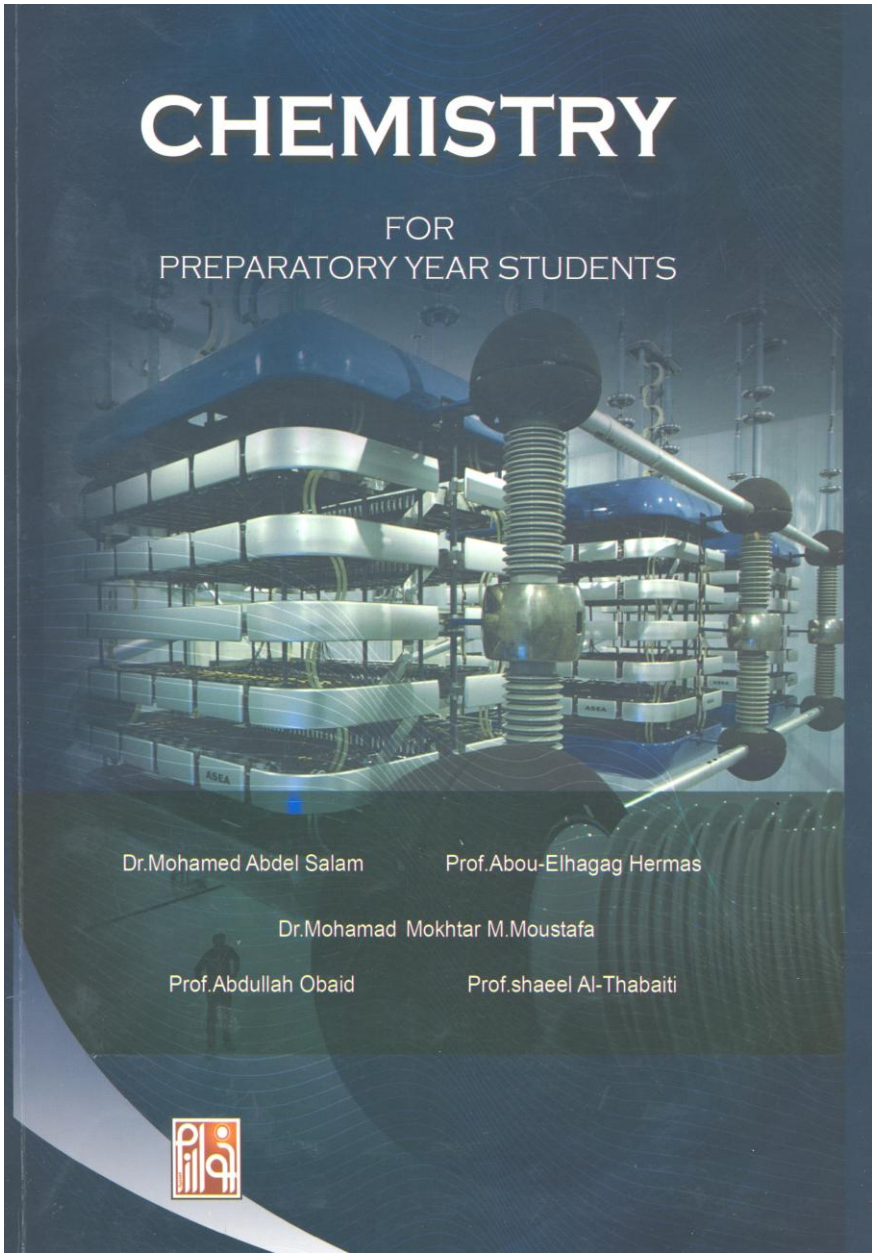
CHEMISTRY
FOR
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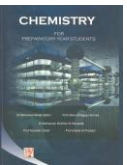
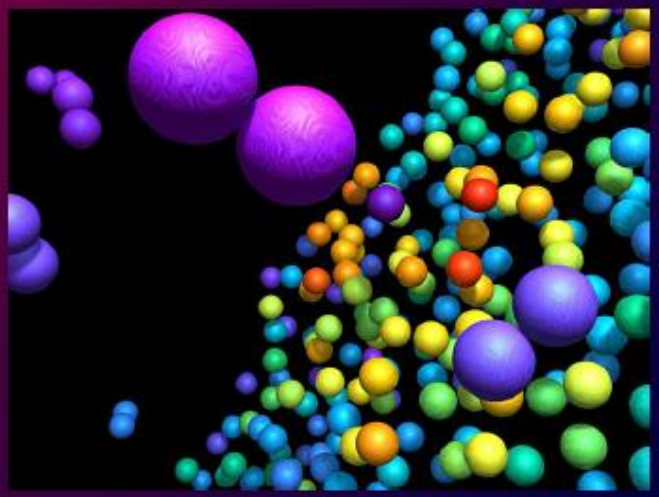
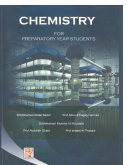


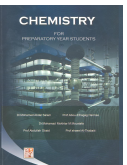
Chapter 1
Atoms, Molecules, Ions & Formulas





Introduction

- **Chemistry** involves studying the composition, behavior, structure, and properties of **mater**.
- **Mater** it is anything that has mass and occupies space.
- **A property** is a characteristic to recognize the type of matter to distinguish it from others.
- Chemistry also provides a background to understanding the properties of matter in terms of atoms.
- **Atom** is the smallest building block of matter.
- The variety of matter in our world is due to combinations of only about 100 very basic, substances called elements.
- **Element** is composed of a unique kind of atom.
- The properties of matter relate not only to the kind of atoms it contains (composition), but also to the arrangements of these atoms (structure). Atoms can combine to form molecules.
- **Molecules** are made up of two or more atoms joined together in specific shapes.



Measurements

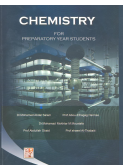
The International System of Measurements (SI)

There are seven SI base units:

PROPERTY	UNIT	SYMBOL
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Amount	Mole	mol
Temperature	Kelvin	K
Electrical Current	Ampere	A
Luminosity	Candela	Cd

Derived Units: Units that are made up of some combination of SI base units are called **Derived Units**.

PROPERTY	UNIT	SYMBOL	DEFINITION
Force		N	$kg\ m/s^2$
Pressure	Pascal	Pa	N/m^2 or $kg/m\ s^2$
Energy	Joule	J	$kg\ m^2/s^2$ or $N\ m$
Electrical Charge	Coulomb	C	$A\ s$
Electrical Potential	Volt	V	J/C
Frequency	Hertz	s^{-1} or Hz	$1/s$



SI Prefixes: used with the base units in order to increase or decrease the value that they represent.

PREFIX	SYMBOL	NUMERICAL EQUIVALENT
exa-	E	1 000 000 000 000 000 000 (10^{18})
peta-	P	1 000 000 000 000 000 (10^{15})
tera-	T	1 000 000 000 000 (10^{12})
Giga	G	1 000 000 000 (10^{9})
Mega	M	1 000 000 (10^{6})
Kilo	k	1000 (10^{3})
hecto-	h	100 (10^{2})
deca-	da	10 (10^{1})
deci-	d	0.1 (10^{-1})
Centi	c	0.01 (10^{-2})
milli-	m	0.001 (10^{-3})
micro-	μ	0.000 001 (10^{-6})
nano-	n	0.000 000 001 (10^{-9})
pico-	p	0.000 000 000 001 (10^{-12})
femto-	f	0.000 000 000 000 001 (10^{-15})
atto-	a	0.000 000 000 000 000 001 (10^{-18})

To remove a prefix from a value, insert the numerical value of the prefix in place of the symbol.

Convert 5.83 pm to meters.

Replace "p" with x 10^{-12}

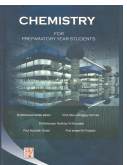
= 5.83 x 10^{-12} m

To insert a prefix into a value, insert both the prefix and the inverse of its numerical value.

Convert 0.000462 g to milligrams

(note that the inverse of milli is 10^{+3})

= 0.000462 x 10^{+3} mg = 4.62 x 10^{-1} mg OR 0.462 mg



The Modern Atomic Theory

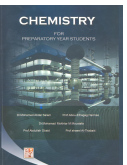
Modern Atomic theory has four assumptions:

1. **Atoms make up all matter.**

2. **The atoms of one element are different from the atoms of another element.**

3. **Atoms combine in definite ratios to make compounds.**

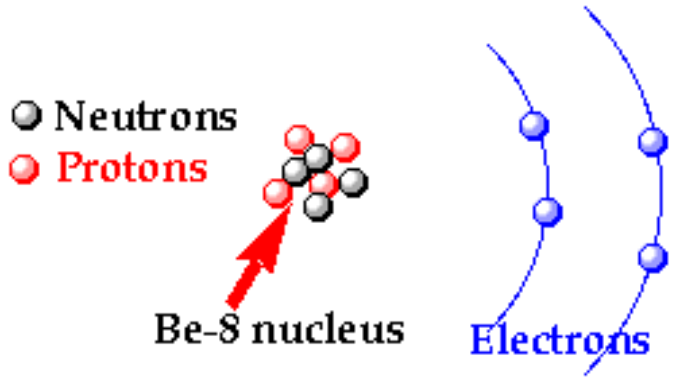
4. **Combinations of atoms in compounds can change only when a chemical reaction happens. This means reactions alter atom combinations, but the identity of the atoms themselves remain the same.**

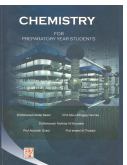


Structure of Atoms

- Atoms are made up of three main particles, neutron, electron, and proton.

Particle	Symbol	Charge	Mass
electron	e^-	-1 (negative)	0.0005486 amu
proton	p^+	+1 (positive)	1.007276 amu
neutron	n^o	0 (neutral)	1.008665 amu





Atomic number, Z:

- **The identity of an element is controlled by the number of protons in the nucleus.**
- **In the neutral atom: number of protons inside the nucleus is the same number of electrons around the nucleus.**

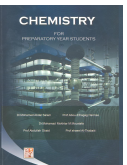
Atomic number = # of Protons = # of Electrons

- **Every element has its own unique atomic number.**

What is the atomic number for nitrogen, N?

Nitrogen is in the seventh position in the periodic table.

This means nitrogen atoms have 7 protons in the nucleus, 7 electrons around the nucleus, and they have an atomic number of 7.



Mass number, A:

It is equal to the sum of neutrons and protons inside the nucleus, because the "massive" particles in the atom are protons and neutrons.

Mass number = # of Protons + # of neutrons

Number of neutrons = A - Z
Number of neutrons = Mass number - Atomic number

How many neutrons, electrons and protons are in an atom of $^{23}_{11}Na$?

Sodium, Na, has atomic number 11.

# of Protons =11 # of Electrons = 11

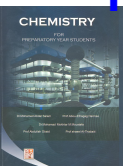
Number of neutrons = A - Z

Number of neutrons = 23 - 11 = 12

An atom with a mass number of 39 contains 20 neutrons. What is the atomic number and identity of the element?

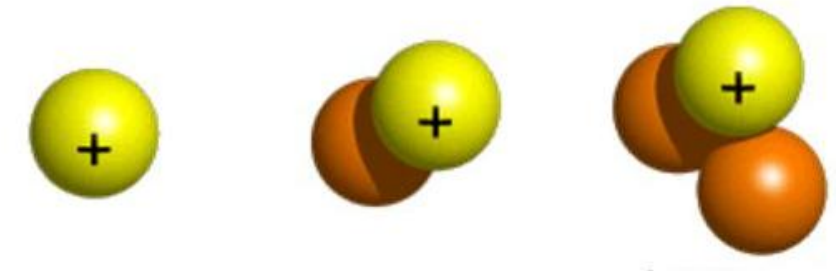
The atomic number is Z = 39- 20 =19.

The identity is potassium because K is element 19



Isotopes

- Isotopes of an element are atoms that have the same number of protons, but different numbers of neutrons (or different mass number or different atomic mass).



Hydrogen-1
(Protium)
1 protons
0 neutrons
1 electrons

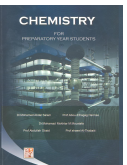
Hydrogen-2
(Deuterium)
1protons
2 neutrons
1 electrons

Hydrogen-3
(Tritium)
1protons
2 neutrons
1 electrons

Carbon-12
6 protons
6 neutrons
6 electrons

Carbon-13
6 protons
7 neutrons
6 electrons

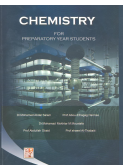
Carbon-14
6 protons
8 neutrons
6 electrons



Isotope abundances

- The isotopes of an element do not occur with equal frequency.
- The relative abundance depends on the relative stability of the isotope.
- The isotopes contribute to the average atomic mass based on their abundance.
- The atomic weights in the periodic table are weighted averages.
- This means the tabulated value doesn't match any actual atom, but is closer to the most common isotope.

Average weight = % First isotope abundance x its mass
+
% Second isotope abundance x its mass



What is the average atomic mass for thallium, Tl, if there are two isotopes with the following masses and abundances? (Tl-203 (203Tl) has a mass of 203.059 amu with an abundance of 29.52 %, Tl-205 (205Tl) has a mass of 205.059 amu with an abundance of 70.48 %)

Step 1: Convert percents to decimals 29.52 % to 0.2952 and 70.48 % to 0.7048 Step 2: Average weight = 0.2952 x (203.059 amu) + 0.7048 x (205.059 amu)

204.466 amu rounded off to 204.5 amu

Copper has two isotopes, one with mass 62.9298 amu and abundance 69.09%. Calculate the mass of the second isotope where the atomic mass of Cu is 63.546.

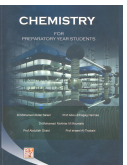
The % abundance of the second isotope = 100-69.09= 30.91

Step 1: Convert 69.09% to 0.6909 and 30.9 to 0.309

Step 2: The atomic mass of Cu is the weighted average of isotopes = 63.546 amu

63.546 amu = 0.6909 x 62.9298 amu + 0.309 x isotope mass

The isotope mass = 64.923 amu



Periodic Table

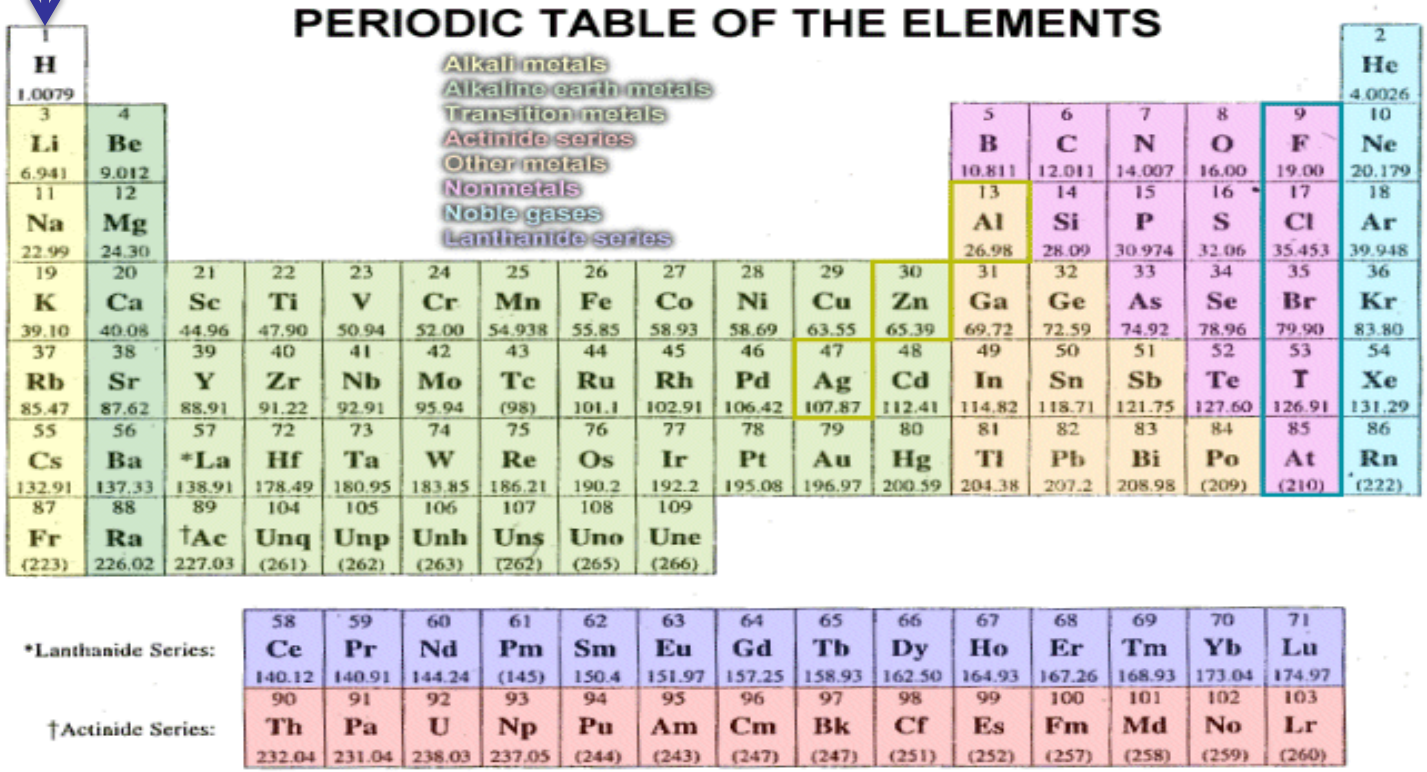
The periodic table is the most important chemistry reference there is.

It arranges all the known elements in an informative array.

Elements are arranged left to right and top to bottom in order of increasing atomic number.

Groups

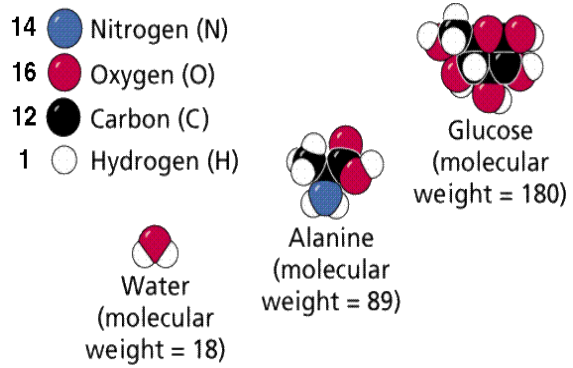
Periods →



Molecules

Molecules are compounds in which the elements are in definite, fixed ratios and those atoms are held together usually by chemical bonds.

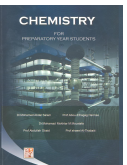
For example: water, glucose, and alanine.



Ions

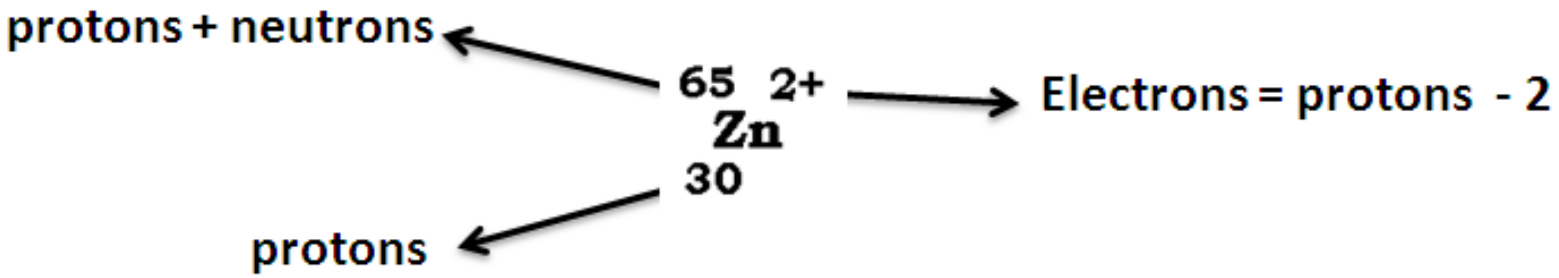
Ion is an electrically charged particle produced by either removing electrons from a neutral atom to give a positive ion (**Cation**) or adding electrons to a neutral atom to give a negative ion (**anion**).

Note: When an ion is formed, the number of protons does not change.



Example: What is the number of electrons (e), neutrons (n) and protons (p) in the zinc ion $(^{65}_{30}Zn^{2+})$?

Answer :



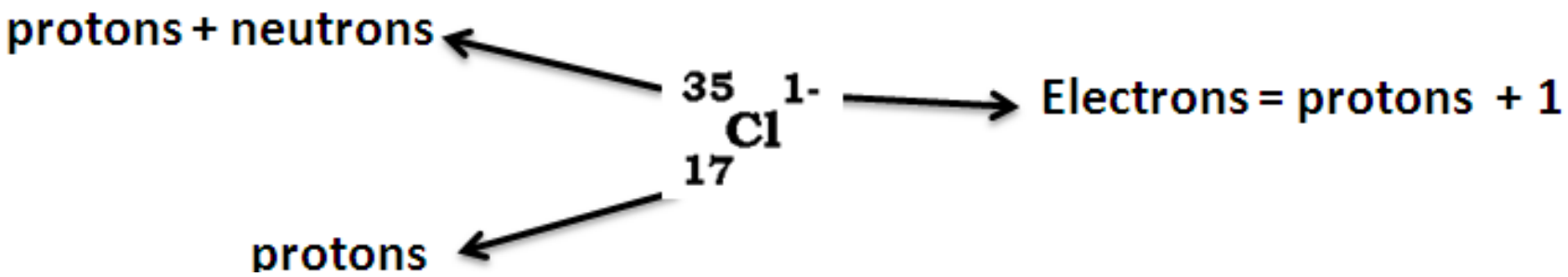
number of protons = 30

number of neutrons = 65 – 30 = 35

number of electrons = 30 – 2 = 28

Example: What is the number of electrons (e), neutrons (n) and protons (p) in the chlorine ion ($^{35}_{17}Cl^-$) ?

Answer :



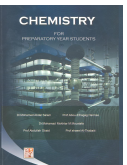
number of protons = 17

number of neutrons = 35 – 17 = 18

number of electrons = 17+1 = 18

Polyatomic ions

Name	Formula	Name	Formula
Ammonium	(NH_4^{1+})		
Chlorate	(ClO_3^{1-})	Bicrbonate	(HCO_3^{1-})
Cyanide	(CN^{1-})	Hydroxide	(OH^{1-})
Nitrate	(NO_3^{1-})	Nitrite	(NO_2^{1-})
Permanganate	(MnO_4^{1-})	Thiocyanate	(SCN^{1-})
Carbonate	(CO_3^{2-})	Chromate	(CrO_4^{2-})
Dichromate	(CrO_4^{2-})	Sulfate	(SO_4^{2-})
Sulfite	(SO_3^{2-})		
Phosphate	(PO_4^{3-})		



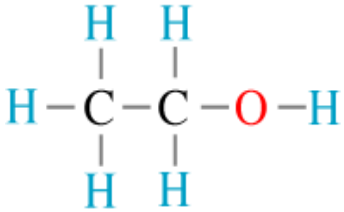
Chemical and structural Formulas

The **chemical formula** tells you how many of each type of atom are in a molecule.

The **structural formula** tells you how many of each type of atoms are in a molecule and also how they are connected.

For example, the chemical formula for ethanol is **C_2H_6O** and

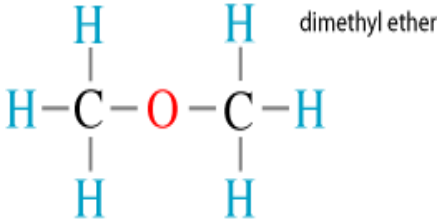
The structural formula of ethanol is

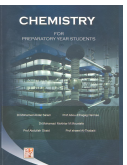


Be carful, the chemical formula could be the same for different molecules, but the structural formula is unique.

The chemical formula for dimethyl ether is **C_2H_6O** and

The structural formula of dimethyl ether is:





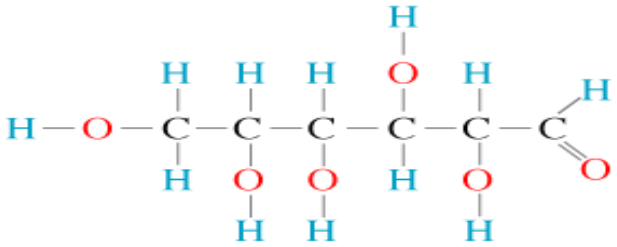
Empirical Formulas (simplest formula)

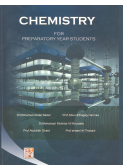
- It shows the simplest whole number ratio of atoms in a molecule.
- For example, hydrogen peroxide's **chemical formula** is H_2O_2, but its **empirical formula** is HO

$$\text{Molecular Formula} = \left(\frac{\text{Molecular weight of unknown (g/mole)}}{\text{mass of Emperical formula}}\right) \text{x Emperical formula}$$

Write the different formulas for the glucose molecule

The chemical formula for glucose is $C_6H_{12}O_6$, but its empirical formula is CH_2O, and its structural formula is



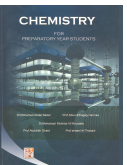


Naming compounds

The elements inside the periodic table are organized in groups (column), where each group has common characteristics.

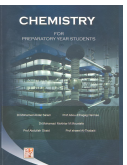
One of these common characteristics is the charge (oxidation number), as the whole group tends to lose or gain certain number of electrons and form ion.

Group	IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIII A
# electrons	1	2	3	4	3	2	1	0
Action	lose	lose	lose	Lose/gain	gain	gain	gain	no
Example	Na^{+}	Ca^{2+}	Al^{3+}	C^{4-} or C^{4+}	N^{3-}	O^{2-}	Cl^{1-}	Ne



Common ions and their names

Element	Name	ion	Type	Name
Li	Lithium	Li^{1+}	Cation	Lithium ion
Na	Sodium	Na^{1+}	Cation	Sodium ion
Mg	Magnesium	Mg^{2+}	Cation	Magnesium ion
Ca	Calcium	Ca^{2+}	Cation	Calcium ion
Al	Aluminum	Al^{3+}	Cation	Aluminum ion
K	Potassium	K^{1+}	Cation	Potassium ion
Cl	Chlorine	Cl^{1-}	Anion	Chlor**ide**
Br	Bromine	Br^{1-}	Anion	Brom**ide**
S	Sulfur	S^{2-}	Anion	Sulf**ide**
O	Oxygen	O^{2-}	Anion	Ox**ide**
N	Nitrogen	N^{3-}	Anion	Nitr**ide**
P	phosphors	P^{3-}	Anion	Phosph**ide**
C	Carbon	C^{4-}	Anion	Carb**ide**
Si	Silicon	Si^{4-}	Anion	Silic**ide**



Rules for naming compounds

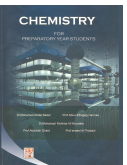
Ionic compounds (compounds contain cations and anions)

- The cation is named first and the anion is named second
- Be sure the net charge is **ZERO**
- **P.S. For** Ionic compounds that contain transition metals cations (more than one possible oxidation state), write the oxidation state between two bracket.

Example: Write the names for the following molecules: $AlCl_3$, Na_2S, K_2O, MgH_2, FeO, Fe_2O_3, $CaCO_3$, $AlPO_4$, $Zn(OH)_2$, $KMnO_4$, $CuSO_4$, $AgNO_3$.

Answer:

Compound	Name	Compound	Name
$AlCl_3$	Aluminum Chlor***ide***	**Na_2S**	Sodium Sulf***ide***
K_2O	Potassium Ox**ide**	**MgH_2**	Magnesium Hydr**ide**
FeO	Iron (II) Ox**ide**	**Fe_2O_3**	Iron (III) Ox**ide**
$CaCO_3$	Calcium Carbonate	**$AlPO_4$**	Aluminum Phosphate
$Zn(OH)_2$	Zinc Hydroxide	**$KMnO_4$**	Potassium Permanganate
$CuSO_4$	Copper (II) Sulfate	**$AgNO_3$**	Silver Nitrate



How to write the formula

1- Identify the symbol for both cation and anion.

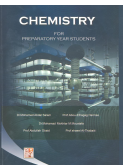
2- Write them and the charge underneath them.

3- Remove the charge (+ or -), and leave the number.

4- Exchange the numbers

5- Make the numbers as simple as possible (exact number and no fractions).

6- Write the formula using the final numbers from step 5.



Example: Write the chemical formula for Calcium sulfate, Aluminum oxide, Iron(II) nitrate.

Answer:

Calcium sulfate

Using the above mentioned method:

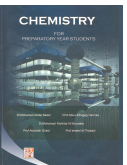
1- Calcium is Ca^{2+}, and sulfate is (SO_4^{2-})

2- Write them and the charge underneath them

	Ca	(SO_4)
	2+	2-
3- Remove the charge	Ca	(SO_4)
	2	2
4- Exchange the numbers	Ca	(SO_4)
	2	2
5- Divide both numbers by 2:	Ca	(SO_4)
	1	1

6- Write the formula:

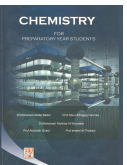
$Ca_1 (SO_4)_1$ **or** $CaSO_4$



Naming Covalent compounds

Covalent compounds contain no charge and they are formed from non-metals located at the right hand side of the periodic table. *The number of the atoms must be written* before the name of the element *using the following prefix* (Drop a prefix is if the *mono* is to appear at the beginning of the name).

Number of atoms	Prefix	Number of atoms	Prefix
one	Mono-	**Two**	Di-
Three	Tri-	**Four**	Tetra-
Five	Penta-	**Six**	Hexa-



Example: Write the names for the following molecules: CO, N_2O_4, NO, SO_2, PCl_5

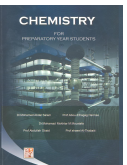
Answer:

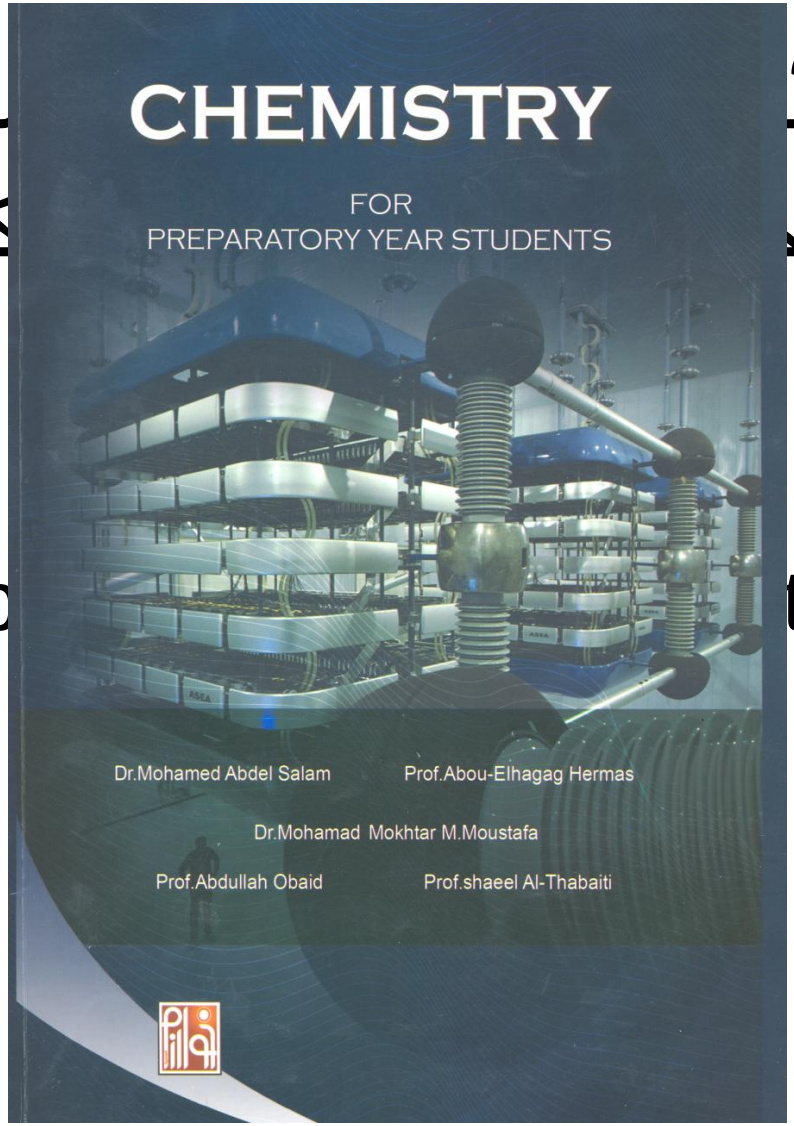
Compound	Name	Compound	Name
CO	Carbon **mono**xide	N_2O_4	**Di**nitrogen **tetra**oxide
NO	Nitrogen **mono**xide	SO_2	Sulfur **di**oxide
PCl_5	Phosphorus **penta**chloride	HBr	Hydrogen **mono**chloride

Example: Write the Chemical formula for: Carbon dioxide, sulfur trioxide, dihydrogen monoxide, phosphorous trichloride, nitrogen dioxide.

Answer:

Name	Formula	Name	Formula
Carbon dioxide	**CO_2**	**sulfur trioxide**	**SO_3**
dihydrogen monoxide	**H_2O**	**dihydrogen monoxide**	**H_2O**
phosphorous trichloride	**PCl_3**	**nitrogen dioxide**	**NO_2**

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