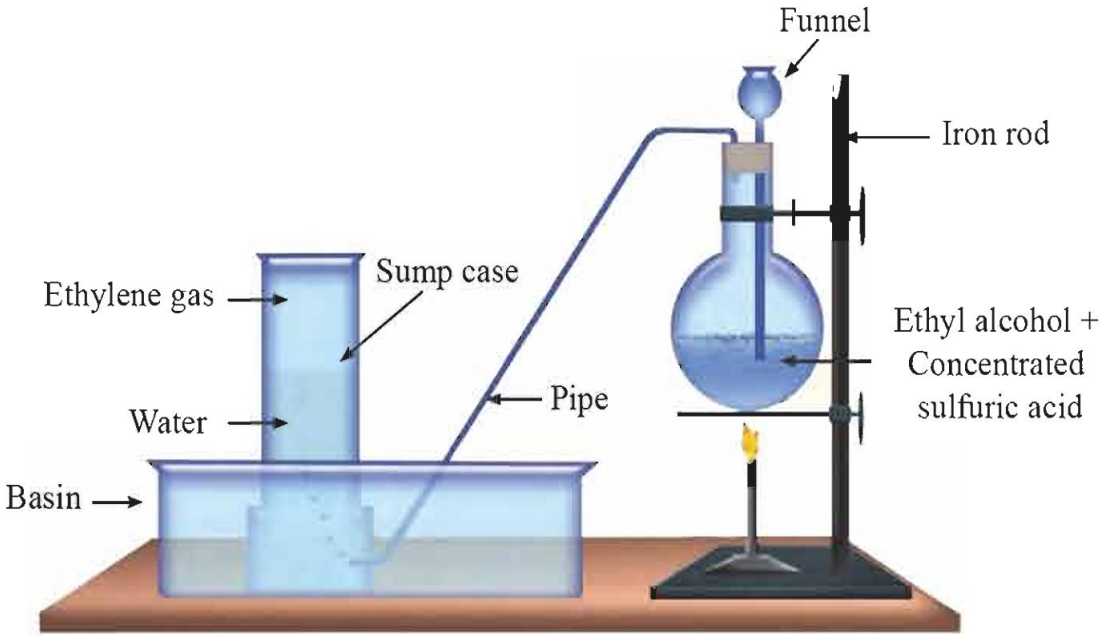


Structure of Ethylene

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 H_2SO_4 up to 170℃ in the figure below.
<u>The sulfuric acid</u> removes water molecule (H_2O) from the 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 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.

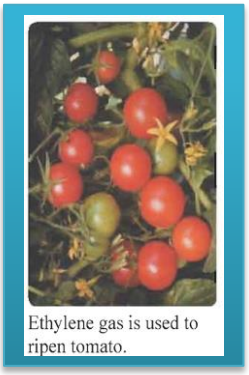
$$C_2H_4 + 3O_2 \xrightarrow{\Delta} 2CO_2 + 2H_2O$$

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.

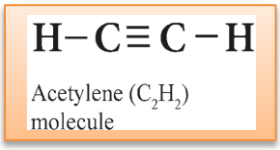
Q: How can you distinguish between saturated hydrocarbons such as methane and unsaturated hydrocarbons such as ethylene?


Ethylene gas is used to ripen tomato.

A/ By the reaction with red bromine water.

Ethylene + red bromine water → red color disappears
Unsaturated hydrocarbon

Methane + red bromine water → red color doesn't disappear
Saturated hydrocarbon



Acetylene (C_2H_2) molecule

3-Acetylene (C_2H_2):

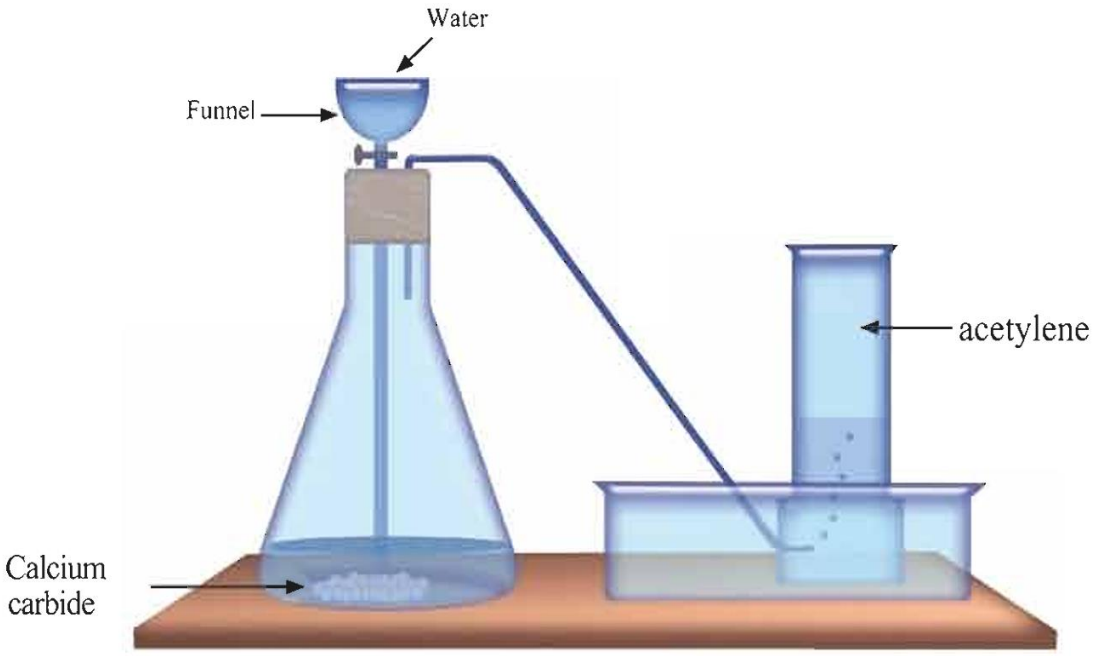
It is a hydrocarbonic compound with the molecular formula of (C_2H_2) in which the two carbon atoms combine with each other in triple covalent bonds. It is an example of the unsaturated hydrocarbons called "Alkynes".

a) Preparation of Acetylene:

Acetylene can be produced by the reaction of calcium carbide CaC_2, with water H_2O.

$$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$$

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



An apparatus for preparation acetylene

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 forms a smoky flame.

4- It burns with oxygen gas in making a faded blue flame and high temperature:

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

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
Unsaturated hydrocarbon

Methane + red bromine water → red color doesn't disappear
Saturated hydrocarbon

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 is converted into carbon dioxide CO_2 and ethanol C_2H_5OH by effect of enzyme.

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

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 its 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.

Sperto:- It is undrinkable alcohol as some; poisonous substances like methyl alcohol are added to it. Some dyeing substances are added to it to make its color different from pure ethyl alcohol.

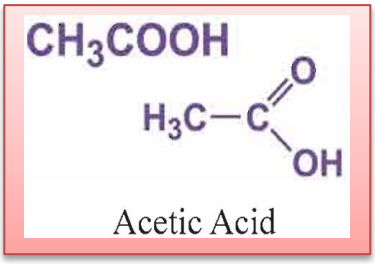
c) Q: What is the effect of Ethyl Alcohol on Human Beings?

A/ 1-Drinking alcohol disturbs the consistency between the muscular and nervous systems.
2-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 (CH3COOH):

a) Industrial Preparation:

Acetic acid is produced industrially by the reaction of acetylene C_2H_2 with water using sulfuric acid and other facilitating factors. A chain reaction occurs and finally produces acetic acid.



b) Properties of Acetic Acid:

What are the Properties of Acetic Acid?

A/ 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):

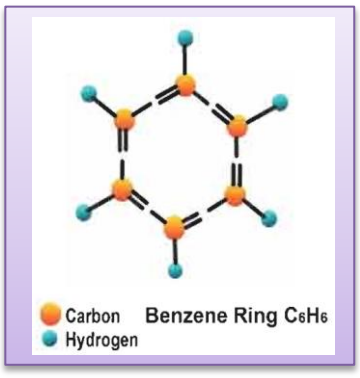
Benzene can be extracted from coal tar which is one of the petrol products and is fugitive (vapor quickly).
Benzene is a hydrocarbonic compound consisting of carbon and hydrogen. Its complete combustion results in a very smoky flame?
Because of the high percentage of carbon (6C:6H).
Benzene is the simplest compound in the group of hydrocarbons which are called "Aromatic Hydrocarbons" because of their distinctive smells.

Benzene vapors very quickly and boils at (80℃). It's not soluble in water.

Benzene is used for:

1-As an important industrial solvent to paints and many important industrial products.

2-It is also used in the production of insecticides, nylon, modern detergents, ets.



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.

6.11 1. It's insoluble in water and lighter than air.
2. It's saturated hydrocarbon.
3. The amount of carbon is less when compared with the amount of hydrogen.

CH_4 C : H
1 : 4

6.12: In acetylene the amount of carbon are equal the amount of hydrogen
C_2H_2 C : H
2 : 2

In benzen the amount of carbon is equal the amount of hydrogen C_6H_6 C : H
6 : 6

6-6

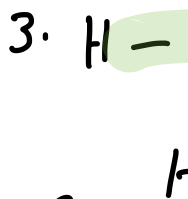
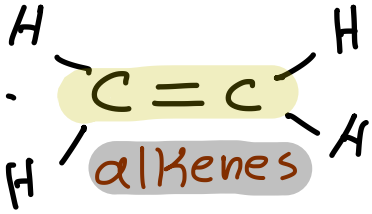
1. $CH_3COONa + NaOH \longrightarrow CH_4\uparrow + Na_2CO_3$

2. $CH_4 + 2O_2 \xrightarrow{\Delta} CO_2 + 2H_2O + energy$

$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$

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

3. $2H_2O + CaC_2 \longrightarrow C_2H_2 + Ca(OH)_2$

Methane	Ethylene	Acetylene
1. CH_4	1. C_2H_4	1. C_2H_2
2. Saturated hydrocarbon	2. Unsaturated hydrocarbon	2. Unsaturated hydrocarbon
3.  alkanes	3.  alkenes	alkynes 3. $H-C\equiv C-H$
Single covalent bonds	double covalent bonds	triple covalent bonds
4. Colorless	4. Colorless	4. Colorless
5. Odorless	5. Sweet and musky odor	5. bad smell like garlic
6. Highly insoluble in water	6. insoluble in water	6. insoluble in water
7. Doesn't react with red bromine water	7. React with red bromine water removes its color	7. React with red bromine removes its color
8. Burns with O_2 smokeless flame	8. Burns with O_2 Smoky flame	8. Burns with O_2 faded blue flame

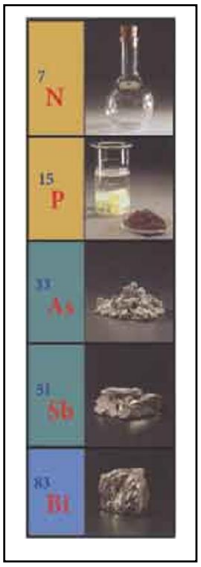
Group VA:

Q:What are group VA elements?

A/ Group five (VA) consist of nitrogen (N), phosphorus (P), arsenic (As), antimony (Sb) and bismuth (Bi). All the elements in this group have five electrons in their outer shells.

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						



Q:What are the general characteristics of group VA?

A/ Although the five elements of this group <u>form less than 0.2% of the Earth's crust</u>, 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.

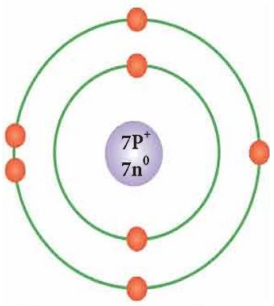
The most important properties of the group VA elements are:

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

2-Nitrogen is <u>gaseous</u>, the rest of the elements are <u>solids</u> in normal conditions.

3-The chemical properties vary on a regular basis from phosphorous to bismuth. Phosphorus and nitrogen have the propensity to form covalent compounds. Other elements like bismuth and arsenic form ionized compounds.

4-The acidic and basic properties of the elements' oxides also vary from being acidic (phosphorus) to basic (bismuth).



Electron configuration of Nitrogen


Arsenic


Antimony

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

$_7$N: $1s^2$ $2s^2$ $2p^3$ 1(K): $2e^-$, 2(L): $5e^-$

Occurrence of nitrogen in nature:

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

Preparation of Nitrogen:

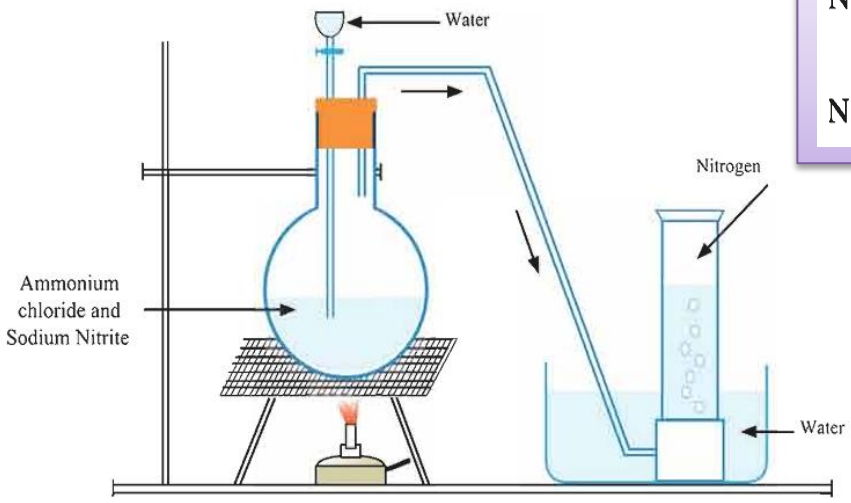
Nitrogen can be produced in two ways:

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 equations:

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

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



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 copper oxide (CuO).

Properties of nitrogen:

1-Physical properties:

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

2-Chemical properties:

Under certain conditions, nitrogen reacts with some other elements. For example,
1-Heating nitrogen leads to direct interaction between nitrogen and magnesium, lithium and calcium.

2-When mixed with oxygen and the mixture is put under a spark, nitrogen produces nitrogen oxides (NO_2 and NO).

3-Heating nitrogen with gaseous hydrogen under high pressure and with an appropriate catalyst produces ammonia NH_3 (Haber - Bosch process), according to the following equation:

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

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

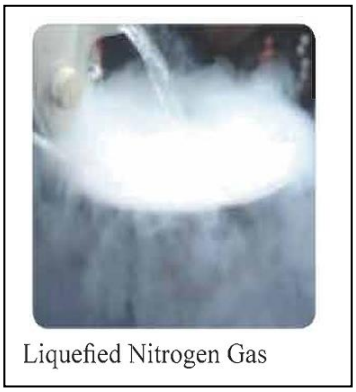
Uses of nitrogen:

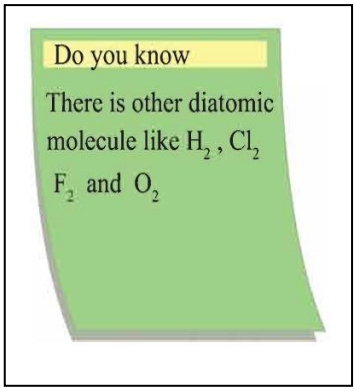
1-It is used to produce ammonia industrially.
It is the most important use of nitrogen? - Due to the vital importance of this substance in the production of fertilizers and in the production of nitric acid HNO_3 (Ostwald process).

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.

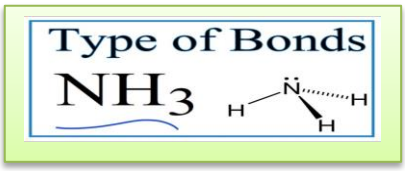
4-It is used as an inert agent in containers and tanks of flammable materials.

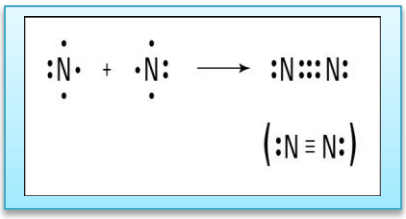

Liquefied Nitrogen Gas



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):

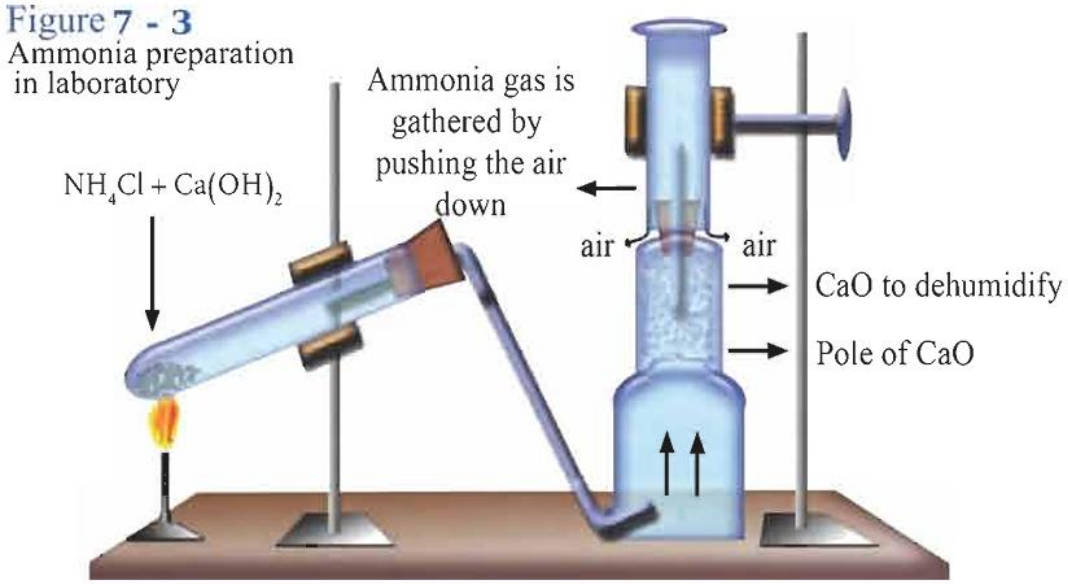
It is one of the important compounds of nitrogen and hydrogen.
It occurs in nature as a result of the process of decay of animals and plants upon death.
Ammonia occurs also in soil in the form of ammonium salts.

a) Preparation of Ammonia in Laboratory:

Gaseous ammonia can be produced in the laboratory by:
Heating the salt of ammonium chloride NH_4Cl with calcium hydroxide $Ca(OH)_2$, as in the following equation:

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

The gas ammonia is collected by downward?
A/ Because ammonia is lighter than air.
Removal of air after passing it in a pole of calcium oxide CaO?
A/ To remove any moisture with the gas.



b) Industrial Preparation of Ammonia:

Large quantities of ammonia can be produced industrially by:
Haber-BOSCH Process:- which involves the direct combination of nitrogen N_2 and hydrogen H_2 to produced NH_3. As in the following equation:

$N_2 + 3H_2 \rightarrow 2NH_3$

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

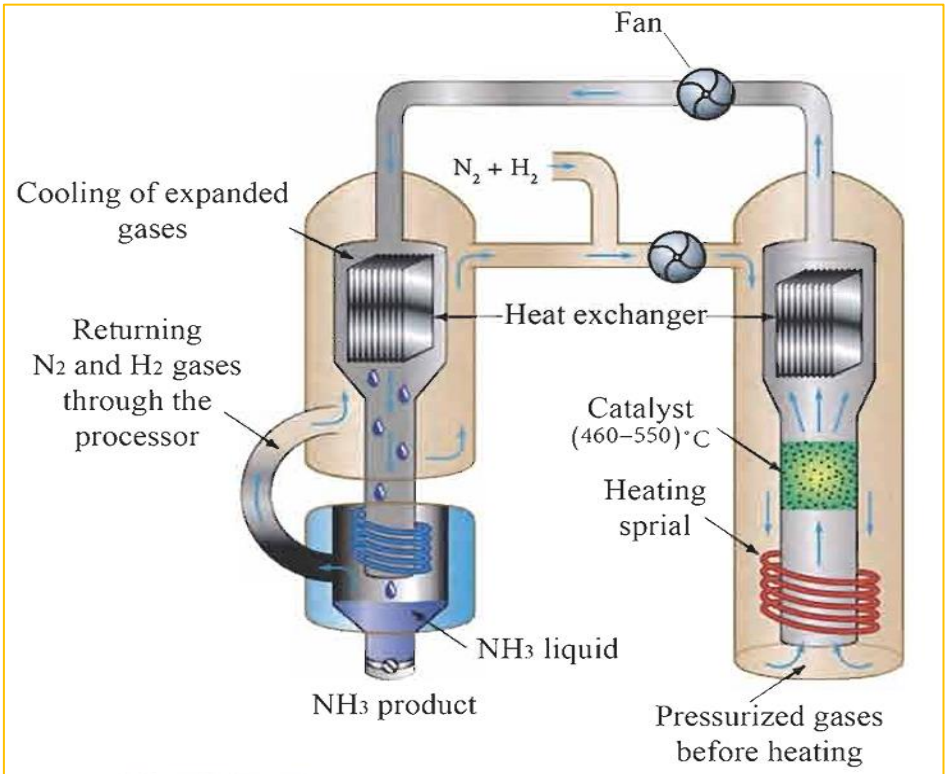


Figure 7 - 4 Ammonia production by Haber process


Scientist:
FREDS HABER

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.**

Q:Explain the fountain experiment of ammonia solubility in water?

A/ The device used in this experiment consists of
1-a glass. Half of the glass is filled with water with two drops of phenolphthalein.
It also consists of 2-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 ?
A/ because of its basically (ammonia solution is act as a base).

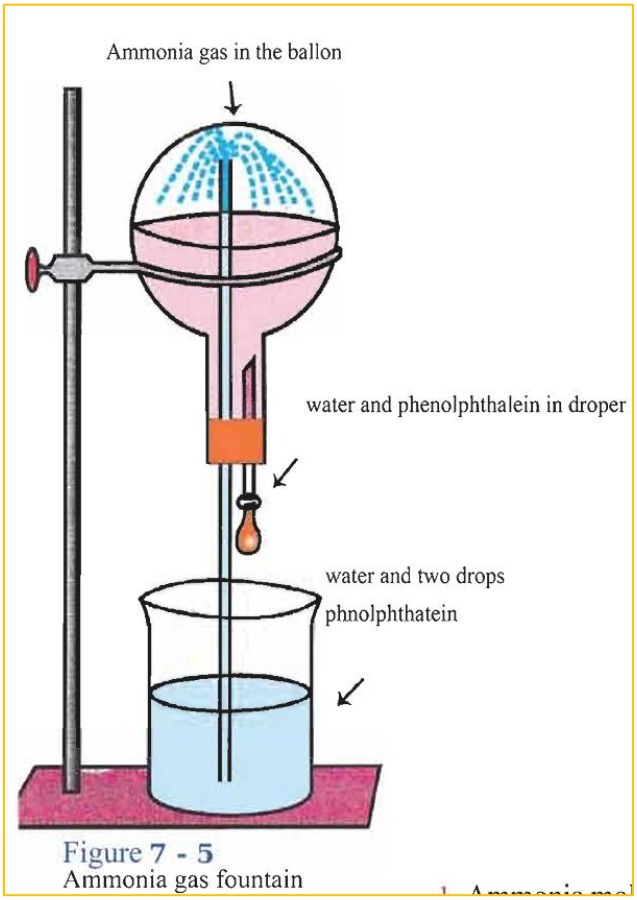


Figure 7 - 5
Ammonia gas fountain

3-It can be liquidized at room temperature with 8-10 atm pressure.

4-The boiling point of liquid Ammonia is (-33.5°C) under the normal atmospheric pressure.

5-It vapors at high temperature and for this reason it is used in refrigeration and ice production.

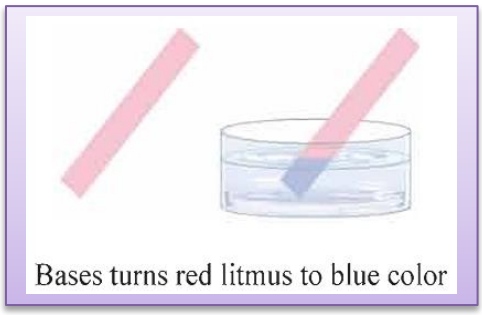
Chemical properties of Ammonia:

1-Ammonia molecule (NH_3) is chemically stable, yet it can release nitrogen (N_2) 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:

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

3-Ammonia solution turns the red litmus paper into blue. (Ammonia is a base)


Bases turns red litmus to blue color

Test of Ammonia:

Q:How can you test (detect) ammonia?

A/ Ammonia can be detected, when ammonia reacts with hydrogen chloride, it produces white dense vapor which is ammonium chloride NH_4Cl.

$$NH_{3(g)} + HCl_{(g)} \longrightarrow NH_4Cl_{(g)}\uparrow$$

Ammonia Hydrogen chloride Ammonium chloride (white dense vapor)

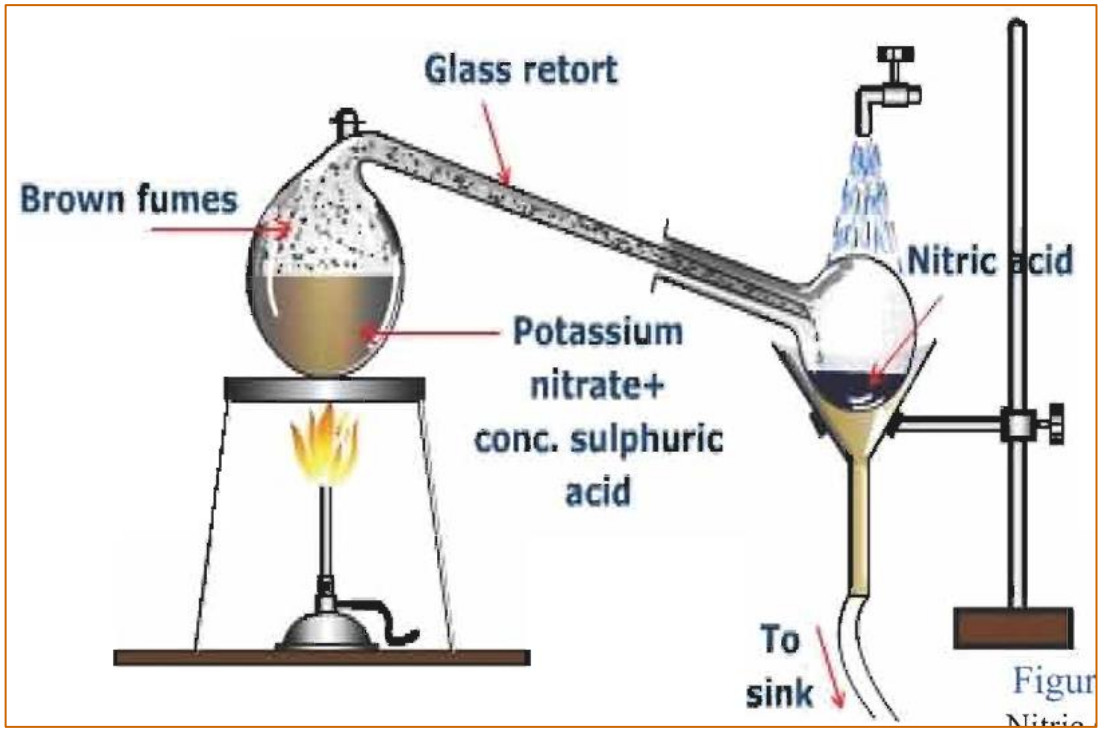
2-Nitric Acid HNO_3:

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

Preparation of Nitric Acid in Laboratory:

This acid is usually prepared by heating a mixture of potassium nitrate salt (KNO_3) with sulfuric acid (H_2SO_4) in the glass retort, and the nitric acid vapor resulting from the interaction is condensed in a water-cooled vessel.
The interaction can be expressed in the following equation.

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



Industrial preparation of the acid:

The acid (HNO_3) can be prepared artificially in commercial quantities by method of Ostwald whereby ammonia is oxidized in air, platinum acts as a catalyst.

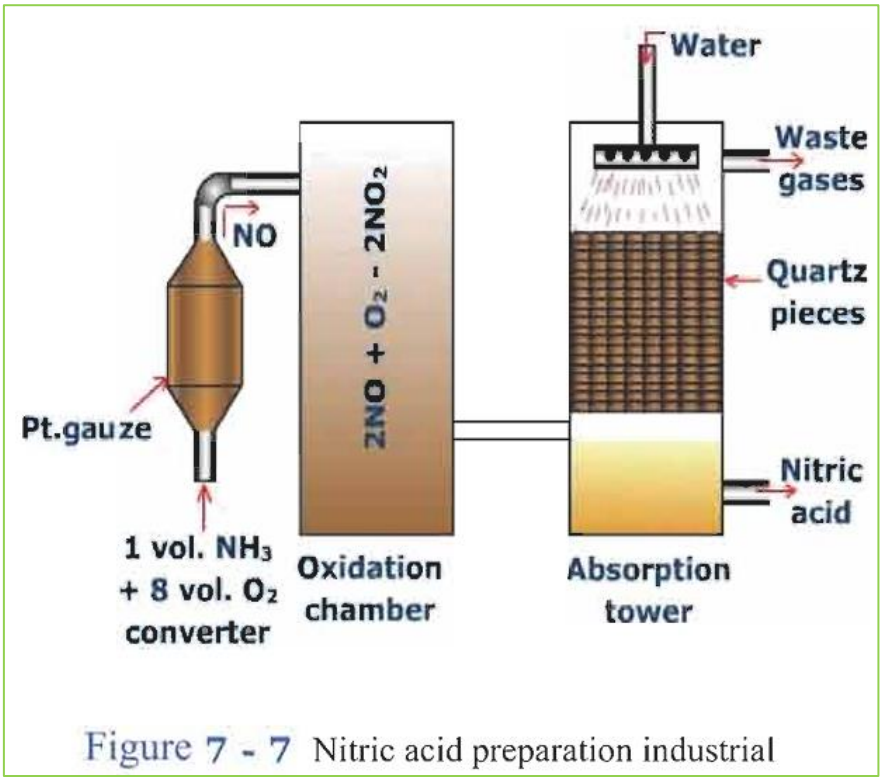
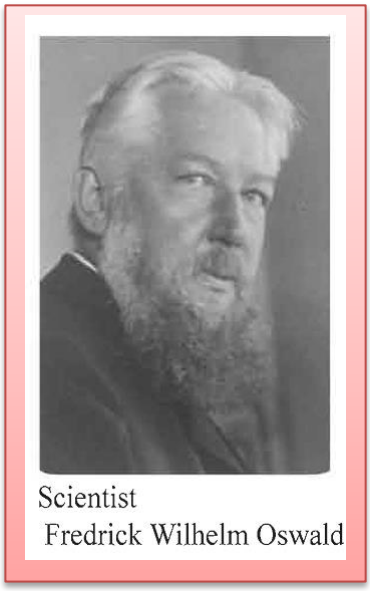


Figure 7 - 7 Nitric acid preparation industrial



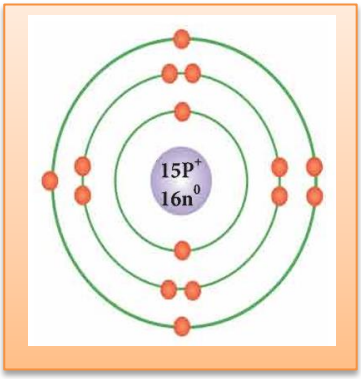
Scientist
Fredrick Wilhelm Oswald

Properties of nitric acid:

1-Pure acid is colorless
2-It has odorous fumes
3-The color of the impure acid (or the pure acid after leaving for a period of time) is yellow?
A/ Due to containing soluble nitrogen oxides (especially NO_2).
4-The acid is completely dissolving in water forming a mixture of (68%).
5-It boils at 120.5°C.

PHOSPHOROUS:

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



Chemical Symbol: P
Atomic Number :15
Mass Number :31

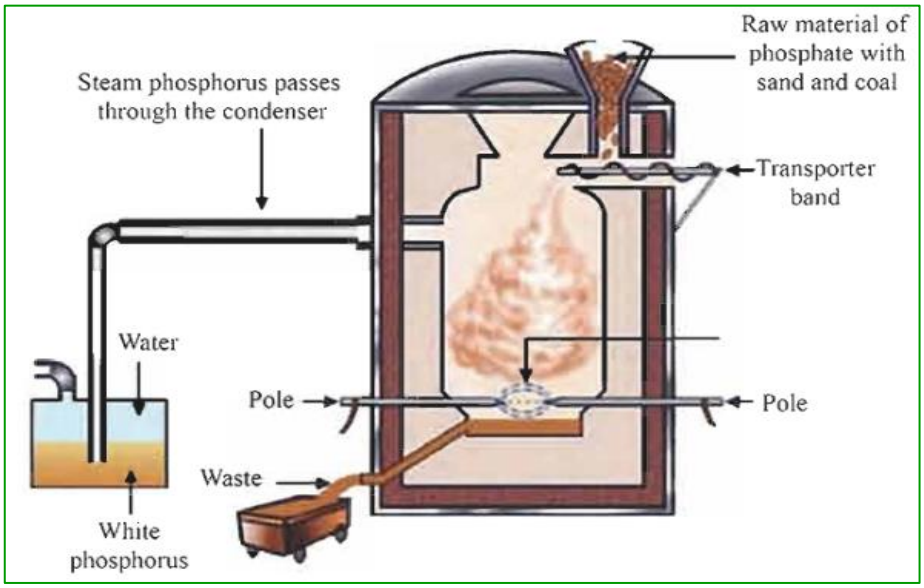
1-Existence of Phosphorous:

1-This element is an essential component in living things,
2-It is found in nerve cells, bones and cell cytoplasm.
3-It is not found freely in nature, yet, it is extensively found various minerals.
4-Apatite ores [apatite: impure form of calcium phosphate $Ca_3(PO_4)_2$]are important source of this element.
***Huge deposits of this mineral (apatite) are found in different parts of the world including Iraq.**

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.

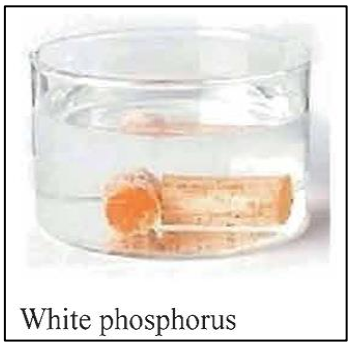
Phosphorous is normally produced by heating calcium phosphate ($Ca_3(PO_4)_2$) with sand (SiO_2) and carbon (C) in an electrical oven at high temperature, air-tight, as in the following equation: $2Ca_3(PO_4)_2 + 6SiO_2 + 10C \xrightarrow{1500\ ^\circ C} 6CaSiO_3 + 10CO + P_4$

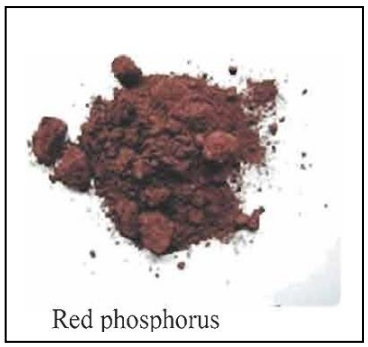


The resulting phosphorous is white, sometimes called yellow phosphorous it is cast in the form of cylinder bars.

-The casting process and preservation is done underwater?

A/ Because of the low temperature of flammability, fast integration with oxygen, high flammability in air.


White phosphorus


Red phosphorus

Properties of Phosphorous:

1-Phosphorous is normally white (yellowish) having a waxy form.

2-As for pure phosphorous, it is solid colorless and transparent.

3-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.

***White phosphorous is more active than red phosphorous under normal temperatures?**

A/ 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.

Chemical luminance (glitter):-When white phosphorous glows in the dark, looking pale green when exposed to damp air 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). $P_4 + 5O_2 \longrightarrow 2P_2O_5$

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

Table 7-1: Comparison of white and red phosphorous

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

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 a preservative for some food products, meat and many other uses. Which have major importance in manufacturing phosphate fertilizers.

Industrial Uses of some Phosphorous compounds:

1-Matchsticks:

Matchsticks are processed by Ammonium Phosphate solution $(NH_4)_3PO_4$.

1-This material [$(NH_4)_3PO_4$] helps burn the matchstick in a smokeless flame.
2-It also helps keep the flame burning completely.
3-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 $KClO_3$.
c-Friction material like glass powder.
d-Glue material to bind the ingredients of the paste.


Matchsticks:

Q: How can you ignite the matchstick?

A/ 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 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:

$$Ca_3(PO_4)_2 + 2H_2SO_4 \longrightarrow Ca(H_2PO_4)_2 + 2CaSO_4$$

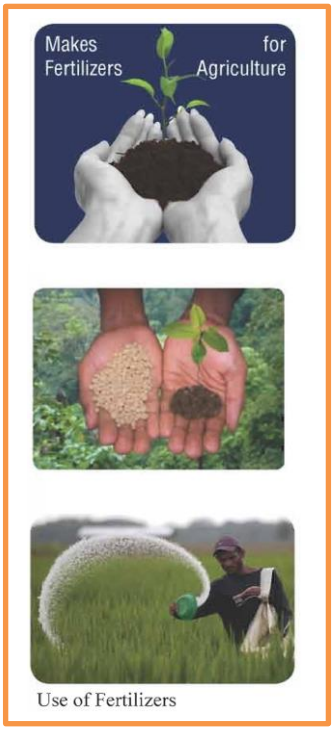
calcium phosphate (insoluble in water) | sulfuric acid | super-phosphate (soluble in water) | calcium sulfate

This fertilizer is used to increase soil fertility.

Other kinds of phosphate fertilizers can be prepared through the reaction of phosphoric acid H_3PO_4 with calcium phosphate $Ca_3(PO_4)_2$ to form a fertilizer commercially called triple super-phosphate $Ca(H_2PO_4)_2$ 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.



Use of Fertilizers

Super-phosphate fertilizer: Soluble in water fertilizer results from proceeding calcium phosphate with Sulfuric acid. $Ca(H_2PO_4)_2$

triple-phosphate fertilizer: phosphate fertilizer can be prepared by the reaction of phosphoric acid H_3PO_3 with Calcium phosphate $Ca_3(PO_4)_2$ its much better than ordinary phosphate it doesn't contain Calcium Sulfate $CaSO_4$

CHAPTER QUESTIONS 07

7.1 Complete the following statements;

1- Atomic number of nitrogen is.....7..... therefore its nucleus contains.....7..... proton which.....7.....electrons rotate around of nucleus.

2- Atomic number of phosphorus is.....15..... therefore it nucleus contains proton,.....15..... which.....15.....electrons rotate around of nucleus.

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

a) flammable material such as.....Sb_2S_3 antimony sulfide.....

b) An oxidizing material such as.....Potassium chlorate $KClO_3$.....

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

4- Nitrogen has ..diatomic..in nature. Chemical symbol of nitrogen.....N_2.....

5- NH_3 is symbol of ....ammonia..... molecule. This molecule consists of 1 atom nitrogen and three atoms...hydrogen.. NH_3

6- What is the benefits of fertilizer of phosphate?

Increase Soil fertility

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. nitrite

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

6 7.1 effect of phosphate fertilizer on spice السنبلياتيه

① It strengths plant stems.
② It accelerates plant growth.
③ It increases plant resistance to diseases.

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

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

b) $Ca_3(PO_4)_2 + 2H_2SO_4 \longrightarrow Ca(H_2PO_4)_2 + 2CaSO_4$

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

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. True

b) Highly tempretures are used in preparation of ammonia in industry. False heat, high pressure, catalyst

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

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

e) White phosphorus is poisonous material thus it is stored under water. False Because of the low temperature of flammability, fast integration with oxygen and high flammability in air.

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

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

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

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

ammonium chloride — calcium hydroxide — calcium chloride — water — ammonia

(b) $Ca_3(PO_4)_2 + 2H_2SO_4 \longrightarrow Ca(H_2PO_4)_2 + 2CaSO_4$

calcium phosphate — sulfuric acid — ordinary Super Phosphate — calcium sulfate

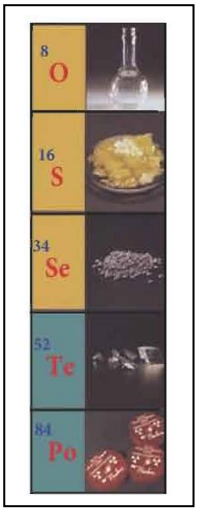
(c) $2Ca_3(PO_4)_2 + 6SiO_2 + 10C \xrightarrow{1500^\circ C} 6CaSiO_3 + 10CO + P_4$

calcium Phosphate — Silica — Carbon — calcium Silicate — carbon monoxide — Phospho...

Group VIA:

Group VIA (6A) elements appear on the right side of the periodic table.
They include five elements: Oxygen (O), Sulfur (S), Selenium (Se), Tellurium (Te), Polonium (Po).

1 IA												13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H	2 IIA																2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 ← VIIIB →	9	10	11 IB	12 IIB	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						



Q:What are the general properties of group VIA?

A/1-Elements of this group are characterized by gradual increase in their atomic numbers, whereby oxygen and sulfur considered as non-metal while selenium and tellurium have non-metallic properties, as for polonium, it has pure metal properties.

2-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
Selenium

Sulfur

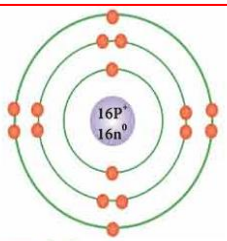


Figure 8-2
Electron configuration of sulfur

8-3 SULFUR

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

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.

($CuFeS_2$)

Preparation of Sulfur:

a-Preparation of Sulfur in Laboratory:

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

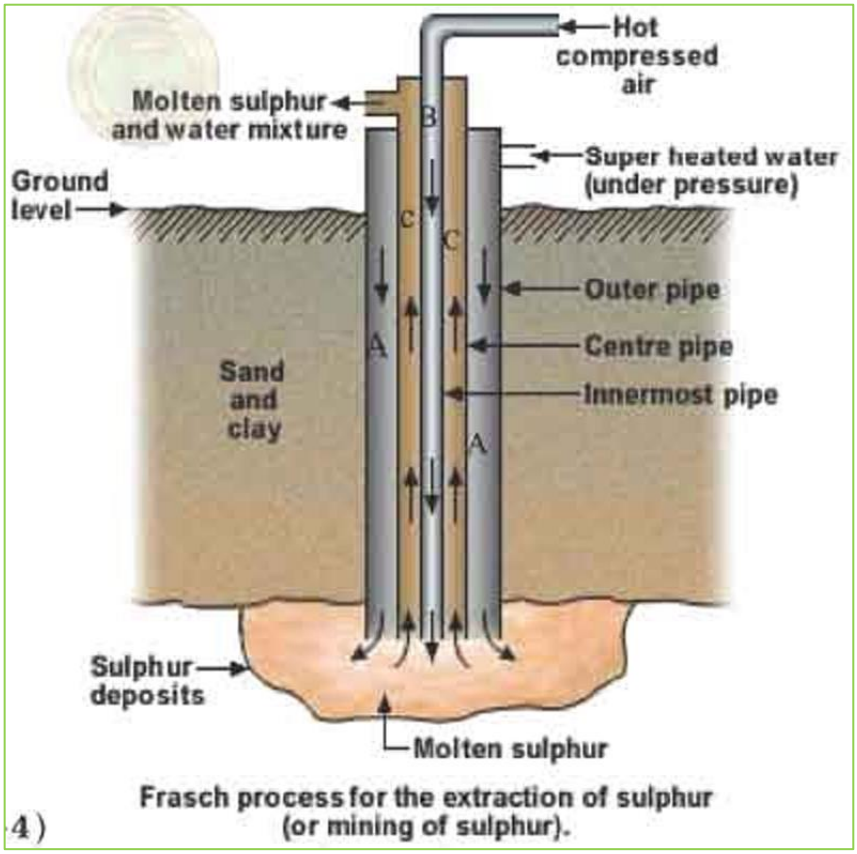
$$\underset{\text{hydrochloric acid}}{2HCl} + \underset{\text{sodium thiosulfate}}{Na_2S_2O_3} \xrightarrow{-10\,^\circ C} \underset{\text{sulfur}}{S\downarrow} + \underset{\text{sulfur dioxide}}{SO_2\uparrow} + \underset{\text{sodium chloride}}{2NaCl} + \underset{\text{water}}{H_2O}$$

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 equipment's, consisting of three overlapping tubes pivotally centered.
1-Pressurized and superheated to 170°C water vapor is pushed into the outer tube (A) to where sulfur converges, this pressure melts sulfur underground.

2-Pressurized air from tube (B) lifts up molten sulfur through tube (C) the middle tube. Sulfur comes out to the surface from this tube (C) mixed with some air bubbles.

3-Molten sulfur is cast in large basins and left to cool down and solidify.
4-Much of the sulfur produced 99.5% - 99.9% pure, therefore in needs no further re-purification.



4) Frasch process for the extraction of sulphur (or mining of sulphur).

3-General Properties of Sulfur:

1-Physical properties:

a-It is yellow solid substance at standard temperature.

b-Tasteless, with distinctive odor.

c-Insoluble in water, yet dissolves in some inorganic solvents like CS_2 carbon disulfide.

If carbon disulfide is evaporated, sulfur with 8 atoms (S_8) deposits gradually in the form of crystals.

Q: How can you prepare sulfur with 8 atoms?

A/ By dissolving sulfur in carbon disulfide CS_2 and then let the CS_2 evaporated, sulfur with 8 atoms (S_8) deposits gradually in the form of crystals.

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.**

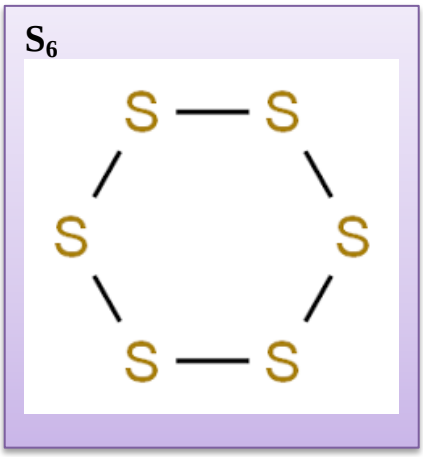
Allotropic elements:-The existence of a chemical element in two or more forms, which vary in physical form, color, arrangement of atoms such as sulfur element.

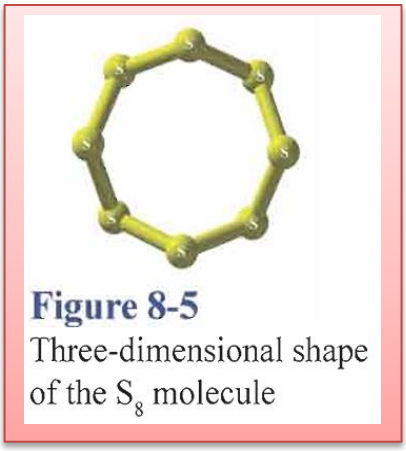
Sulfur has two main forms:

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?
A-Because its crystals look like prism.

2-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, whereby spiral chains are formed .It is less stable than crystal sulfur, it turns to crystal sulfur gradually.

*** Sulfur has the formula S_8 and S_6 , the first form (S_8) is more active than the latter?**
A-Due to the high tension of the rhombic ring.





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 sulfides:

$$S + Fe \xrightarrow{\Delta} FeS$$

iron(II) Sulfide

Exercise 8-1:Write sulfur reaction equation with copper and zinc.

Solution: $S + Cu \longrightarrow CuS$ Copper sulfide , $S + Zn \longrightarrow ZnS$ Zinc sulfide

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 H_2SO_4, producing non-metallic oxides.

$$S + 2H_2SO_4 \xrightarrow{\Delta} 3SO_2 + 2H_2O$$

concentrated and hot sulfur dioxide

With hot concentrated nitric acid HNO_3, it produces non-metal oxides of NO_2:

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

nitrogen dioxide

Uses of Sulfur:

Sulfur has many uses in industrial and agricultural fields,
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, developing films, drug industry.

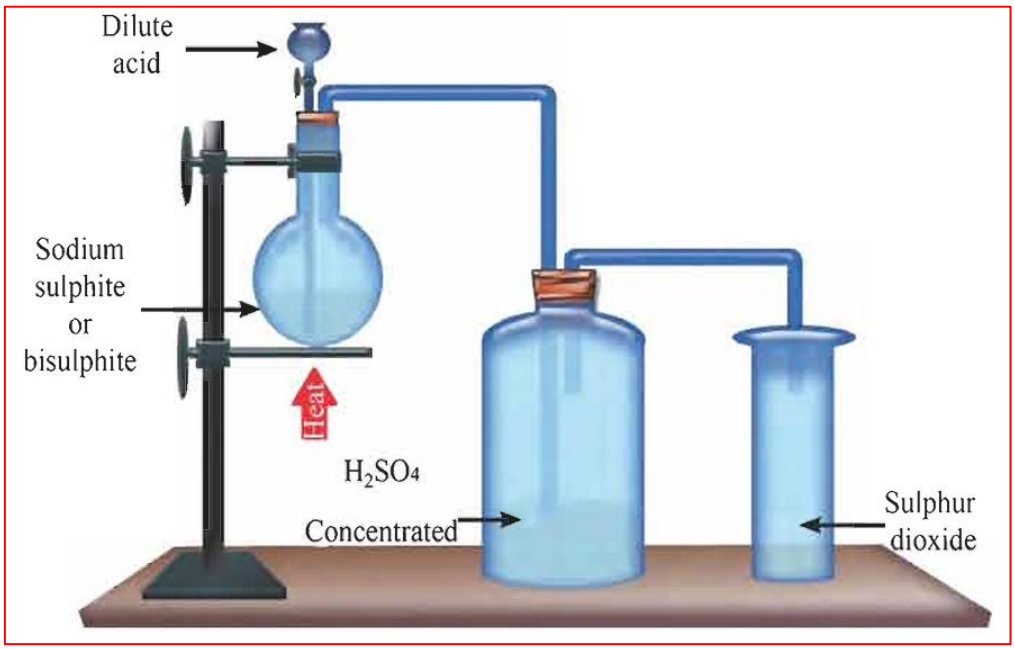
Some Sulfur Compounds:

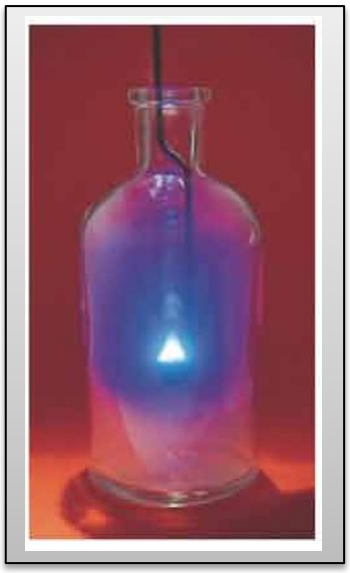
a-Sulfur Dioxide (SO_2):

Sulfur dioxide, SO_2, is produced mainly by burning sulfur with oxygen gas. This gas
1-naturally evaporates in large quantities from volcanic activities.
2-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 (H_2SO_4) to sodium sulfite (Na_2SO_3). It can be collected by pumping air out from above?
A/ Because it is heavier than air.

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





Preparation of sulfur dioxide in laboratory.

1-Sulfur dioxide is a colorless gas with a strong characteristic smell.

2-It is heavier than air.

3-It does not dissolve much in water producing a weak solution of sulfurous acid:

$$SO_2 + H_2O \rightleftharpoons H_2SO_3$$

Sulfurous acid

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 which results according to this equation: $SO_2 + H_2O \rightleftharpoons H_2SO_3$

Large quantities of sulfur dioxide can be collected industrially produced by:

1-The combustion of sulfur in air.

2-The molten sulfur is pumped in special combustion towers.

3-The resultant gas contains some impurities which need to be removed. $S + O_2 \xrightarrow{\Delta} SO_2$

Sulfur dioxide is commercially used in:

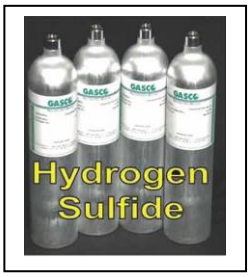
(A)Decolorizing the delicate organic substances such as paper, straw, artificial silk and wool which changed when they are bleached with chlorine gas. However, this bleaching effect does not normally last for a long time.

***Most of the SO_2 bleached materials recover their colors as soon as they are exposed to air.**

(B)This gas can also be used for sterilizing purposes by the process of combustion some quantities inside the places that need to be sterilized.

(C)It is, in addition, used as preservative agent in food industries.

Sulfur (S) can burn spontaneously in air at (400℃) with the existence of oxygen. The combustion releases sulfur dioxide (SO_2) 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:-



1-Serious damages to the health of humans, animals and plants.
2-It is also the main cause of acid rain.

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:-

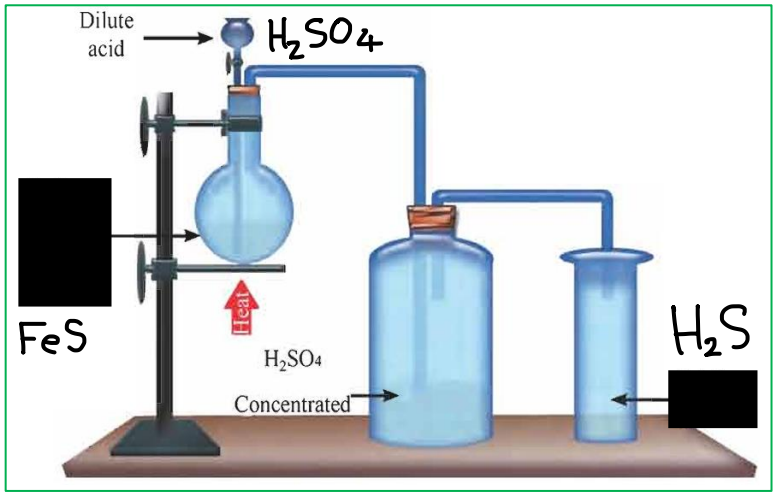
1-The bacterial breakdown of the organic matters.
2-Underground water that contains sulfur as in the mineral water wells in Hammam Al-Aleel in Nineveh Province north of Iraq.
3-From the biological activity of some kinds of bacteria that rely of iron and manganese as part of their food sources.
4-Hydrogen sulfide occurs in almost all the natural and petroleum gases.
5-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.
6-There may also gas emissions in the industries that use sulfur compounds.

Q:How can you prepared hydrogen sulfide gas in laboratory?

A/ H_2S 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 (H_2SO_4) with metal sulfides MS Such as iron(II) sulfide (FeS) as in the following equation:

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

Iron(II) Sulfide



Hydrogen Sulfide

Q: How can you test (detect) hydrogen sulfide gas?

A/ By passing the hydrogen sulfide gas H_2S through in the solutions of metal ions like copper (II) sulfate $CuSO_4$ results in a black precipitate of copper (II) sulfide CuS↓ according to the following equation:

$$H_2S + CuSO_4 \longrightarrow H_2SO_4 + CuS\downarrow$$

Hydrogen sulfide | Copper (II) sulfate | Sulfuric acid | Copper (II) sulfide

c-Sulfuric acid (H_2SO_4):

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

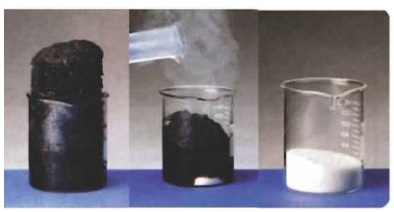
Sulfuric acid

Sulfuric acid is
1-a colorless oily liquid with a high density (1.84g/cm^3).
2-has no characteristic smell when it is pure.
3-it is a highly corrosive strong acid.
4-It is soluble in water at all concentrations and its solutions have high electrical conductivity.

***When H_2SO_4 dissolves in water it generates high temperature, for this reason, cautions must be taken when reducing its concentration.**

Q:Sulfuric acid is usually used as a drying agent?

A/ Because of its high ability to absorb water from the organic compounds. This can be shown when 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:



$$C_{12}H_{22}O_{11} \xrightarrow{\text{Concentrated } H_2SO_4} 12C + 11H_2O$$

Sugar cane | Carbon | Water

Industrial Manufacturing of Sulfuric Acid:

H_2SO_4 can be industrially manufactured by contact process which simply involves:

1-The reaction between sulfur and oxygen to produce sulfur dioxide: $S + O_2 \xrightarrow{V2O5} SO_2$

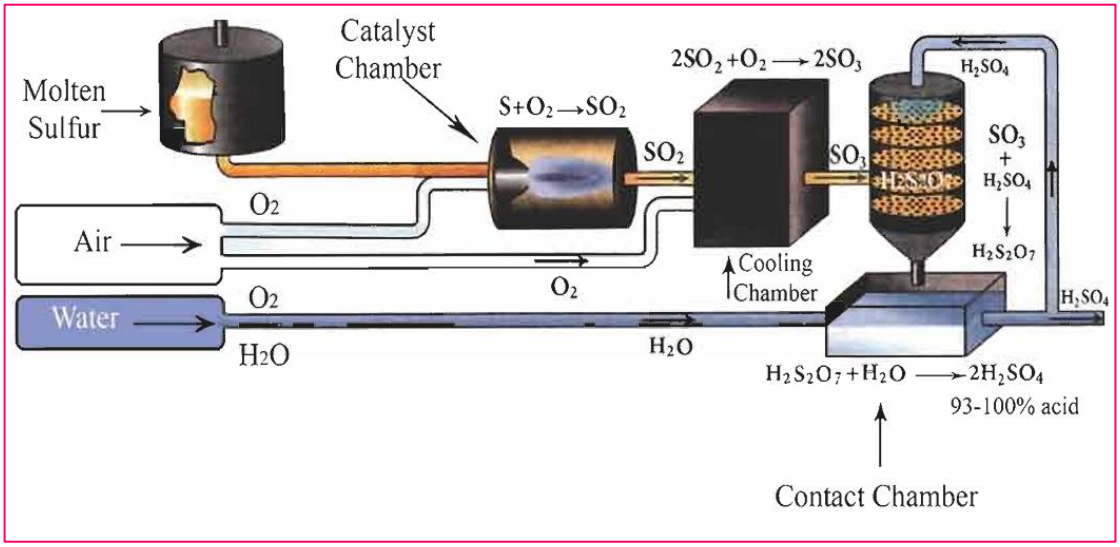
2-Sulfur dioxide is pumped into chamber which contains catalyst to obtain sulfur trioxide.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

sulfur dioxide | sulfur trioxide

3-After that sulfur trioxide is dissolved in water. $SO_3 + H_2O \longrightarrow H_2SO_4$

Sulfuric acid



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 HNO_3 and hydrochloric HCl 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.

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 Zn, zinc oxide ZnO, zinc hydroxide $Zn(OH)_2$ and zinc carbonates $ZnCO_3$ as in the following equations:**

$$ZnO + H_2SO_4 \rightarrow ZnSO_4 + H_2O$$
$$Zn(OH)_2 + H_2SO_4 \rightarrow ZnSO_4 + 2H_2O$$
$$ZnCO_3 + H_2SO_4 \rightarrow ZnSO_4 + CO_2 \uparrow + H_2O$$

Name of Zinc Compounds
ZnO: Zinc oxide
$ZnSO_4$: Zinc sulfate
$Zn(OH)_2$: Zinc hydroxide
$ZnCO_3$: Zinc carbonate

Test of Sulfate ion (SO_4^{2-}) Ion:

Sulfate ions can be identified in their aqueous solutions by adding the solution which contains barium ions (Ba^{2+}) such as barium chloride $BaCl_2$. The result is a white precipitate of barium sulfate $BaSO_4$.

$$BaCl_2 + SO_4^{2-} \rightarrow BaSO_4 \downarrow + 2Cl^-$$

Barium chloride — Sulfate ion — Barium sulfate White precipitate — Chloride ion

8.6 From chapter–8 questions:

A: we have table salt NaCl, chalk and Sulfur.

(1) We put the mixture in water, table salt will dissolve in H_2O while chalk and Sulfur don't.

(2) We will separate the dissolved NaCl by filteration and then let it evaporated by heating or under the Sun.

(3) We will added Carbon di sulfide CS_2 to the mixture of chalk and Sulfur, Sulfur will dissolve in CS_2 but chalk doesn't we separate then by filteration and evaporate the Solvent to get Sulfur in dry.

(4) The chalk remain let it for 10 drying.

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°C while it boils at 100°C.

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;

$FeS + H_2SO_4 \rightarrow FeSO_4 + H_2S$

$SO_3 + H_2O \rightarrow H_2SO_4$

$BaCl_2 + SO_4^{2-} \rightarrow BaSO_4\downarrow + 2Cl^-$

8.1:
oxygen and Sulfur considered as non-metals, while Selenium and tellurium have non-metallic properties, Polonium is a pure metal

8.2: $ns^2\ np^4$

8.4:

① $H_2S + ZnSO_4 \rightarrow H_2SO_4 + ZnS\downarrow$ (Zinc Sulfate)

② $H_2S + (CH_3COO)_2Pb \rightarrow 2CH_3COOH + PbS\downarrow$ (lead acetate)

③ $H_2S + CuSO_4 \rightarrow H_2SO_4 + CuS\downarrow$ (copper Sulfate)

8.7:

$S + Fe \rightarrow FeS$ iron(II) sulfide (metal)

$S + O_2 \rightarrow SO_2$ Sulfurdioxide (non-metal)

8.5:

@ ●Pressurized air from tube (B) lifts up molten sulfur through tube (C) the middle tube. Sulfur comes out to the surface from this tube (C) mixed with some air bubbles.

© By increasing the Sorrounding Pressure.

(b) ●Pressurized and superheated to 170°C water vapor is pushed into the outer tube (A) to where sulfur converges, this pressure melts sulfur underground.

Group VIIA: عناصرالزمرة السابعة

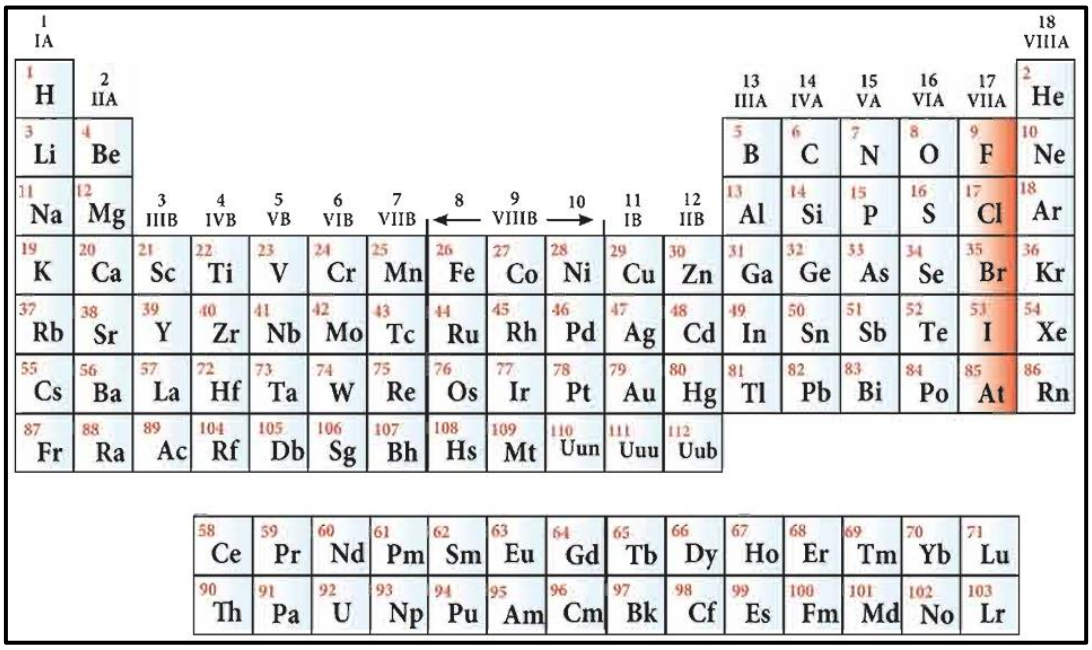
Elements of group 7A are: fluorine (F), chlorine (Cl), bromine (Br), iodine (I), Astatine (At).

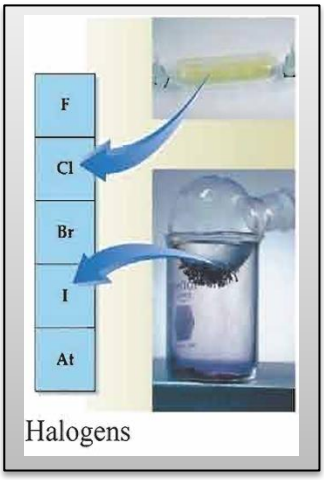
1-Elements of this group are called as halogens.

2-Having extremely non-metallic properties.

3-Highly active, therefore, they are not found freely in nature but combined with other elements.

4-They have similar physical and chemical properties with a gradual shift in these properties, there is also a difference in other properties.





Halogens

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

Q:What are the general properties of group VIIA (halogens)?

A/1-All elements of this group has <u>seven</u> electrons in the outer shell and tend to gain <u>one</u> 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.

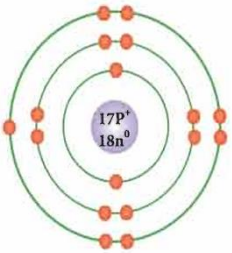
3-Halogens are colorful substances? A/ because they absorb some of the visible rays.

4-Boiling and melting points for halogens <u>increase</u> with the <u>increase</u> in atomic number.

Chlorine Cl_2: **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 HCl.**

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

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

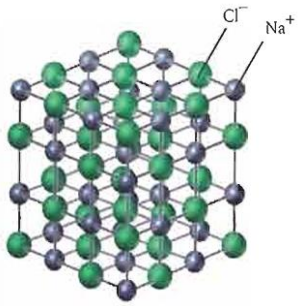


Electron configuration of chlorine atom

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?
A/ Because it tends to gain one electron to form a negative chloride ion (Cl^-).

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).



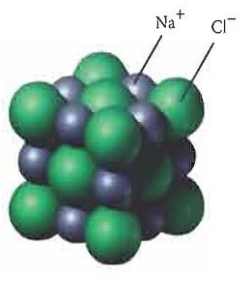


Figure 9-3
Crystal network of sodium chloride

Preparation of Chlorine: (A) Laboratory Preparation:

Cl_2 is prepared by oxidizing concentrated hydrochloric acid HCl with manganese (IV) dioxide MnO_2: $4HCl + MnO_2 \xrightarrow{\Delta} MnCl_2 + 2H_2O + Cl_2\uparrow$

The resultant gas (Cl_2) is refined from HCl and water by passing it through bottles containing water and sulfuric acid consecutively. It is observed that manganese (IV) dioxide MnO_2 is not act as a catalyst but it is consumed after the reaction as an oxidizing agent. (The figure is next page)

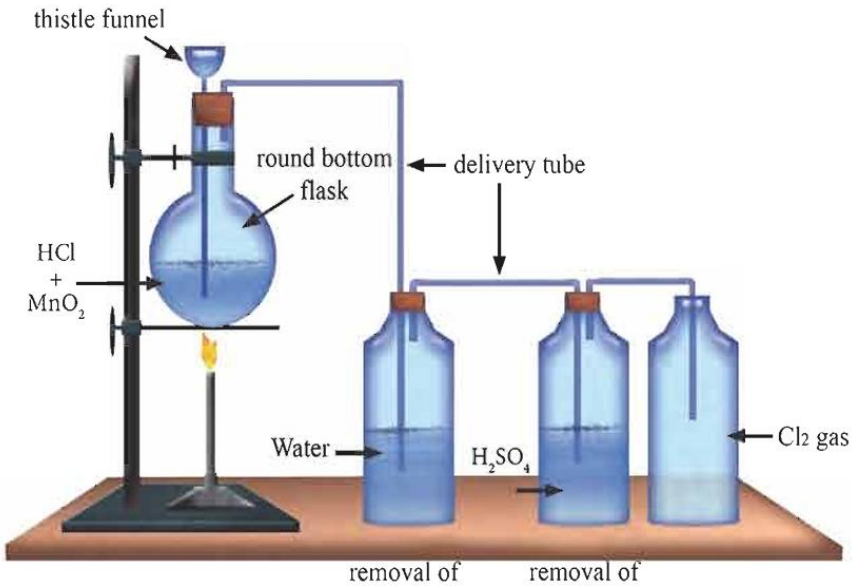


Figure 9-4
Preparation of chlorine gas in laboratory

(B)Industrial Preparation of Chlorine Gas:

Chlorine is prepared industrially through electrolysis of sodium chloride NaCl in water or molten sodium chloride in the electrolytic cell.

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

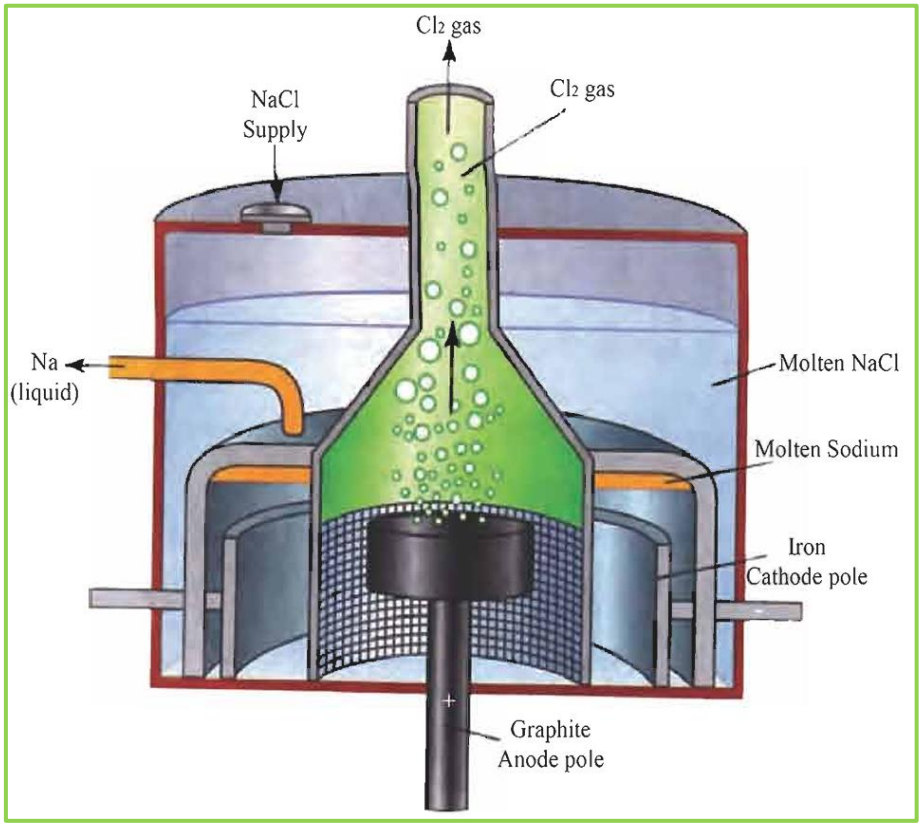


Figure 9-5
Electrolysis device for preparation of chlorine gas from molten NaCl in industry

Properties of Chlorine Gas:

1-It has greenish yellow color.
2- Chlorine gas is collected by pushing air upward. This indicates that chlorine 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: $2P + 3Cl_2 \rightarrow 2PCl_3$ (phosphorus tri chloride)

$2P + 5Cl_2 \rightarrow 2PCl_5$ (phosphorus penta chloride)

7-Chlorine gas reacts with hydrogen to form hydrogen chloride: $H_2 + Cl_2 \rightarrow 2HCl$ (Hydrogen chloride gas)

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 Cl_2 reacts with water H_2O 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[O].
Atomic oxygen[O]:- A highly active substance produced when Cl_2 gas react with H_2O which removes vegetable colors (bleach them), killing germ and sterilize.

$H_2O + Cl_2 \longrightarrow 2HCl + [O]$
(Hydrogen chloride solution; Oxygen in atomic form)

5-Chlorine is used to bleach the colors of clothes, especially cotton clothes. But, it should not to 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 [O] forms during the process which bleaches the colors

$$H_2O + Cl_2 \longrightarrow 2HCl + [O]$$

Hydrogen chloride solution — Oxygen in atomic form

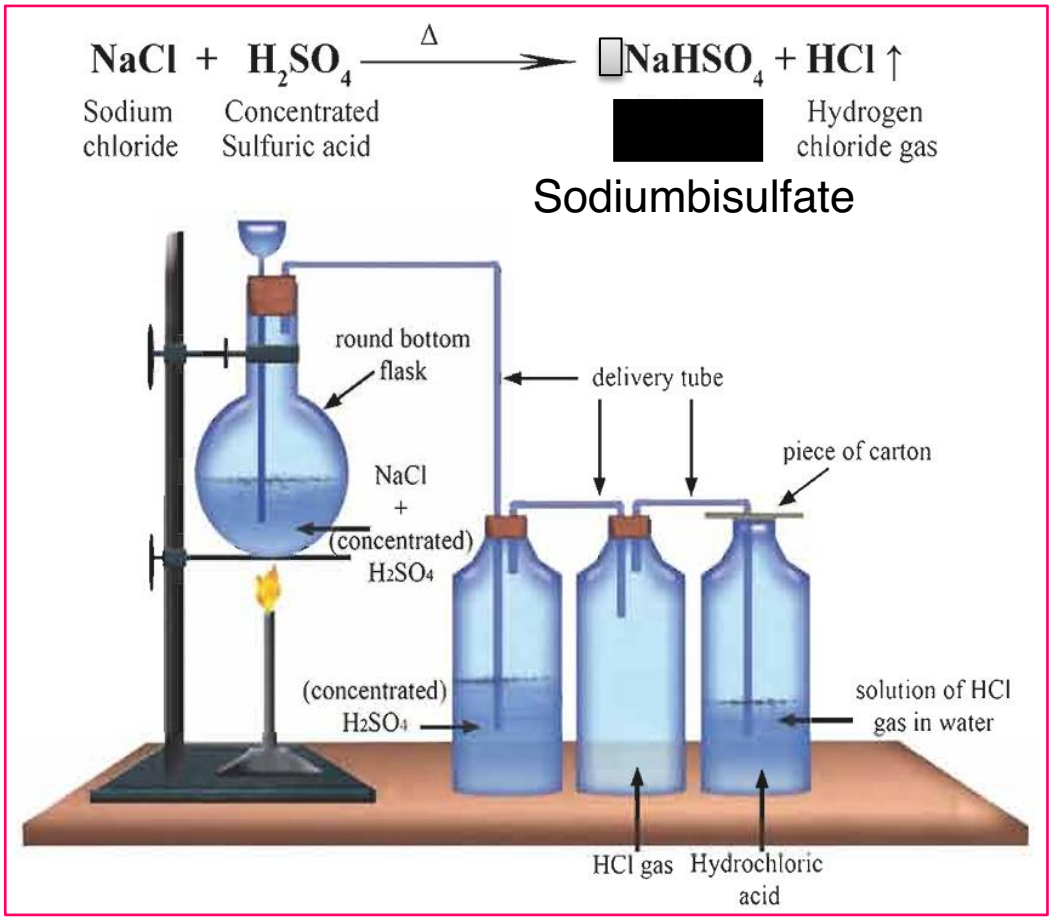
Calcium hypochlorite $Ca(OCl)_2$:- is one of chlorine compounds which is the active substance for the bleaching powder used for bleaching and purification.

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.

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) as in the following equation:



1-An appropriate amount of approximately (10 mg) of pure sodium chloride is put in a glass flask.
2-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.
3-Concentrated sulfuric acid is put in the glass bottle and the connecting tube goes down the acid.
4-Another connecting tube connects the glass bottle with a dry gas collecting bottle.
5-Concentrated sulfuric acid is added to the flask through the tube as to cover the salt.
6-Heating the flask slowly causes a reaction that releases hydrogen chloride gas.
7-Several gas bottles are collected and then sealed with glass covers in order for the properties of the gas to be studied.

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

A gas bottle is sealed with a rubber cover with two holes:
1-a dropper full of water goes through one of the holes.
2-a glass tube goes through the other hole to the bottom of the gas bottle.
3-The outer end of the tube is put a water-full bowel with little orange methylene.
4-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:

5-Hydrochloric acid reacts with iron fillings to form iron (II)chloride and release hydrogen gas.

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

6-It is nonflammable and does not instigate combustion.

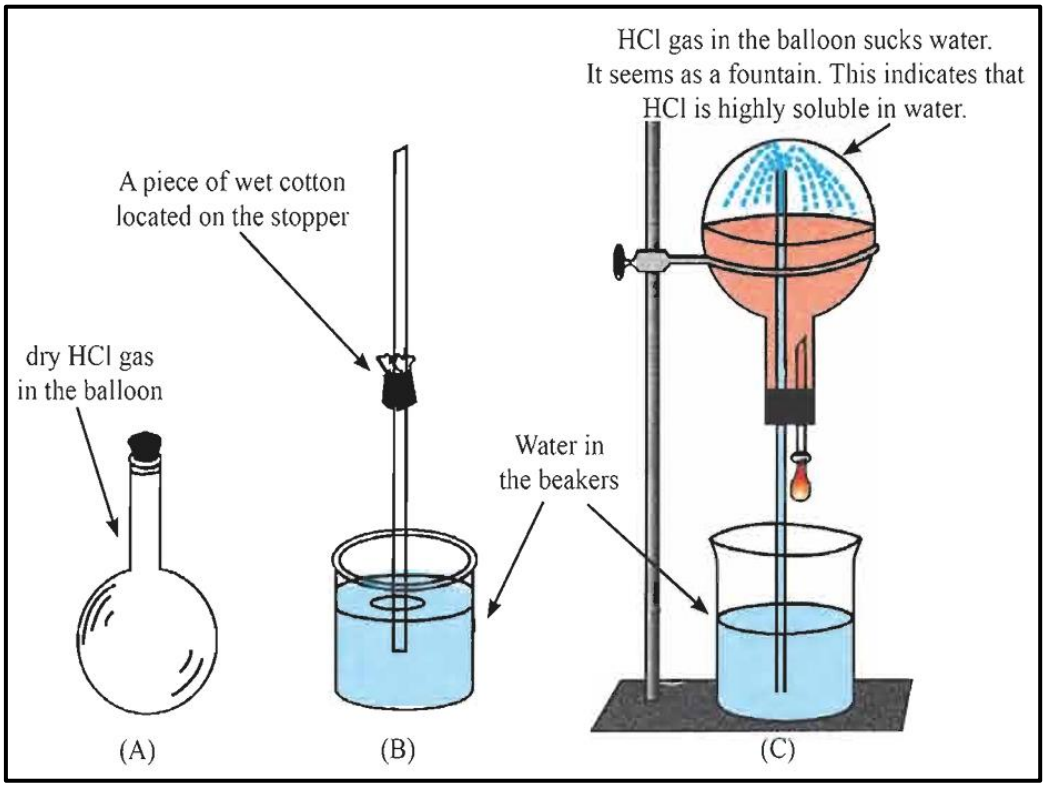


Figure 9-7: Preparation of HCl fountain in the laboratory

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 NH_4Cl forms as a result of the direct union of hydrogen chloride gas with ammonia solution.

$$NH_3 + HCl\uparrow \longrightarrow NH_4Cl$$

Ammonia — **Hydrogen chloride gas** — **Ammonium chloride (white foggy substance)**

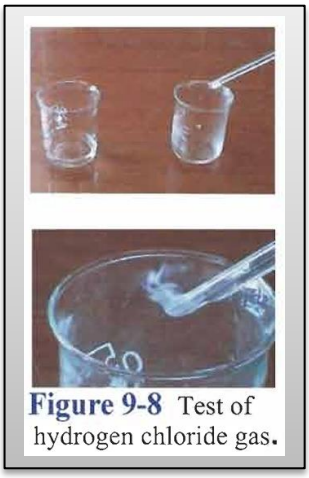


Figure 9-8 Test of hydrogen chloride gas.

***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 tested 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.

CHLORIDES:

Chlorides:- are salts of hydrochloric acid. They are formed when a metal or root such as ammonium NH_4^+ replaces the hydrogen in the acid as in the equations below:

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

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

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 chloride ($PbCl_2$) is soluble only in hot water.

Test of Chlorides:

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

$$\underset{\text{Silver nitrate}}{AgNO_3} + \underset{\text{Sodium Chloride}}{NaCl} \longrightarrow \underset{\text{Silver Chloride (White Precipitate)}}{AgCl\downarrow} + \underset{\text{Sodium nitrate}}{NaNO_3}$$

$$\underset{\text{Silver nitrate}}{AgNO_3} + \underset{\text{Hydrochloric acid}}{HCl} \longrightarrow \underset{\text{Silver Chloride (White Precipitate)}}{AgCl\downarrow} + \underset{\text{Nitric acid}}{HNO_3}$$

1-Hydrogen chloride gas can be prepared in laboratory by the reaction of ..Sodium chloride.. with ..sulfuric acid.. As in the following equation: $NaCl + H_2SO_4 \longrightarrow NaHSO_4 + HCl\uparrow$

2-From the most important properties of hydrogen chloride gas ..1-It is a colorless gas of suffocating odor.., ..2-It is heavier than air and can be collected by removing air upward.. and ..6-It is nonflammable and does not instigate combustion.. 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.

3-If you know that the mass number of chlorine atom is 35 and atomic number is 17 so, the number of electrons is..17.. and the number of protons is ..17.. and the number of neutrons is ..18..

Salt

4-The name of hydrochloric acids is ..Chlorides..

CHAPTER QUESTIONS 09

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

Seven electrons

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

gain one electron

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.

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

$2\,NaCl_{(l)} \xrightarrow{\text{electric current}} 2Na + Cl_2$

$Fe + 2HCl \rightarrow FeCl_2 + H_2\uparrow$

$Mg + 2HCl \rightarrow MgCl_2 + H_2\uparrow$

$H_2 + Cl_2 \rightarrow 2HCl$

$NH_4OH + HCl \rightarrow NH_4Cl + H_2O$

9.6 Explain the reasons of the following.

1) Chlorine gas has Mono Valent as NaCl.

chlorine atom tends to gain one electron to fill the outer shell (third shell).

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

It reacts with water to produce oxygen in its atomic state; this is which removes vegetable colors (bleach them).

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

NH_4Cl ammonium chloride

a result of the direct union of hydrogen chloride gas with ammonia solution.

4) Chlorine is not found freely in nature.

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.

9.7 Which methods are used to determine the following substances?

$AgNO_3 + HCl \rightarrow AgCl\downarrow + HNO_3$
Silver nitrate + Hydrochloric acid → Silver Chloride (White Precipitate) + Nitric acid

a) Hydrochloric acid

b) Hydrogen chloride gas

$NH_3 + HCl\uparrow \rightarrow NH_4Cl$
Ammonia + Hydrogen chloride gas → Ammonium chloride (white foggy substance)

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.

$Mg + 2HCl \rightarrow MgCl_2 + H_2$
Magnesium + Hydrochloric acid → Magnesium chloride + Hydrogen

$NH_4OH + HCl \rightarrow NH_4Cl + H_2O$
Ammonium hydroxide + Hydrochloric acid → Ammonium chloride + water

9.8

Chlorides:- are salts of hydrochloric acid. They are formed when a metal or root such as ammonium NH_4^+ replaces the hydrogen in the acid as in the equations below: