Ministry of Higher Education & Scientific Research

Hilla University College

Criminal Evidence Department

Analytical Chemistry

First year

Lecture One

Introduction to Chemistry



Dr. Ammar M. Al

Chemistry: Is a whole branch of science about ***matter***, which is anything that has mass and occupies space. ***Chemistry*** is the study of the composition and properties of matter and the changes it undergoes.

Branches of Chemistry

1- **Organic Chemistry** involves the study of the structure, properties, and preparation of chemical compounds that consist primarily of carbon and hydrogen.

2-**Inorganic Chemistry** is the study of the properties and behaviour of inorganic compounds. It covers all chemical compounds except organic compounds. Inorganic chemists study things such as crystal structures, metals, catalysts, and most elements in the Periodic Table**.**

3- **Analytical Chemistry:** involves the qualitative and quantitative determination of the chemical components of substances.

4- **Physical Chemistry** —the study of the effect of chemical structure on the physical properties of a substance.

5- **Biochemistry** is the study of chemical reactions that take place in living things. It tries to explain them in chemical terms.

MATTER: Is anything that occupies space and has weight. If you look around you, you will see matter. The table, books, walls, and your body are all composed of matter.

Physical States of Matter. In general, we can group all matter into three groups called states of matter.

(1) Solids. Solids have a definite shape and volume. Examples of solids are books, rocks, pieces of steel, and sand.

(2) Liquids. Liquids have a definite volume but indefinite shape. That is, they take the shape of their container. Water, mercury, alcohol, and oils are liquids.

(3) Gases. Gases have neither a definite shape nor a definite volume. They assume not only the shape of their container but also the volume of their container. Gases may be expanded or compressed to fit the container in which they are being placed. Therefore, the air in an automobile tire would, if released, expand to fill a large weather balloon.

Properties of Matter.

Matter possesses two types of properties, ***physical*** and ***chemical***. From the physical and chemical properties exhibited by a substance, it is possible to isolate, identify, and classify the particular substance.

Physical properties can be observed or measured without changing the composition of matter. Physical properties are used to observe and describe matter.

Physical properties include: smell, color, shape, melting point, boiling point, density, solubility, and polarity.

Chemical properties are any of the properties of matter that may only be observed and measured by performing a chemical reaction.

Examples of Chemical Properties

- reactivity with other chemicals
- toxicity
- coordination number

- flammability (is the ability of a substance to burn or ignite.
- heat of combustion (The **heat of combustion** is the total energy released as **heat** when a substance undergoes complete **combustion** with oxygen under standard conditions)

Energy: is the capacity of a physical system to perform work. However, it's important to keep in mind that just because energy exists, it doesn't mean it's necessarily available to do work. So there are two types of energy: **Kinetic Energy** and **Potential Energy**.

Atom: the smallest component of an element having the chemical properties of the element, consisting of a nucleus containing combinations of neutrons and protons and one or more electrons bound to the nucleus by electrical attraction.

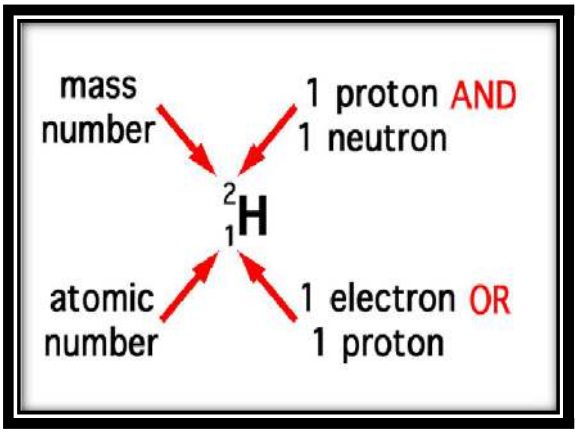
Compound: It is a substance made of more than one type of atom. A chemical process and chemical bonds usually form them bind atoms together.

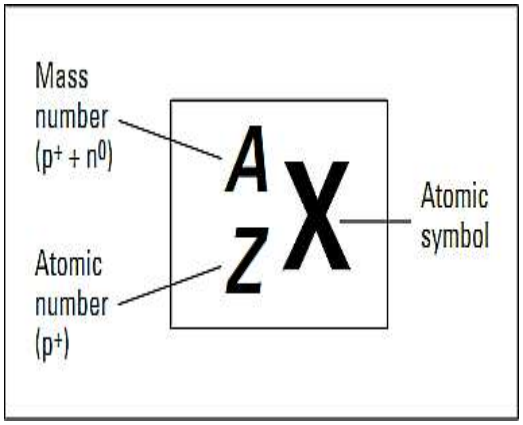
Molecules - This is the smallest unit of a compound. For example, water is *dihydrogen oxide.*

Atomic number (Z): The number of protons in the nucleus of an atom. In electrically neutral atoms, this number is also equal to the number of electrons orbiting about the atom's nucleus.

For example, H =1, Br=35, Cl= 17

Mass numbers (A): the total number of **protons** and **neutrons** in an atomic nucleus. For example





the iron nucleus which has 26 protons and 30 neutrons, is denoted as

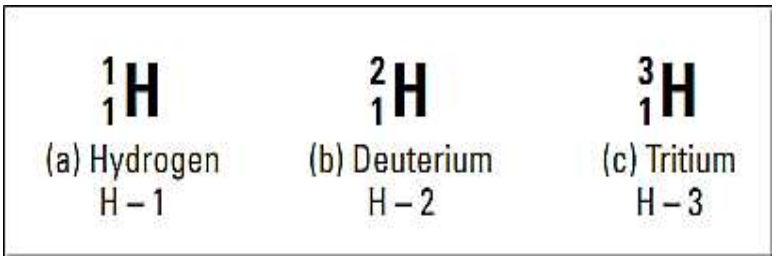
$$^{56}_{26}Fe\ ,$$

Where the total atomic number is (Z = 26) and the mass number (A = 56). The number of **neutrons** is simply the difference (**N = A – Z**)

56-26 =30

Isotopes:-

The atoms of a particular element can have an identical number of protons and electrons but varying numbers of neutrons. If they have different numbers of neutrons, then the atoms are called ***isotopes (****Atoms of the same element that have the same atomic number* but *different numbers of* ***neutrons)***. The figure below shows the three hydrogen isotopes, *Hydrogen* or (**Protium**) which has (1p + 0N), ***Deuterium*** which has (1p + 1N) and ***Tritium*** which has (1p +2N).



Hydrogen Isotopes

Other examples

Element	Isotopes
Carbon (C)	$^{12}_{6}C$, $^{13}_{6}C$, $^{14}_{6}C$
Nitrogen (N)	$^{14}_{7}N$, $^{15}_{7}N$,
Oxygen (O)	$^{16}_{8}O$, $^{17}_{8}O$, $^{18}_{8}O$
Chlorine(Cl)	$^{35}_{17}Cl$, $^{37}_{17}Cl$
Uranium (U)	$^{235}_{92}U$, $^{238}_{92}U$, $^{239}_{92}U$
Sulphur (S)	$^{32}_{16}S$, $^{33}_{16}S$, $^{34}_{16}S$, $^{36}_{16}S$

Each of these isotopes have a different abundance in nature. The table below outlines the average isotopic abundances of elements that are most commonly measured for stable isotope measurements

Hydrogen	Carbon	Nitrogen	Oxygen
^{1}H – 99.984%	**^{12}C – 98.89%**	**^{14}N – 99.64%**	**^{16}O – 99.763%**
^{2}D – 0.0156%	**^{13}C – 1.11%**	**^{15}N – 0.36%**	**^{17}O – 0.0375%**
----	**----**	**----**	**^{18}O – 0.1995%**

Stable vs. Unstable Isotopes

In chemistry, an isotope is a different form of an element which will have a different neutron number and thus has a different mass number as well. But the

chemical properties and other related characteristics remain the same as those of the element. There are two types of isotopes, one which is found in nature, stable and not radioactive, the second type is the one which is naturally radioactive and not stable. Any element having an excess of neutrons in the nucleus as compared to the stable form of an atom tends to be unstable in nature. These elements tend to be radioactive and undergo radioactive decay by emitting energy.

Unstable nuclei decay by giving off ***Alpha*** particles (helium nuclei), ***Beta*** particles (electrons or antielectrons) or ***Gamma*** particles (photons of high energy electromagnetic radiation).

The examples of naturally occurring stable and radioactive or unstable isotopes are mentioned below:

Naturally occurring stable isotopes	**Radioactive unstable isotopes**
Carbon 12	**Carbon 14**
Calcium40 Calcium43 Calcium 46	**Calcium 48**
Vanadium 51	**Vanadium 50**
Germanium70 Germanium72 Germanium 74	**Germanium 76**
Selenium74 Selenium76 Selenium78 Selenium 80	**Selenium 82**
Krypton80 Krypton82 Krypton84 Krypton 86	Krypton 78
Rubidium 85	Rubidium 87

Average Atomic Mass

The calculation of the average atomic mass of an atom is performed using the relative abundance data from the isotope of each atom

The average atomic mass of an element is the sum of the masses of its isotopes, each multiplied by its natural abundance (the decimal associated with the percent of atoms of that element that are of a given isotope).

[(% abundance of isotope) (mass of isotope)] + [(% abundance of isotope) (mass of isotope)] + [...]/100

100

For example

the natural abundance for chloro isotopes is 75.78% ^{35}Cl (34.968853amu*) and 24.22% ^{37}Cl (36.9659033amu*). Calculate the atomic mass of Cl

$$^{35}_{17}Cl, \quad ^{37}_{17}Cl$$

75.78%, 24.22%

Average atomic mass = [(75.78) (34.968853)] + [(24.22) (36.9659033)]/ 100= 35.45

Example 2

The natural abundance for boron isotopes is 19.9% 10B (10.013 amu*) and 80.1% 11B (11.009 amu*). Calculate the atomic mass of boron.

Average atomic mass = [(19.9%) (10.013)] + [(80.1%) (11.009)]/100= 10.811 (note that this is the value of atomic mass given on the periodic table)

****Amu*** is the atomic mass unit, which is defined as $1/12^{th}$ the mass of a carbon-12 atom. This value provides a reference point for measuring relative atomic masses.

* The average atomic mass is also known as the molar mass or relative atomic mass (**RAM**).

Tables of Isotopic Masses and Natural Abundances

These tables list the mass and percent natural abundance for the stable nuclides.

Z	Name	Symbol	Mass of Atom (u)	% Abundance
1	Hydrogen	^{1}H	1.007825	99.9885
	Deuterium	^{2}H	2.014102	0.0115
	Tritium	^{3}H	3.016049	*
2	Helium	^{3}He	3.016029	0.000137
		^{4}He	4.002603	99.999863
3	Lithium	^{6}Li	6.015122	7.59
		^{7}Li	7.016004	92.41
4	Beryllium	^{9}Be	9.012182	100
5	Boron	^{10}B	10.012937	19.9
		^{11}B	11.009305	80.1
6	Carbon	^{12}C	12.000000	98.93
		^{13}C	13.003355	1.07
		^{14}C	14.003242	*
7	Nitrogen	^{14}N	14.003074	99.632
		^{15}N	15.000109	0.368
15	Phosphorus	^{31}P	30.973762	100
16	Sulphur	^{32}S	31.972071	94.93
		^{33}S	32.971458	0.76
		^{34}S	33.967867	4.29
		^{36}S	35.967081	0.02
17	Chlorine	^{35}Cl	34.968853	75.78
		^{37}Cl	36.965903	24.22
18	Argon	^{36}Ar	35.967546	0.3365
		^{38}Ar	37.962732	0.0632
		^{40}Ar	39.962383	99.6003
19	Potassium	^{39}K	38.963707	93.2581
		^{40}K	39.963999	0.0117
		^{41}K	40.961826	6.7302
20	Calcium	^{40}Ca	39.962591	96.941
		^{42}Ca	41.958618	0.647
		^{43}Ca	42.958767	0.135
		^{44}Ca	43.955481	2.086

,

							^{46}Ca	45.953693	0.004
8	Oxygen	^{16}O	15.994915	99.757			^{48}Ca	47.952534	0.187
		^{17}O	16.999132	0.038					
		^{18}O	17.999160	0.205	21	Scandium	^{45}Sc	44.955910	100
9	Fluorine	^{19}F	18.998403	100	22	Titanium	^{46}Ti	45.952629	8.25
							^{47}Ti	46.951764	7.44
10	Neon	^{20}Ne	19.992440	90.48			^{48}Ti	47.947947	73.72
		^{21}Ne	20.993847	0.27			^{49}Ti	48.947871	5.41
		^{22}Ne	21.991386	9.25			^{50}Ti	49.944792	5.18
11	Sodium	^{23}Na	22.989770	100	23	Vanadium	^{50}V	49.947163	0.250
							^{51}V	50.943964	99.750
12	Magnesium	^{24}Mg	23.985042	78.99					
		^{25}Mg	24.985837	10.00	24	Chromium	^{50}Cr	49.946050	4.345
		^{26}Mg	25.982593	11.01			^{52}Cr	51.940512	83.789
							^{53}Cr	52.940654	9.501
13	Aluminum	^{27}Al	26.981538	100			^{54}Cr	53.938885	2.365
14	Silicon	^{28}Si	27.976927	92.2297	25	Manganese	^{55}Mn	54.938050	100
		^{29}Si	28.976495	4.6832					
		^{30}Si	29.973770	3.0872	26	Iron	^{54}Fe	53.939615	5.845
							^{56}Fe	55.934942	91.754

Z	Name	Symbol	Mass of Atom (u)	% Abundance
		^{57}Fe	56.935399	2.119
		^{58}Fe	57.933280	0.282
27	Cobalt	^{59}Co	58.933200	100
28	Nickel	^{58}Ni	57.935348	68.0769
		^{60}Ni	59.930791	26.2231
		^{61}Ni	60.931060	1.1399
		^{62}Ni	61.928349	3.6345
		^{64}Ni	63.927970	0.9256
29	Copper	^{63}Cu	62.929601	69.17
		^{65}Cu	64.927794	30.83
30	Zinc	^{64}Zn	63.929147	48.63
		^{66}Zn	65.926037	27.90
		^{67}Zn	66.927131	4.10
		^{68}Zn	67.924848	18.75
		^{70}Zn	69.925325	0.62
31	Gallium	^{69}Ga	68.925581	60.108
		^{71}Ga	70.924705	39.892
32	Germanium	^{70}Ge	69.924250	20.84
		^{72}Ge	71.922076	27.54
		^{73}Ge	72.923459	7.73
8	Oxygen	^{16}O	15.994915	99.757
		^{17}O	16.999132	0.038
		^{18}O	17.999160	0.205
9	Fluorine	^{19}F	18.998403	100
10	Neon	^{20}Ne	19.992440	90.48
		^{21}Ne	20.993847	0.27
		^{22}Ne	21.991386	9.25
11	Sodium	^{23}Na	22.989770	100
12	Magnesium	^{24}Mg	23.985042	78.99
		^{25}Mg	24.985837	10.00
		^{26}Mg	25.982593	11.01
13	Aluminum	^{27}Al	26.981538	100
14	Silicon	^{28}Si	27.976927	92.2297
		^{29}Si	28.976495	4.6832
		^{30}Si	29.973770	3.0872

Z	Name	Symbol	Mass of Atom (u)	% Abundance
38	Strontium	^{84}Sr	83.913425	0.56
		^{86}Sr	85.909262	9.86
		^{87}Sr	86.908879	7.00
		^{88}Sr	87.905614	82.58
39	Yttrium	^{89}Y	88.905848	100
40	Zirconium	^{90}Zr	89.904704	51.45
		^{91}Zr	90.905645	11.22
		^{92}Zr	91.905040	17.15
		^{94}Zr	93.906316	17.38
		^{96}Zr	95.908276	2.80
41	Niobium	^{93}Nb	92.906378	100
42	Molybdenum	^{92}Mo	91.906810	14.84
		^{94}Mo	93.905088	9.25
		^{95}Mo	94.905841	15.92
		^{96}Mo	95.904679	16.68
		^{97}Mo	96.906021	9.55
		^{98}Mo	97.905408	24.13
		^{100}Mo	99.907477	9.63
43	Technetium	^{98}Tc	97.907216	*
		^{46}Ca	45.953693	0.004
		^{48}Ca	47.952534	0.187
21	Scandium	^{45}Sc	44.955910	100
22	Titanium	^{46}Ti	45.952629	8.25
		^{47}Ti	46.951764	7.44
		^{48}Ti	47.947947	73.72
		^{49}Ti	48.947871	5.41
		^{50}Ti	49.944792	5.18
23	Vanadium	^{50}V	49.947163	0.250
		^{51}V	50.943964	99.750
24	Chromium	^{50}Cr	49.946050	4.345
		^{52}Cr	51.940512	83.789
		^{53}Cr	52.940654	9.501
		^{54}Cr	53.938885	2.365
25	Manganese	^{55}Mn	54.938050	100
26	Iron	^{54}Fe	53.939615	5.845
		^{56}Fe	55.934942	91.754