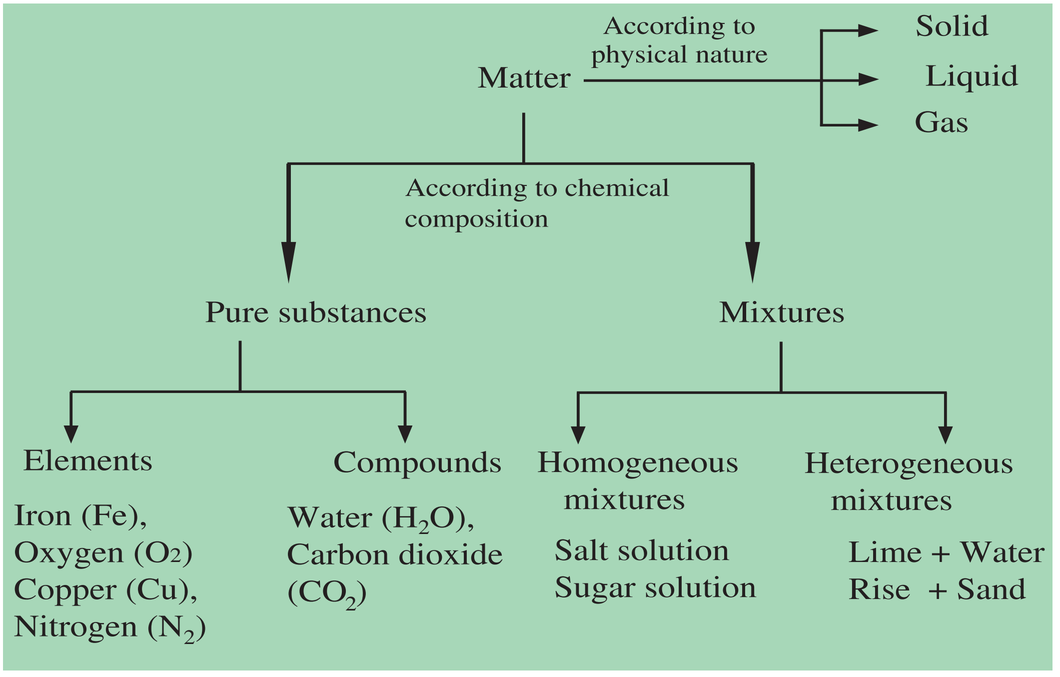
Chemistry

Structure of Matter 03

The things in our environment can be classified into two main categories as matter and energy. Those that occupy space and have a mass are called matter. The classification of matter according to their physical nature and chemical composition is shown in the following chart.



Atoms are the building units of matter. The atom is composed of subatomic particles. Of them, protons, electrons and neutrons are the main subatomic particles.

The electron is a negatively charged particle. Proton has a positive charge while neutrons have no charge. With the identification that particles called electrons, protons and neutrons constitute matter, and as a result of the effort taken to describe how those particles are organized in matter, the atomic model was introduced. According to the nuclear model put forward by Ernest Rutherford in 1911, there is a very small area called nucleus at the centre of the atom.

If the atom is a football ground, nucleus is a small volume, even smaller than a chickpea at its centre. From this example, it is clear that the nucleus of an atom is very small relative to an atom. Protons and neutrons are accumulated in the nucleus. The nucleus is positively charged.

Electrons revole around the nucleus. The number of electrons in an atom is equal to the number of protons. However the protons and electrons are oppositely charged and therefore, the atom is electrically neutral.

3.1 The Planetary Model of the Atom

The planetary model of the atom was introduced by Ernest Rutherford. Electrons move around the nucleus in which the positive charge of the atom is concentrated. This is similar to the solar system where the planets revolve around the sun (Fig. 3.1).

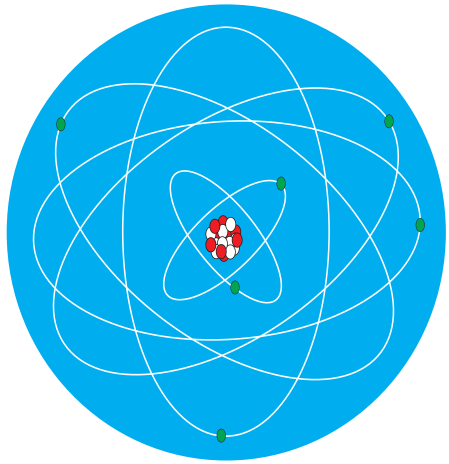


Fig - 3.1 - The planetary model of the atom

Though electrons are attracted by the positive charge of the nucleus, they do not fall on the nucleus. This is because electrons revolve very fast around the nucleus. Niels Bohr who further elaborated the Rutherford's model stated that the electrons move in definite paths or shells around the positively charged nucleus.The shells in which the electrons revole around the nucleus are assigned either numbers 1, 2, 3, 4...... or letters K, L, M, N...... respectively starting from the nearest to the nucleus.

The shells are also known as energy levels. Each energy level has a specific energy. When moving away from the nucleus this energy increases. Nevertheless, the difference between the energy levels decreases (Fig 3.2). In an atom, there is a maximum number of electrons in any energy level.Table 3.1 gives the total number of electrons in the first four energy levels nearest to the nucleus. There is a specified energy for each energy level.

Table 3-1

Level	Maximum number of electrons
1 (K)	2
2 (L)	8
3 (M)	18
4 (N)	32

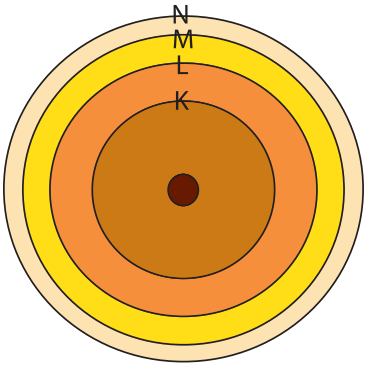


Fig - 3.2

Assignment 3.1

Make models of the atom to show its three dimentional nature by selecting suitable materials according to the instructions of the teacher. Display your creations in your classroom.

- ## Atomic number

The atomic number is the number of protons in an atom of the element.

Atomic number of the element = number of protons in an atom of the element

For example, there are 11 protons in the nucleus of a sodium atom. Thus, the atomic number of sodium is 11.The number of protons in every atom of the same element is equal. The number of protons in different elements is different. Therefore, the atomic numbers of two atoms of different elements will never be the same. **Hence, the atomic number of an element is a unique characteristic of that element.** For instance, if the atomic number of an element is 6, it means that the element is carbon. In no other element, the atomic number is equal to 6. The atomic number of an element is symbolised by Z. In a neutral atom, the number of protons is equal to the number of electrons in it. So, it implies that the atomic number of an element is equal to the number of electrons in an atom of that element.

However, when chemical reactions take place, electrons may be either lost from or gained by atoms. Such charged atoms are called ions. The number of electrons in an ion may be less or more than the number of protons. But, since the number of protons in an ion formed by a particular atom does not change, its atomic number remains unchanged.

- ## Mass number

Of the fundermental subatomic particles called protons, neutrons and electrons contained in an atom, electrons are very light. The mass of protons and neutrons is nearly equal.Approximately, the mass of an electron is 1/1840 the mass of a proton. So in comparison to the mass of protons and neutrons in an atom, the mass of electrons is negligibly small. Therefore, the mass of an atom depends only on the mass of protons and neutrons. **The sum of the number of protons and neutrons in the nucleus of an atom is called the mass number.**

$\therefore$ **mass number = number of protons + number of neutrons**

Symbol A signifies the mass number of an element.

- Atomic number of sodium is 11.
- Hence, a sodium atom contains 11 protons.
- If it contains 12 neutrons,the mass number of the sodium atom = 11+12=23.

There is a standard way of writing the atomic number and mass number of an element. On the left hand side of the symbol of the relevant elemant, the atomic number is written at the bottom and the mass number at the top.

Example (The mass number of sodium (Na) is 23.
Its atomic number is 11.

$$^{A}_{Z}\mathbf{X} \qquad\qquad ^{23}_{11}\mathbf{Na}$$

A - mass number
Z - atomic number

atomic number - 11
mass number - 23

The difference between the mass number and the atomic number gives the number of neutrons in the atom.

3.2 Electronic Configuration

The maximum number of electrons that can be accomodated in the respective energy levels according to the atomic model accepted at present was discussed earlier. Representing how electrons are filled in the respective energy levels from the one nearest to the nucleus of an atom and outwards is called electronic configuration. Let's look at an example. The atomic number of sodium is 11. Therefore, a sodium atom has 11 protons and 11 electrons. Those eleven electrons in the sodium atom are distributed as 2 electrons in the first energy energy level, 8 electrons in the second energy level and 1 electron in the third energy level. Hence the electronic configuration of sodium can be written as follows.

Na - 2, 8, 1

Table 3.2 - Electronic configurations of the elements with atomic numbers from 1 to 20

Element	Symbol	Atomic number	Electronic configuration			
			K	L	M	N
Hydrogen	H	1	1			
Helium	He	2	2			
Lithium	Li	3	2	1		
Beryllium	Be	4	2	2		
Boron	B	5	2	3		
Carbon	C	6	2	4		
Nitrogen	N	7	2	5		
Oxygen	O	8	2	6		
Fluorine	F	9	2	7		
Neon	Ne	10	2	8		
Sodium	Na	11	2	8	1	
Magnesium	Mg	12	2	8	2	
Aluminium	Al	13	2	8	3	
Silicon	Si	14	2	8	4	
Phosphorus	P	15	2	8	5	
Sulphur	S	16	2	8	6	
Chlorine	Cl	17	2	8	7	
Argon	Ar	18	2	8	8	
Potassium	K	19	2	8	8	1
Calcium	Ca	20	2	8	8	2

When an energy level of an atom of an element is the last energy level bearing electrons, the maximum number of electrons it can accommodate is 8. Thus, the number of electrons in the energy levels of potassium and calcium are not 9 and 10.

3.3 Modern Periodic Table

As at present, more than 115 elements have been discovered. Studying their properties individually is a very tedious task. Scientists in various parts of the world collect information about elements and their compounds continuously. This host of information is so large and diverse that no one is able to memorise all the facts about them. Therefore different scientists have attemted to classify elements in varrious ways.The periodic classification is the greatest result of this attempt. A Periodic Table for classifying elements was first introduced by Dmitri Mendeleeff ,a Russian scientist.

The modern Periodic Table (Fig. 3.3) is based on the atomic number and the electronic configuration. The periodic law states that the properties of elements are periodic functions of their atomic number. This means that when the elements are arranged in the ascending order of their atomic numbers, elements with similar properties recur at regular intervals of elements.

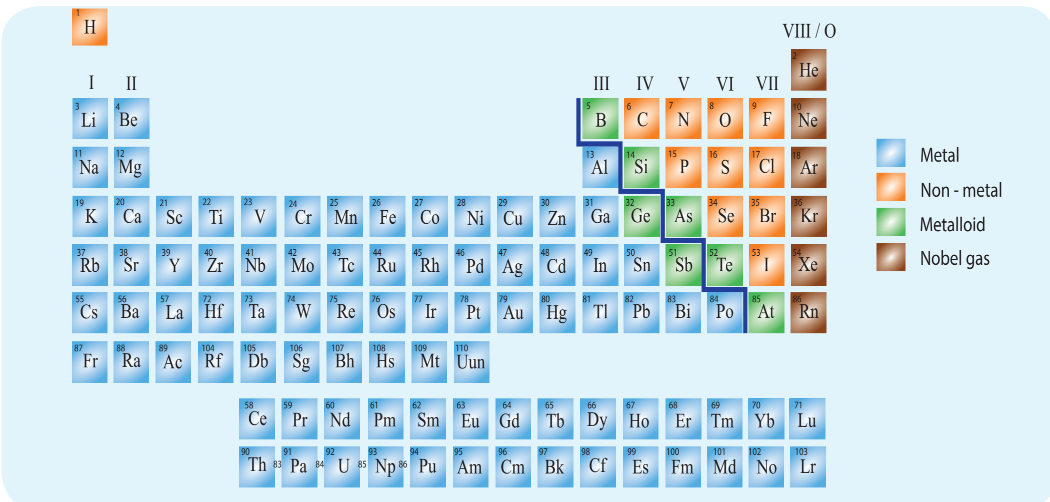


Fig. 3.3 - The modern Perodic Table

In this grade only the elements with atomic numbers from 1 - 20 are studied. Fig 3.4 shows that part.

In the PeriodicTable, horizontal rows are called **Periods** while vertical columns are known as **Groups**.

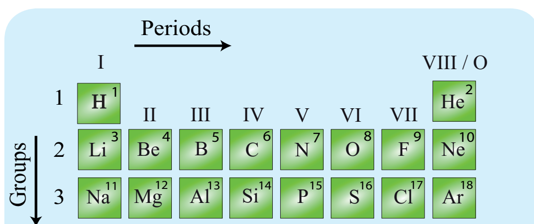


Fig. 3.4 - A part of modern Perodic Table

• Dividing Elements into Periods

The Period to which an element belongs is decided by the number of energy levels (shells) carrying electrons in an atom of that element.

Period 1 - Only the first energy level carries electrons

Period 2 - Only the first and second energy levels carry electrons

Period 3 - Only the first, second, and third energy levels carry electrons

Period 4 - Only the first, second, third and fourth energy levels carry electrons

H	1	Period 1
He	2	
Li	2, 1	Period 2
Be	2, 2	
B	2, 3	
C	2, 4	
N	2, 5	
O	2, 6	
F	2, 7	
Ne	2, 8	
Na	2, 8, 1	Period 3
Mg	2, 8, 2	
Al	2, 8, 3	
Si	2, 8, 4	
P	2, 8, 5	
S	2, 8, 6	
Cl	2, 8, 7	
Ar	2, 8, 8	
K	2, 8, 8, 1	Period 4
Ca	2, 8, 8, 2	

• Dividing Elements into Groups

The properties of an element depends on the number of electrons present in its outermost energy level. These are known as valence electrons. As per the above table, it is seen that the properties of lithium which has only one valence electron is similar to that of sodium.

Sodium too which has only one valence electron. It is seen that the properties of any element in the upper horizontal row is similar to those of the element below it.

The group to which an element belongs is decided by the number of electrons in its outermost energy level.

Number of electrons in the outer energy level	Group to which the element belongs
Elements with 1 electron in the outer energy level	Group I
Elements with 2 electrons in the outer energy level	Group II
Elements with 3 electrons in the outer energy level	Group III
Elements with 4 electrons in the outer energy level	Group IV
Elements with 5 electrons in the outer energy level	Group V
Elements with 6electrons in the outer energy level	Group VI
Elements with 7electrons in the outer energy level	Group VII
Elements with 8 electrons in the outer energy level or with a stable electronic configuration	Group VIII / 0

Groups to which the 20 elements from hydrogon to calcium belong

Element	Atomic number	Electronic configuration	Group to which the element belongs
H	1	1	I
He	2	2	VIII / 0
Li	3	2, 1	I
Be	4	2, 2	II
B	5	2, 3	III
C	6	2, 4	IV
N	7	2, 5	V
O	8	2, 6	VI
F	9	2, 7	VII
Ne	10	2, 8	VIII / 0
Na	11	2, 8, 1	I
Mg	12	2,8,2	II
Al	13	2, 8, 3	III

Si	14	2, 8, 4	IV
P	15	2, 8, 5	V
S	16	2, 8, 6	VI
Cl	17	2, 8, 7	VII
Ar	18	2, 8, 8	VIII / 0
K	19	2, 8, 8, 1	I
Ca	20	2, 8, 8, 2	II

How to Find the Position of an Element in the Periodic Table

Example :- Atomic number of magnesium (Mg) is 12.

Electronic configuration - 2, 8, 2

The number of energy levels carring electrons in a magnesium atom is 3.

So, it is an element in Period 3. Number of electrons in the outer energy level of a magnesium atom is 2.

Therefore it belongs to Group II

Magnesium is in Group II and Period 3 of the Periodic Table.

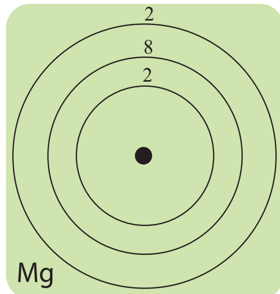


Fig. 3.5

Example - Atomic number of potassium (K) is 19.

Electronic configuration - 2, 8, 8,1

The number of energy levels carrying electrons in a potassium atom is 4.Therefore it is an element in Period 4.

A potassium atom has one electron in its outer energy level.

Therefore it belongs to Group I.

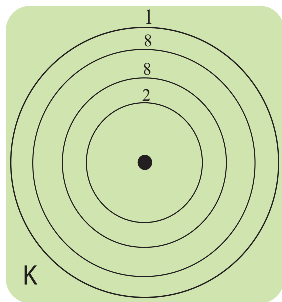


Fig 3.5

Thus potassium is found in Group I and Period 4 of the Periodic Table.

The location of the elements with atomic number 1 - 20 in the periodic table

Table 3.3 Groups and periodic of first 20 elements

Atomic number	Element	Electronic Configuration	Period of the element	Group of the element
1	H	1	1	I
2	He	2	1	VII / 0
3	Li	2, 1	2	I
4	Be	2, 2	2	II
5	B	2, 3	2	III
6	C	2, 4	2	IV
7	N	2, 5	2	V
8	O	2, 6	2	VI
9	F	2, 7	2	VII
10	Ne	2, 8	2	VIII / 0
11	Na	2, 8, 1	3	I
12	Mg	2, 8, 2	3	II
13	Al	2, 8, 3	3	III
14	Si	2, 8, 4	3	IV
15	P	2, 8, 5	3	V
16	S	2, 8, 6	3	VI
17	Cl	2, 8, 7	3	VII
18	Ar	2, 8, 8	3	VIII / 0
19	K	2, 8, 8, 1	4	I
20	Ca	2, 8, 8, 2	4	II

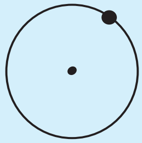
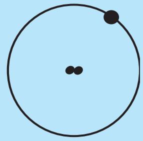
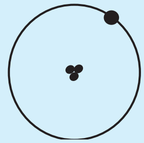
3.4 Isotopes

Among the atoms of the same element too, there may be atoms with different number of neutrons. But their atomic number, that is the number of protons, is equal. That means, there may be atoms with different mass numbers in the same element. **The atoms with different mass numbers in the same element are known as isotopes of that element.**

Examples for isotopes

Hydrogon has three isotopes. They are called protium, deuterium and tritium.

Table 3.4 - Isotopes of hydrogen

Isotope	Protium	Deuterium	Tritium
Atomic model	 electrons 1 protons 1 neutrons 0	 electrons 1 protons 1 neutrons 1	 electrons 1 protons 1 neutrons 2
Atomic number	1	1	1
Mass number	1	2	3
Standard representation	${}^{1}_{1}H$	${}^{2}_{1}H$	${}^{3}_{1}H$

Chlorine has two isotopes. They are ${}^{35}_{17}Cl$, ${}^{37}_{17}Cl$.

Chlorine gas does not contain ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$ in equal amounts. In hundred parts of gas, 75 parts are ${}^{35}_{17}Cl$ and 25 parts are ${}^{37}_{17}Cl$. This ia called the percentage abundance of the respective isotopes.

3.5 Patterns Seen in the Periodic Table

In the Periodic Table it can be seen that the physical and chemical properties of the elements change according to a systematic pattern across a Period from left to right and from top to bottom of a Group. To study those patterns, let's consider the following properties of the elements.

- First ionisation energy
- Electronegativity

• First ionisation energy

In accordance with the nuclear model of the atom, its electrons orbit the nucleus. The negatively charged electrons are attracted by the positively charged nucleus, so to remove an electron from an atom energy must be supplied to overcome that attraction. When an electron is removed from an atom, it becomes a positive ion.

I	II	III	IV	V	VI	VII	VIII / O
H 1310							He 2372
Li 519	Be 897	B 799	C 1085	N 1406	O 1314	F 1682	Ne 2080
Na 495	Mg 738	Al 577	Si 786	P 1018	S 1000	Cl 1255	Ar 1521
K 418	Ca 590						

Fig. 3.7 - First ionisation energy values of the elements with atomic numbers 1-20 (kJ mol^{-1})

The first ionisation energy of an element is the minimum energy that should be supplied to an atom in the gaseous state to remove an electron to form a unipositive gaseous ion. The formation of a unipositive gaseous ion by removing an electron from an atom in the gaseous state can be represented by a chemical equation as follows.

$$Na(g) \longrightarrow Na^{+}(g) + e$$

This energy is a comparatively small value for an atom. Therefore, this value is given for 6.022 x 10^{23} atoms or a mole of atoms. Fig. 3.7. indicates the values for one mole of atoms of respective elements. Accordingly, the first ionisation energy of sodium is 495 kJ mol^{-1} .

In a given Period, the Group I elements have the minimum first ionisation energy. Also in every Period, Group VIII elements have the maximum ionisation energy .From left to right in a Period, the first ionisation energy varies in a regular manner. This is confirmed when the variation of ionisation energies in the second and third periods are examined using the graph (Fig 3.8).

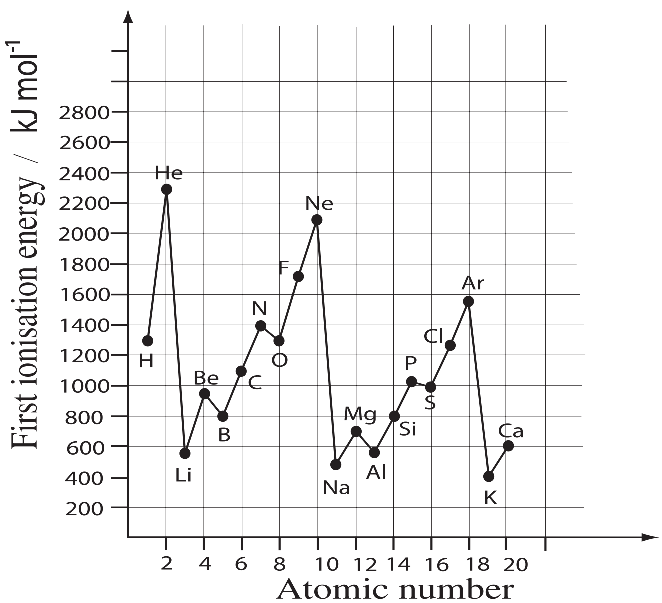


Fig. 3.8 - The graph of ionisation energy variatins against atomic number for first 20 elements

Assignment - 3.2

Draw a graph of the first ionisation energy values of elements of atomic numbers 1 - 20 given in the Fig. 3.7, against the atomic number. Use a graph paper for this assignment. Describe how the first ionisation energy varies across a Period from left to right and from top to bottom in a Group using your graph.

It is seen that in Group I elements, values of the first ionisation energy decrease from top to bottom of the Group. You can understand this by examining the values of the other groups also. Therefore, it can be concluded that, from top to bottom of a Group, the ionisation energy decreases. Descending a group, the number of energy levels in an atom increases.Therefore, the attraction exerted by the nucleus on the electrons in the outer energy level becomes less making the removal of electrons easier.

- ## Electronegativity

Electronegativity means the ability of an atom of an element to attract the electrons of a bond towards itself when it is bonded to an atom of another element. The attraction of an atom of higher electronegativity towards electrons is greater than that of lower electronegativity. More about electronegativity will be discussed under the unit on chemical bonds.

As per the Pauling scale, fluorine is considered the element of highest electronegativity. There are several scales to quantify the electronegativity of which the Pauling scale has been adopted here. Pauling scale does not assign electronegativity values to noble gases (Noble gases show less tendency to form chemical bonds).

Study the electronegativity values and the graph that illustrates the variation of electronegativity values well. It can be seen that the electronegativity increases from left to right across a Period. It is also seen that, down a Group, electronegativity decreases.

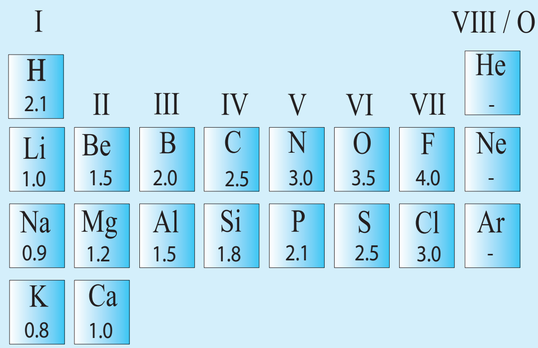


Fig 3.9 - Panling electronegativity values of the elements with atomic numbers 1-20

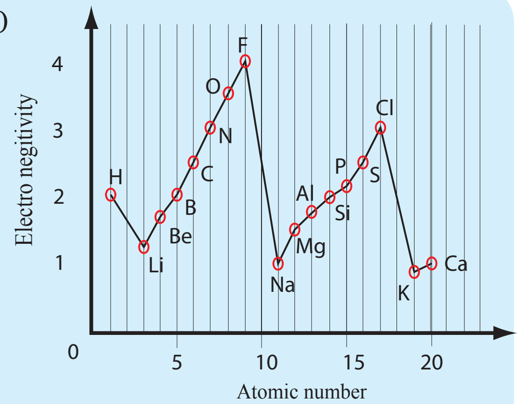


Fig 3.10 - Variation of electronegitivity against atomic number

3.6 Metals, Non - metals and Metalloids

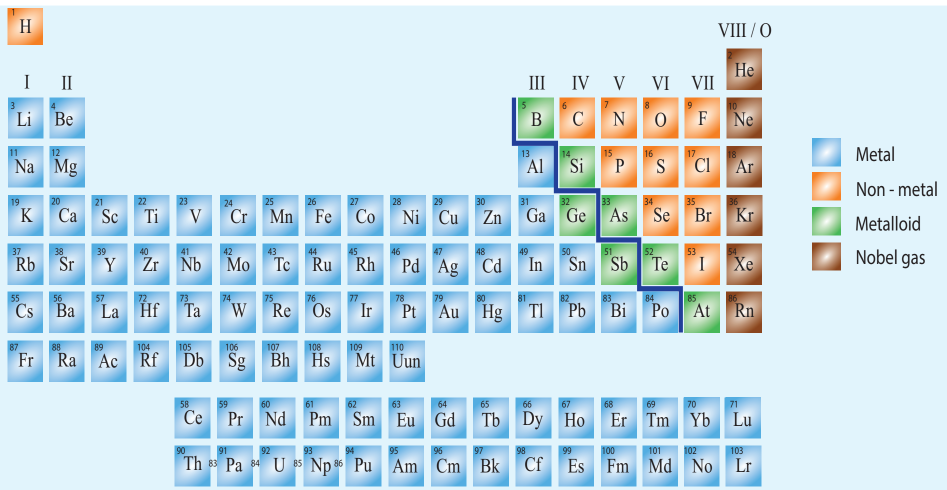


Fig. 3.11 - The modern Perodic Table

The elements written in blue in the boxes on the left hand side of this pattern are metals. The elements indicated in brown on the right hand side are non - metals(including nobel gasses).The elements indicated in light green around the steps have properties in between the metals and non - metals. Therefore they are called metalloids.

• Metals

Of the elements identified so far, more them 80 are metals. In nature, these exist as native metals as well as compounds of metals. Metals such as silver and gold are found as native metals in nature whereas many metals such as iron, aluminium, magnesium and sodium exist as their compounds.

Physical Properties of Metals

Given below are some properties of metals.

- Have a metallic lustre (have a shiny surface).
- Sonorous (give a ringing sound when struck).
- Exist in solid state at room temperature (mercury, though a metal is a liquid)
- Malleable (can be hammered into sheets) and ductile (can be drawn into wires)
- Good conductors of heat and electricity
- Generally have a high density

Chemical Properties of Metals

- Metals form positive ions or cations by losing electrons.
- They combine with oxygen to form basic oxides.
- The oxides when dissolved in water form basic solutions.

• Some Metallic Elements

Sodium

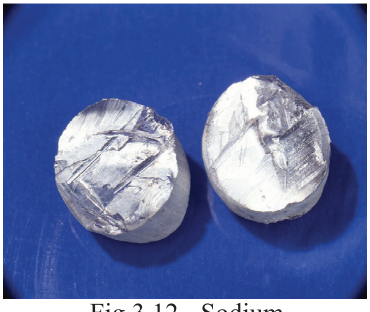


Fig 3.12 - Sodium

Sodium is a metallic element belonging to Group I of the Periodic Table. It is a highly reactive element. It never exists as the native metal. Because of its high reactivity it exists only as compounds. Sodium chloride, the main compound containing sodium occurs in sea water.

Activity 1

Do this activity under the directions of your teacher.

- Observe and report on how sodium metal is stored in the laboratory.
- Take out a piece of sodium using forceps, place it on a dry surface and cut it with a knife.
- Leave it for about five minutes. Note the observations.

Sodium metal is stored in paraffin oil or kerosene so that it does not come into contact with air. When sodium metal is taken out of paraffin oil, its lustre disappears. The metal can easily be cut with a knife. The freshly cut surface offers a silvery lustre but it gets tarnished after some time.

Physical properties of sodium metal

- It is a soft metal which can easily be cut with a knife.
- It floats on water because its density (0.97 g cm^{-3}) is less than that of water.
- It is a conductor of heat and electricity.

Chemical properties of sodium metal

- Sodium shows a high reactivity towards oxygen. It reacts rapidly with oxygen in air to form the oxide of the metal.
- Sodium metal vigourously reacts with cold water forming sodium hydroxide and hydrogen gas.
- It reacts violently with dilute acids and forms salt and hydrogen gas (Since this is extremely dangerous you shouldn't attempt this.)

Uses of sodium

- Production of sodium cyanide used in the extraction of gold and silver
- Making sodium amalgam which is used as a reducing agent in organic chemistry
- Extraction of metals such as titanium and zirconium from their compounds
- Production of indigo dye used to dye trouser materials (Denim)
- Using the production of street lamps with a yellow glow

Magnesium

Fig 3.13 - Magnesium

Magnesium is a light, reactive metal. It does not exist as the native metal in nature. In sea water it occurs as magnesium chloride. When exposed to air magnesium tarnishes so its lustre cannot be seen. But when cleaned with a sand paper, the lustre becomes visible.

Physical properties of magnesium

- It is a good coductors of heat and electricity.
- Has a higher density than that of water (Density is 1740 kg m^{-3}).

Chemical properties of magnesium

- When heated in air, magnesium burns with a bright white flame giving white magnesium oxide.
- Magnesium does not react with cold water but reacts with hot water. As a result, it forms magnesium hydroxide and hydrogen gas. When the metal is strongly heated in steam, magnesium oxide and hydrogen gas are formed.
- Magnesium rapidly reacts with dilute acids and forms the corresponding magnesium salt and hydrogen gas.

Uses of magnesium

- By mixing magnesium with aluminium, an alloy called magnelium is produced(This alloy is strong and resistant to corrosion. It is used in aircraft industry and in making parts of automobiles).
- Production of medicines (e.g. milk of magnesia).
- Used as a metal that prevents corrosion of iron.

• Non - metals

Generally, non – metals have properties opposite to those of metals. There are non – metals which occur as native elements as well as compounds of other elements. Some non – metals occur in solid state while some others exist in liquid and gaseous states. At room temperature carbon, sulphur, phosphorus and iodine exist in the solid state. Bromine is a liquid at room temperature. Chlorine, fluorine, nitrogen and oxygen are some non - metals occurring in the gaseous state. Non - metals do not have a metallic lustre. They cannot be hammered into sheets or drawn into wires. Many non – metals are brittle and are poor conductors of heat and electricity. However graphite, a non - metal is a conductor of electricity. Non-metals have a relatively low density but the density of diamond is high.

Chemical Properties of Non – metals

- Non - metals form negative ions (anions).
- Many oxides formed by non – metals with oxygen are acidic. Mostly these exist in the gaseous state. They easily dissolve in water and form acids.

• Some Non – metallic Elements

Nitrogen

Nitrogen exists as a free and diatomic gas in the atmosphere. About 78.1% by volume in the atmosphere is nitrogen gas. Nitrogen is also present as a component in animal and plant proteins. Nitrogen also exists as a constituent element in soil air, in organic substances such as humus and in nitrates, nitrites and ammonium compounds.

Physical properties of nitrogen

- It is colourless and odourless.
- It is lighter than air and is slightly soluble in water.

Chemical properties of nitrogen

- Nitrogen is a non - supporter of combustion.
- It is a gas of very low reactivity. Nevertheless, at high temperatures, nitrogen gas reacts with non metals such as oxygen, hydrogen, carbon and silicon as well as with metallic elements such as magnesium and aluminium.
- When sent through a strong electric arc, nitrogen combines with oxygen in the atmosphere to form unstable nitric oxide gas. The nitric oxide gas so formed reacts further with oxygen in air to form an acidic gas, nitrogen dioxide. During lightning, this process occurs naturally.

- Under special conditions nitrogen gas reacts with hydrogen gas to form ammonia gas. Industrially ammonia is manufactured by this method. Ammonia so prepared is used as a raw material to produce nitrogen containing fertilizers and explosives.
- When heated, nitrogen gas reacts with metals like magnesium to form metal nitrides.

Uses of nitrogen gas

- Nitrogen gas is used to produce ammonia in industrial scale, chemical fertilizers and other nitrogen compounds.
- Since it is an inert gas, it is used to fill electric bulbs and thermometers.
- When making electronic devices, a nitrogen gas environment is used.
- When storing some substances, nitrogen is used as a blanketing gas.
- When packaging milk powder, nitrogen is used.
- Liquid nitrogen is used as a coolant.
- It is also used to fill vehicle tires.

Sulphur

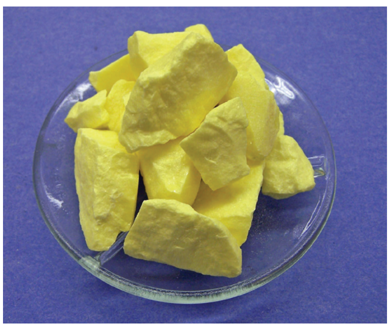


Fig 3.14 - Sulphur

Sulphur is an element that exists in different forms in nature. Those forms are referred to as **allotropes.** Sulphur occurs in crystalline form as a yellow brittle solid (Fig. 3.14) and in amorphous form as a white powder. In nature, it is found both as a native element as well as compounds like sulphates and sulphides. It is a constituent element in some amino acids found in the bodies of living beings. Sulphur clearly shows the properties of non – metals.

Physical properties of sulphur

- It is a poor conductor of electricity.
- Sulphur is insoluble in water. It is slightly soluble in organic solvents and very soluble in carbon disulphide.

Chemical Properties of sulphur

- Sulphur burns with a blue flame in air and forms sulphur dioxide gas.

- When heated with sulphur, many metals form the metal sulphide.

Uses of sulphur

- Sulphur is used to produce sulphuric acid, vulcanize rubber,and make calcium and magnesium sulphites which are used to bleach wood pulp.Its is also used to produce paints containing sulphides, solvents like carbon disulphide, sulphur dioxide gas, matches, crackers, and gun powder.
- Sulphur is also used in the production of vine, beer and medicines and is used as a fungicide.

Carbon

Diamond graphite

Fig - 3.15

Carbon is a non – metal element occurring in abundance. It occurs as carbon dioxide gas in the atmosphere, animal and plant tissues, all organic compounds, coal, petroleum products and other hydrocarbons containing carbon. It is an element showing allotropy. Carbon has crystalline forms as well as amorphous forms. In crystalline forms, atoms are orderly arranged but in amorphous forms there is no such arrangment

Crystalline carbon (allotrops of carbon) : diamond, graphite, Fularine
Amorphous carbon : charcoal, lamp soot, coal

Physical properties of carbon

Physical properties of carbon differ according to the allotropic form of carbon. Except diamond, the other forms of carbon are black in colour and exit in the solid state. Their density is relatively low. But diamond is the form with highest density. Diamond is much valued because of its high refractive index and hardness. Diamond is a poor conductor of electricity. But, graphite is a good conductor of electricity. Charcoal has the ability to absorb gases.

Chemical properties of carbon

Carbon is an element of low reactivity. It combines with oxygen at very high temperatures but does not react with substances like acids, bases and chlorine. Amorphous forms like charcoal react chemically.

- When strongly heated and ignited charcoal reacts with oxygen to form carbon dioxide.
- At high temperatures, carbon reacts with calcium oxide forming calcium carbide.

Usess of Carbon

Different allotrops of carbon has different uses. Some of the uses of carbon are given in the table 3.5 given below

Table 3.7

Form of carbon	Uses
Amorphous carbon	• Production of black colour ink • Vulacanizing rubber
Coal	• A fuel
Graphite	• Making pencils • Making electrodes of electrochemical cells • Used as a lubricant
Diamond	• Making jewellery • Cutting glass and gems • Used as pivots at points in machines that are subject to wear away
Charcoal	• Absorbing gases • Purification of water
Carbon fibres and Carbon tubes	• Used to produce goods reinforced by Nano materials. • Carbon fiber is very light and it is very strong.

Some Metalloids

Silicon

Fig 3.16 - silicon

Except oxygen, silicon is the most abundant element in the Earth's crust. As compounds, silicon occurs in both crystalline and amorphous forms. Quartz, sand and gems such as emerald are crystalline silicon compounds. Clay is an amorphous silicon compound. The melting point of silicon is 1410 ^{0}C.

Uses Of Silicon

- Used in making tranistors and diodes.
- Used in making solar cells.
- Used in makings computer equipments.

Boron

Pure boron occurs as a black, crystalline solid. It melts at 2200 ^{0}C and has a density of 3300 kg m^{-3}.Its reactivity is relatively low. Therefore it does not react even if heated to high temperatures in air. At very high temperatures amorphous boron reacts with substances like oxygen, nitrogen , nitric acid , concentrated sulphuric acid, carbon and sulphur to form the corresponding compounds.

Fig 3.17 - Boron

Uses of Boron

- Used in welding metals.
- Used in making skin cream.
- Used in making glass that can be heated into a high temperature.

• Acidic, basic and amphoteric nature of oxides

An oxide is a chemical compound that combined element with oxygon.

Elements in Period 3	Na	Mg	Al	Si	P	S	Cl
Oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl_2O_7
Acidic/ basic nature	Strongly basic	Weakly basic	Amphoteric	Very weekly acidic	Weakly acidic	Strongly acidic	Very stongly acidic

Acidity of the oxides increases →

Basicity of the oxides decreases

When the oxides of elements in Period 3 are considered, there is a clear pattern in the variation of their acidic and basic properties.The oxide of sodium which is on the left of the Period 3 is strongly basic and magnesium oxide is weakly basic.

From silicon to chlorine, the acidity of the oxides increases. Aluminium oxide shows both acidic and basic properties. Such oxides are called amphoteric oxides. Accordingly, from left to right of a Period in the Periodic Table, the basicity of the oxides decreases and their acidity increases.

Assignment - 3.3

Find a long form of a Periodic Table. Study it well and refering to it report information on the elements.

Assignment - 3.4

Select one element from the metals, non - metals and metalloids you studied. Gather information about it (textbooks, internet, supplementary readers on chemistry may be used). Make a poster contaning the information of the element. Present your information to the class.

3.7 Chemical Formulae

- ### Valency

The combining ability of an atom of an element is known as the valency. This is measured relative to hydrogen. Accordingly, the valency of an element is either the number of hydrogen atoms which can combine with or can be replaced by an atom of that element. The electrons present in the outermost energy level of an atom of an element are called valence electrons. Some elements can have several valencies. The number of valence electrons in an atom of an element is generally equal to its highest valency.

The valency of an element is equal to the number of electrons lost from or gained by an atom of that element or the number of pairs of electrons shared between the atoms during chemical combination.

We know that chemical symbols are used to identify elements easily.

Carbon	C	Calcium	Ca
Potassium	K	Sulphur	S

Similarly, chemical symbols are also used to signify chemical compounds with ease. For instance, H_2O is used to represent water, a compound consisting of two hydrogen atoms and one oxygen atom. This is called the chemical formula of water.

If there is a number at the bottom of the symbol of an element in a chemical formula, it indicates the number of atoms of that element present in a molecule of the compound. If there is no such number, only one atom of that element is present in a molecule of that compound.

For example, chemical formula of glucose is $C_6H_{12}O_6$. This means that a glucose molecule comprises 6 carbon atoms, 12 hydrogen atom and 6 oxygen atoms.

There are instances where the chemical formula does not represent a molecule. Table salt, known as sodium chloride is such a compound. Solid sodium chloride does not contain discrete molecules.

It is an ionic lattice composed of alternately arranged Na^+ and Cl^- ions. In the lattice Na^+ and Cl^- ions are present in the ratio of 1:1, so its formula is written as NaCl.

• Writing Formulae Using Valency

Compounds are formed by the attachment of atoms or ions of elements by chemical bonds. Therefore, to write the formula of a compound, their combining powers or valencies should be known. The formula is written so that the respective combining powers are balanced.

- The valency of hydrogen is 1.
- The valency of oxygen is 2.
- So, two hydrogen atoms can combine with one oxygen atom.
- This is written as H_2O.
- The valency of nitrogen is 3.
- Hence, three hydrogen atoms can combine with one nitrogen atom.
- This is written as NH_3.
- The valency of carbon is 4. So, four hydrogen atoms can combine with one carbon atom.
- This is written as CH_4.

Table 3.6 - Valencies of the elements from atomic numbers 1 to 20

Atomic number	Element	Symbol	Valency
1	Hydrogen	H	1
2	Helium	He	0
3	Lithium	Li	1
4	Beryllium	Be	2
5	Boron	B	3
6	Carbon	C	4
7	Nitrogen	N	3
8	Oxygen	O	2
9	Fluorine	F	1
10	Neon	Ne	0
11	Sodium	Na	1
12	Magnesium	Mg	2
13	Aluminium	Al	3
14	Silicon	Si	4
15	Phosphorus	P	5,3
16	Sulphur	S	6,2
17	Chlorine	Cl	7,1
18	Argon	Ar	0
19	Potassium	K	1
20	Calcium	Ca	2

So, what is done in writing the chemical formula of a compound is connecting the atoms so that their combining powers become equal. This is done by exchanging the valencies of the two elements and writing them at the bottom end on the right hand side of the respective symbols.

01.	**Sodium chloride**	
	Symbol	Na Cl
	Valency	1 1
	Chemical formula	Na_1Cl_1
		$NaCl$
02.	**Calcium chloride**	
	Symbol	Ca Cl
	Valency	2 1
	Chemical formula	Ca_1Cl_2
		$CaCl_2$
03.	**Sodium oxide**	
	Symbol	Na O
	Valency	1 2
	Chemical formula	Na_2O_1
		Na_2O
04.	**Calcium oxide**	
	Symbol	Ca O
	Valency	2 2
	Chemical formula	Ca_2O_2
		CaO
05.	**Magnesium nitride**	
	Symbol	Mg N
	Valency	2 3
	Chemical formula	Mg_3N_2
		Mg_3N_2

• Polyatomic Ions (Radicals)

A polyatomic ions is an orderly arranged group of atoms of elements with a charge.

Table 3.7 - Some common polyatomic ions

Radical	Chemical formula	Valency
Ammonium	NH_4^+	1
Hydronium	H_3O^+	1
Nitrate	NO_3^-	1
Hydrogencarbonate (Bicarbonate)	HCO_3^-	1
Hydroxide	OH^-	1
Permanganate	MnO_4^-	1
Hydrogensulphate (Bisulphate)	HSO_4^-	1
Chromate	CrO_4^{2-}	2
Dichromate	$Cr_2O_7^{2-}$	2
Sulphate	SO_4^{2-}	2
Carbonate	CO_3^{2-}	2
Phosphate	PO_4^{3-}	3

Let's consider the formulae of the following as examples for compounds with polyatomic ions.

Sodium nitrate

Na^+ NO_3^-

Valency 1 1

$NaNO_3$

Chemical formula $NaNO_3$

Potassium carbonate

K^+ CO_3^{2-}

Valency 1 2

K_2CO_3

Chemical formula K_2CO_3

Magnesium nitrate

Mg^{2+} NO_3^-

Valency 2 1

$Mg_1(NO_3)_2$

Chemical formula $Mg(NO_3)_2$

Ammonium phosphate

NH_4^+ PO_4^{3-}

Valency 1 3

$(NH_4)_3PO_4$

Chemical formula $(NH_4)_3PO_4$

When there are more than one radical in the chemical formula of a compound, they are written within parentheses.

Summary

- Atoms are the building units of matter.
- Atoms are formed by the three main subatomic particles, electrons, protons and neutrons.
- At different times different models were proposed for the structure of the atom.
- Ernest Rutherford presented the planetary model for the atom.
- Niels Bohr stated that electrons move in definite paths or shells around the positively charged nucleus.
- The modern Periodic Table is based on the patterns observable in the properties of elements when they are arranged in the ascending order of their atomic number.
- Elements are divided into Groups according to the number of electrons in the outermost shell (energy level) of their atoms.
- Element are divided into Periods in accordance with the number of shells (energy levels) with electrons in their atoms.
- The minimum amount of energy required to remove an electron from a gaseous atom of an element to form a unipositive ion in gaseous state is known as its first ionisation energy.
- A regular pattern can be seen in the variation of the first ionisation energy of elements across a Period from left to right.
- Down a Group, the first ionisation energy of elements decreases.
- When an atom is joined to another atom by a covalent bond, the ability of that atom to attract electrons in the bond towards itself is called its electronegativity.
- The electronegativity of elements increases across a Period and decreases down a Group.
- Across a Period from left to right accidity of oxides formed by the elements increases; their basicity decreases.
- Across a Period from left to right, the metallic properties of elements decrease; non - metallic properties increase.
- Based on the physical and chemical properties, elements can be classified as metals, non –metals and metalloids.
- Majority of the elements so far identified are metals.

Exercise

01. Complete the following sentences.

i. The mass number of an element is 14 and its atomic number is 6. This atom contains .... electrons.

ii. An atom of an element consists of 19 protons, 19 electrons and 18 neutrons. The mass number of this atom is ....

iii. The sum of the number of protons and the number of neutrons in the nucleus of an atom is known as its.................

02' The atomic number of aluminium is 13 and its mass number is 27.

i. Write the atomic number and mass number of aluminium in the standard form.

ii. What is the number of neutrons in an aluminium atom?

03' Complete the following table.

Element	Number of		
	electrons in an atom	protons in an atom	neutrons in an atom
$^{31}_{15}P$			
$^{7}_{3}Li$			
$^{24}_{12}Mg$			
$^{40}_{20}Ca$			
$^{35}_{17}Cl$			

04' Write the chemical formulae of the following compounds.

i. Lithium fluoride

ii. Beryllium chloride

iii. Aluminium oxide

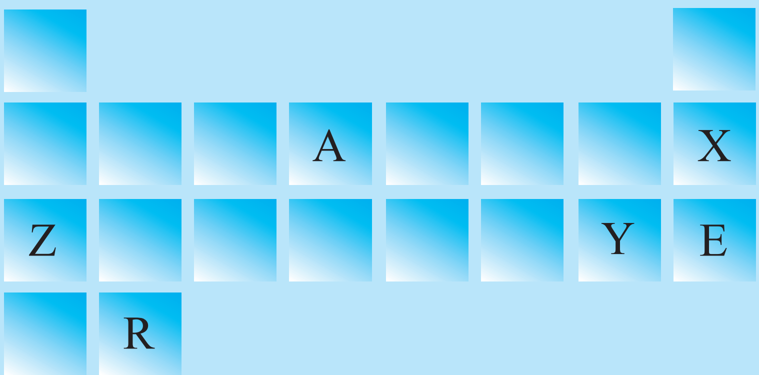
05' Write the chemical formulae of the following compounds.

i. Ammonium chloride
ii. Calcium hydroxide
iii. Calcium phosphate
iv. Magnesium sulphate
v. Aluminium nitrate
vi. Potassium permanganate
vii. Calcium chromate
viii. Ammonium dichromate
ix. Sodium hydrogencarbonate (Sodium bicarbonate)
x. Potassium carbonate

06. What valencies should the following elements have?

i. Lithium
ii. Carbon
iii. Calcium
iv. Sulphur
v. Chlorine

07' A part of the Periodic Table is shown below. The symbols given in it are not true symbols of the respective elements. Answer the questions below that are based on them.



i. Identify the element / elements that behave (s) as a nooble gas.
ii. Mass number of Y is 35. Find the number of protons and neutrons in an atom of Y.
iii. Write the electronic configuration of R.

iv. How many valencies are shown by A?

v. A compound is formed by the reaction between A and Y. Write the probable formula of this compound.

vi. Name two metallic elements.

08' D, E, G, J, L, M, Q, R, and T are nine consecutvne elements in the Periodic Table. R is a noble gas belonging to Period 3.

i. Of these elements, identify the two elements belonging to the same Group.

ii. To which Group of the Periodic Table do those element belong?

iii. Of the above, name the element of highest electronegativity?

iv. Write the formula of the compound formed by the reaction between E and M.

v. Of the above, identity the element with four valence electrons and write its electronic configuration.

vi. Of the above, name the element with highest first ionivsation energy.

Technical terms

Electronic configuration	ඉලෙක්ට්‍රෝන වින්‍යාසය	இலத்திரன் நிலையமைப்பு
Isotopes	සමස්ථානික	சமதானிகள்
Periodic table	ආවර්තිතා වගුව	ஆவர்த்தன அட்டவணை
Periods	ආවර්ත	ஆவர்த்தனம்
Groups	කාණ්ඩ	கூட்டம்
Valency	සංයුජතාව	வலுவளவு
First ionization energy	ප්‍රථම අයනීකරණ ශක්තිය	முதலாம் அயனாக்கச் சக்தி
Electro negativity	විද්‍යුත් සෘණතාව	மின்னெதிர்த்தன்மை
Metals	ලෝහ	உலோகம்
Non- metals	අලෝහ	அல்லுலோகம்
Metalloids	ලෝහාලෝහ	உலோகப்போலி
Acidic	ආම්ලික	அமிலம்
Basic	භාෂ්මික	காரம்
Amphoteric	උභයගුණී	ஈரியல்பு