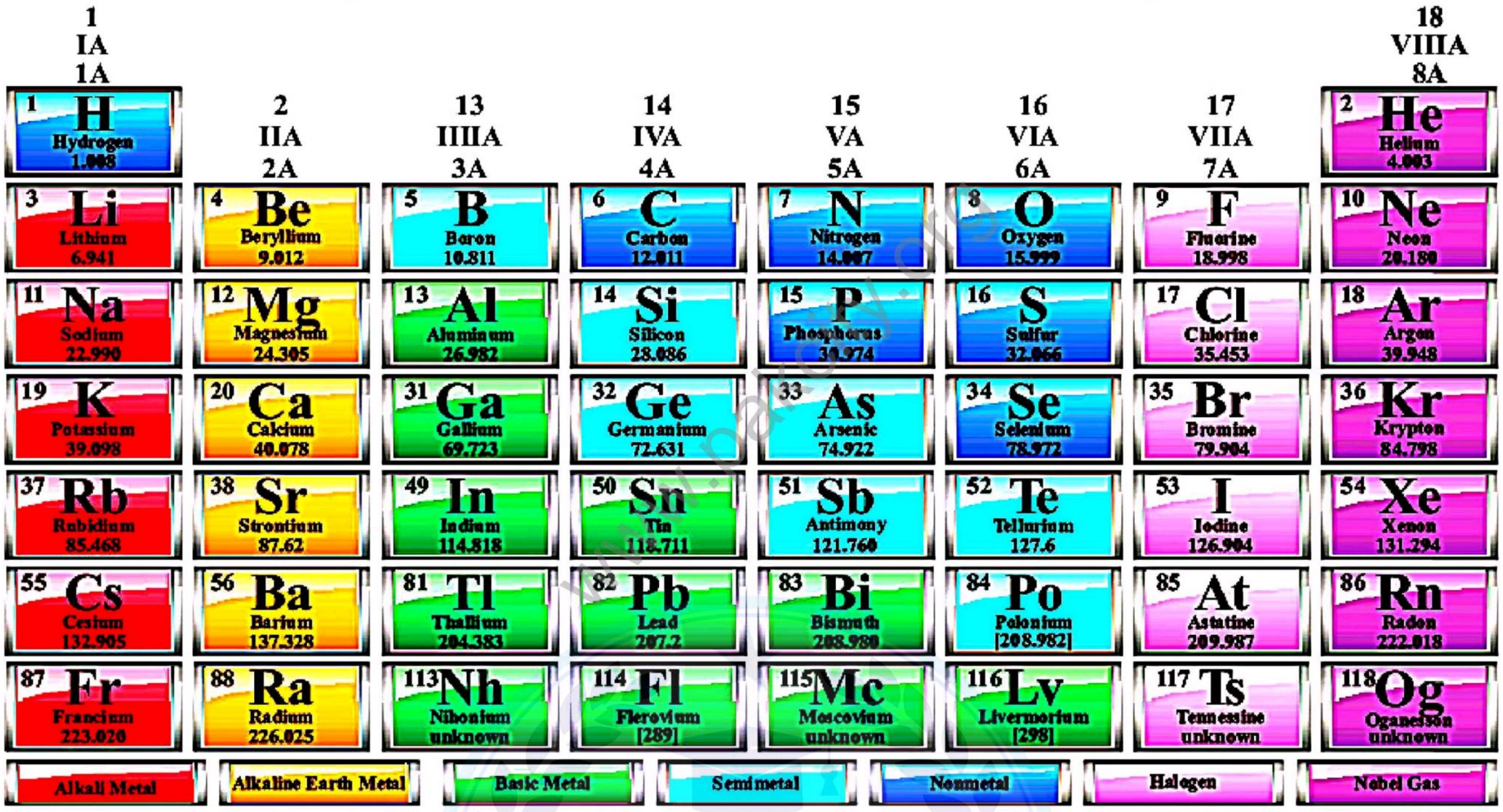
CHAPTER
1

CHEMISTRY OF REPRESENTATIVE ELEMENTS



1 IA 1A	2 IIA 2A	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008							2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012	5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.972	35 Br Bromine 79.904	36 Kr Krypton 84.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	113 Nh Nihonium unknown	114 Fl Flerovium [289]	115 Mc Moscovium unknown	116 Lv Livermorium [298]	117 Ts Tennessine unknown	118 Og Oganesson unknown

Alkali Metal	Alkaline Earth Metal	Basic Metal	Semimetal	Nonmetal	Halogen	Nobel Gas

Representative Elements:

Elements in the periodic table from group I-A to VIII-A are called representative elements. They are found in excess amount in nature that's why they're called as representative elements.

Representative Elements are further divided into s-block elements and p-block elements.

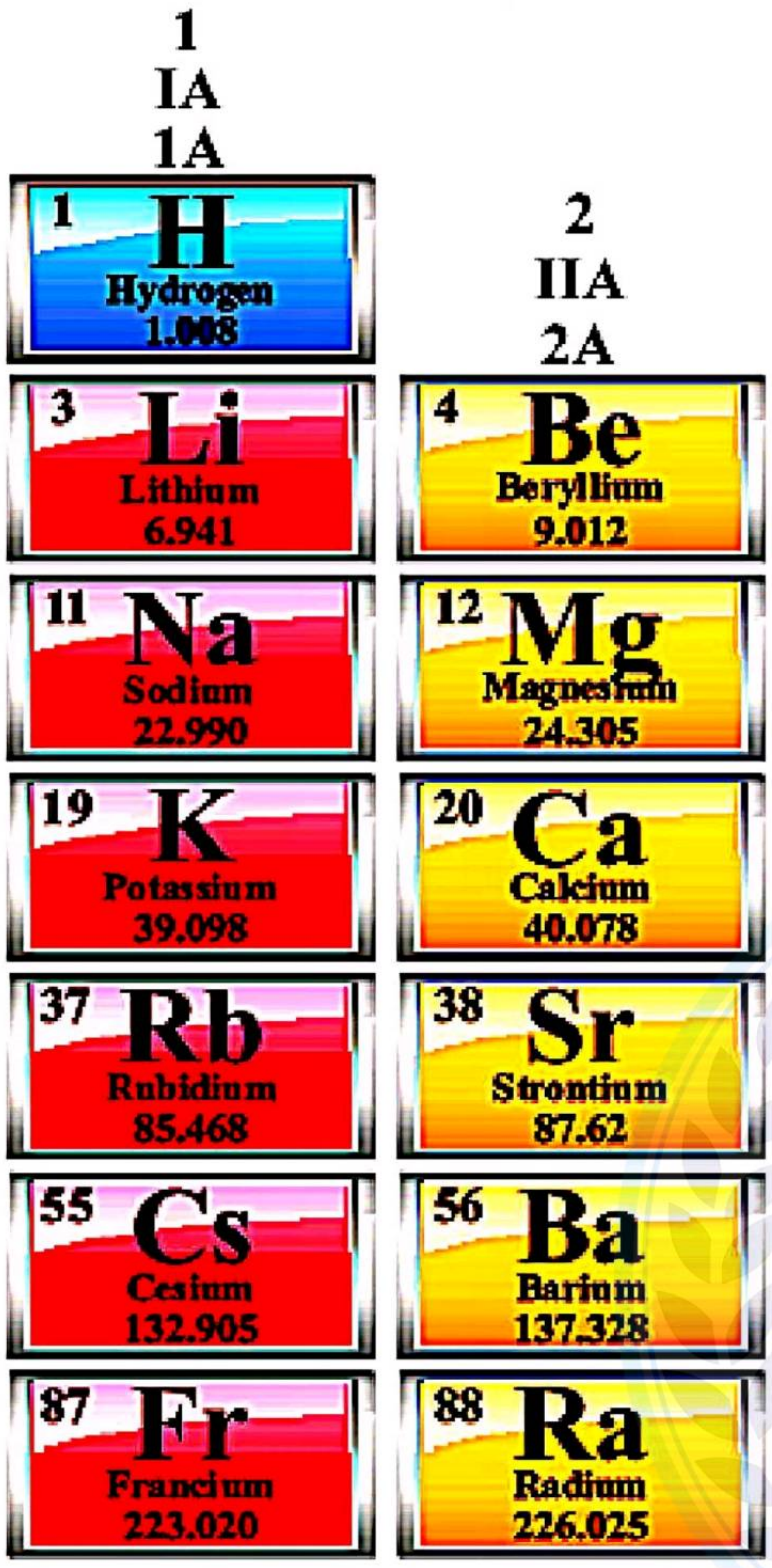
s-block Elements:

The elements in which the valence electron enters in s-orbital is called s-block elements. Elements of group I-A and II-A are included in s-block elements.

The general valence shell electronic configuration of s-block elements can be given by ns^{1-2}.

Elements of group I-A are also called “Alkali Metals” and the general valence shell electronic configuration of this group is ns^1.

Elements of group II-A are also called “Alkaline Earth Metals” and the general valence shell electronic configuration of this group is ns^2.



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55 Cs Cesium 132.905	56 Ba Barium 137.328
87 Fr Francium 223.020	88 Ra Radium 226.025

p-block Elements:

The elements in which the valence electron enters in p-orbital is called s-block elements. Elements of group III-A to VIII-A are included in s-block elements.

The general valence shell electronic configuration of p-block elements can be given by ns^2, np^{1-6}.

Elements of group III-A are also called “Boron Family” and the general valence shell electronic configuration of this group is ns^2,np^1.

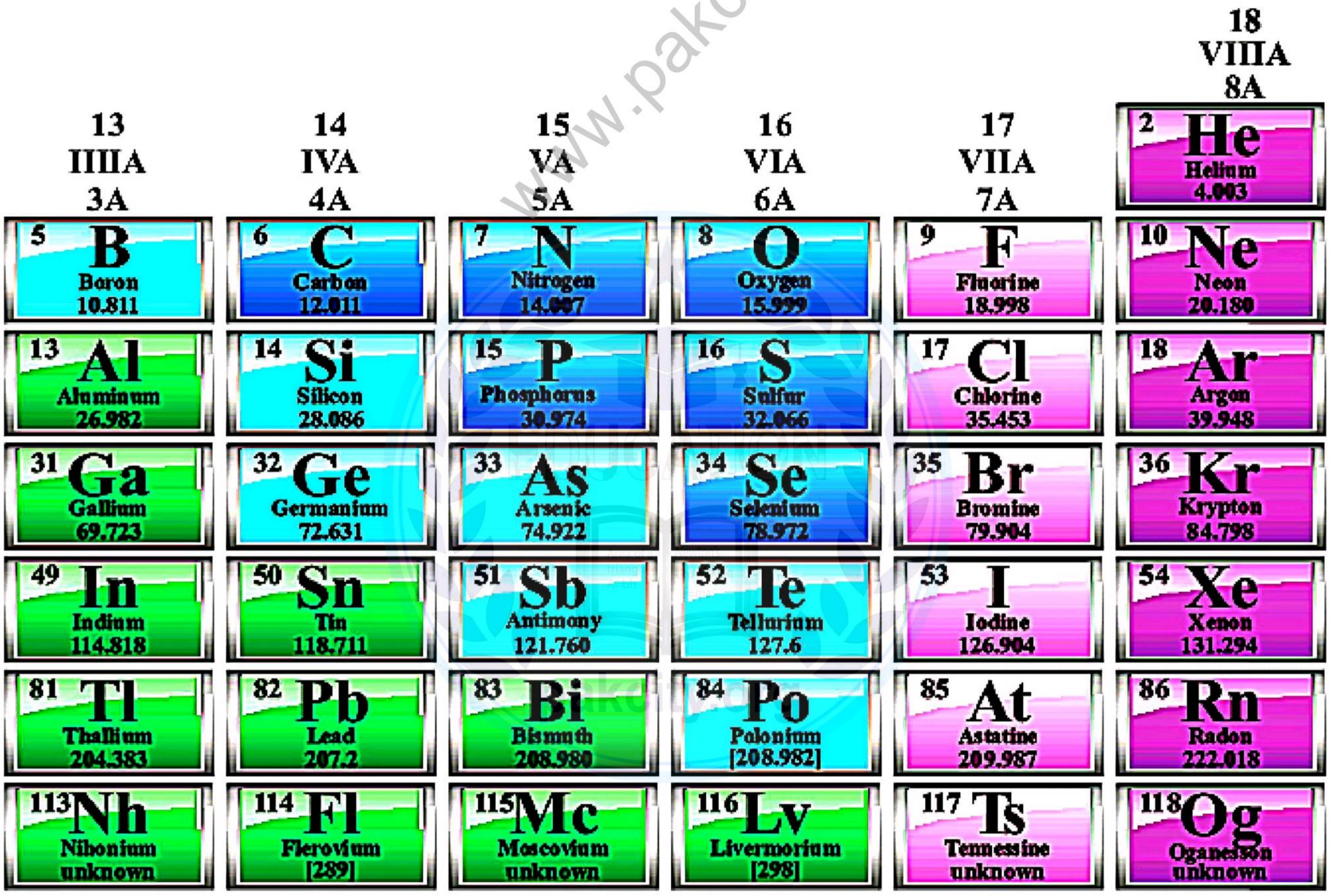
Elements of group IV-A are also called “Carbon Family” and the general valence shell electronic configuration of this group is ns^2,np^2.

Elements of group V-A are also called “Nitrogen Family or Pnictogens” and the general valence shell electronic configuration of this group is ns^2, np^3.

Elements of group VI-A are also called “Oxygen Family or Chalcogens” and the general valence shell electronic configuration of this group is ns^2, np^4.

Elements of group VII-A are also called “Halogens” because they are salt formers and the general valence shell electronic configuration of this group is ns^2, np^5.

Elements of group VIII-A are also called “Noble gases or Inert gases” and the general valence shell electronic configuration of this group is ns^2, np^6.



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GENERAL GROUP TRENDS OF REPRESENTATIVE ELEMENTS

The regular variations in the properties of elements in a group is called group trends.

The regular variations in the properties of elements in a period is called periodic trends.

1) Atomic Radii

2) Ionization Energy

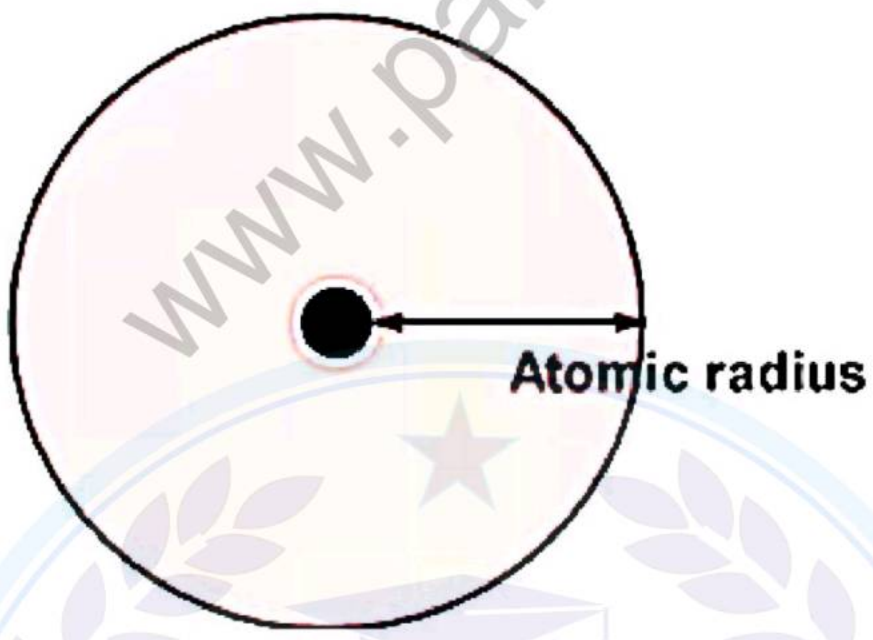
3) Electronegativity

4) Electrical conductivity

5) Melting Point and Boiling Point

Atomic Radii

"Atomic radius is the distance between the nucleus of an atom to its outermost electron shell".



The unit of atomic radius is Angstrom (Å)

Atomic radius is directly proportional to the number of shells and inversely proportional to the magnitude of nuclear charge.

Down the group in periodic table, atomic radius increases due to increase in number of shells.

From left to right along a period in the periodic table, atomic radius decreases due to increase in magnitude of nuclear charge. The increasing nuclear charge shrinks the orbits due to electrostatic attraction between proton and electron.

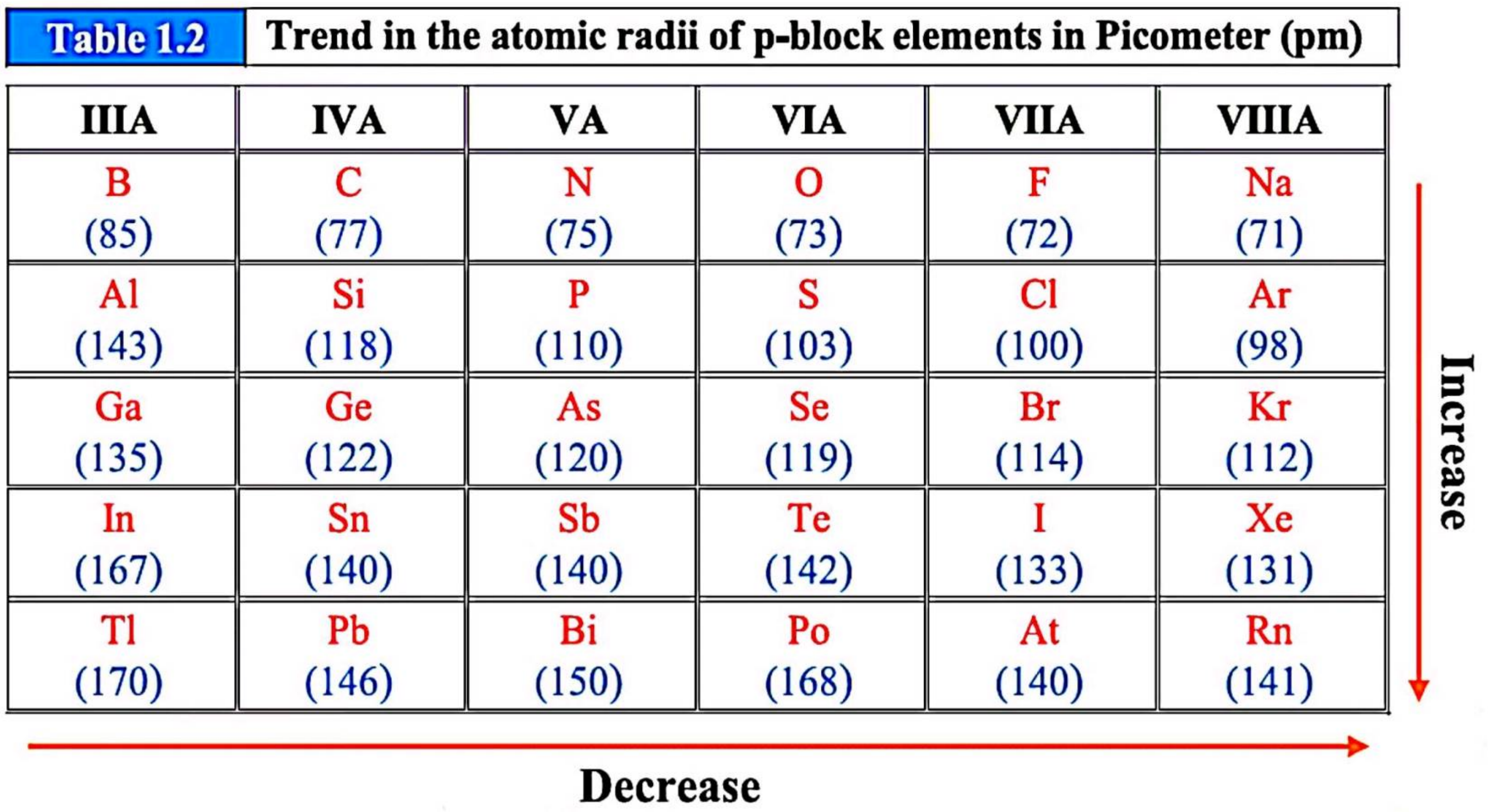


Table 1.2 Trend in the atomic radii of p-block elements in Picometer (pm)

IIIA	IVA	VA	VIA	VIIA	VIIIA
B (85)	C (77)	N (75)	O (73)	F (72)	Na (71)
Al (143)	Si (118)	P (110)	S (103)	Cl (100)	Ar (98)
Ga (135)	Ge (122)	As (120)	Se (119)	Br (114)	Kr (112)
In (167)	Sn (140)	Sb (140)	Te (142)	I (133)	Xe (131)
Tl (170)	Pb (146)	Bi (150)	Po (168)	At (140)	Rn (141)

Increase

Decrease

MCQ’s:

1. Which element has the largest atomic radius?

A	Li	B	Na	C	K	D	Rb

2. Which elements has the smallest atomic radius?

A	Be	B	Mg	C	Ca	D	Sr

3. Which elements has the largest atomic radius?

A	Li	B	Be	C	B	D	C

4. Which group has the biggest atoms?

A	I-A	B	II-A	C	III-A	D	IV-A

Give reasons for the following:

1. Cs atom is bigger than Li atom.

Ans. Cs contains more number of shells than Lithium, that’s why it has a larger atomic radius.

2. Na atom is bigger than Mg atom.

Ans. Magnesium atoms have more nuclear charge, so there will be more shrinking effect in orbits. Due to this face, sodium is bigger is size.

Ionization Energy

"It is the energy needed to remove an electron from a neutral atom in the gas phase".

Ionization energy is also called Ionization Potential and it's denoted by IP.

The unit of ionization energy is KJ/mol, Kcal/mol or eV/atom.

For Example: $\mathbf{Na_{2,8,1} + heat \rightarrow Na^{+}_{2,8} + 1e^{-}}$ $\mathbf{\Delta_{IE} = +ve\ KJ/mol}$

Ionization energy is inversely proportional to number of shells. As the number of shell increases, it will be easier to remove electron by providing a little amount of energy.

Ionization energy is directly proportional to the magnitude of nuclear charge. As the nuclear charges increases, the valence shell comes close to the nucleus due to strong electrostatic attraction, hence the removal of electron requires more energy.

Down the group in periodic table, Ionization energy decreases due to increase in number of shells.

From left to right along a period, ionization energy increases due to increase in magnitude of nuclear charge.

Table 1.3 **First ionization energies of representative elements in KJ/mol**

Group IA	Group IIA	Group IIIA	Group IVA	Group VA	Group VIA	Group VIIA	Group VIIIA
Li (520)	Be (900)	B (800)	C (1090)	N (1400)	O (1310)	F (1680)	Ne (2080)
Ne (490)	Mg (730)	Al (577)	Si (780)	P (1060)	S (1001)	Cl (1250)	Ar (1520)
K (420)	Ca (590)	Ga (580)	Ge (762)	As (960)	Se (950)	Br (1140)	Kr (1350)
Rb (400)	Sr (550)	In (560)	Sn (700)	Sb (830)	Te (870)	I (1010)	Xe (1170)
Cs (380)	Ba (500)	Tl (590)	Pb (710)	Bi (800)	Po (810)	At (920)	Rn (1030)

Decrease

Increase

MCQ's:

1. Which element has the highest ionization energy?

A	Li	B	Na	C	K	D	Rb

2. Which elements has the lowest ionization energy?

A	Be	B	Mg	C	Ca	D	Sr

3. Which elements has the highest ionization energy?

A	Li	B	Be	C	B	D	C

4. Which group has the highest ionization energy?

A	I-A	B	II-A	C	III-A	D	IV-A

Give reasons for the following:

1. The ionization energy of Na is more than K.

Ans. Sodium contains a smaller number of shells so that it is difficult to remove its electron due to strong electrostatic attraction. Hence, sodium has more ionization energy than potassium.

2. The ionization energy of Nitrogen is more than oxygen.

Ans. Nitrogen is a stable element due to its half-filled p-sub shell. Due to this reason, it has more ionization energy than oxygen.

Electronegativity (EN)

"It is the measure of the tendency of an atom to attract the shared pair of electrons towards itself when it is involved in a covalent bond".

Electron gaining tendency of an element is also called electronegativity.

Non-metals are electronegative because they have a tendency to accept electron.

There is no unit of electronegativity. Its values were determined by Linus Pauling.

The most electronegative element is Fluorine (F) having EN value 4.0

The least electronegative element in Cesium (Cs) having EN value 0.7

Electronegativity is inversely proportional to the number of shells and directly proportional to the magnitude of nuclear charge.

Down the group in periodic table, EN decreases due to increase in number of shells. From left to right along a period in periodic table, EN increases due to increase in magnitude of nuclear charge.

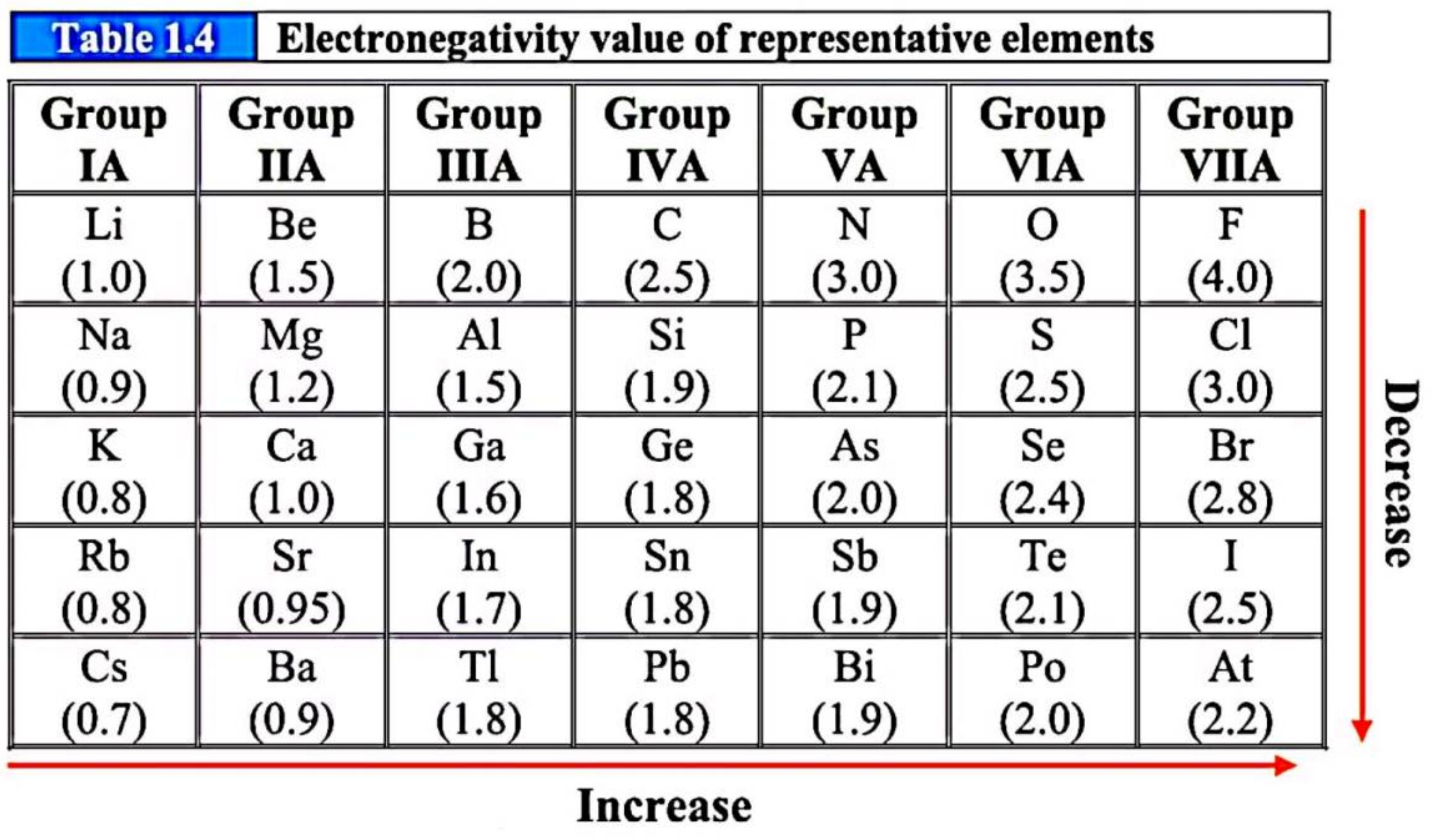


Table 1.4 Electronegativity value of representative elements

Group IA	Group IIA	Group IIIA	Group IVA	Group VA	Group VIA	Group VIIA
Li (1.0)	Be (1.5)	B (2.0)	C (2.5)	N (3.0)	O (3.5)	F (4.0)
Na (0.9)	Mg (1.2)	Al (1.5)	Si (1.9)	P (2.1)	S (2.5)	Cl (3.0)
K (0.8)	Ca (1.0)	Ga (1.6)	Ge (1.8)	As (2.0)	Se (2.4)	Br (2.8)
Rb (0.8)	Sr (0.95)	In (1.7)	Sn (1.8)	Sb (1.9)	Te (2.1)	I (2.5)
Cs (0.7)	Ba (0.9)	Tl (1.8)	Pb (1.8)	Bi (1.9)	Po (2.0)	At (2.2)

Decrease

Increase

MCQ's:

1. Which element has the highest electronegativity?

A	Li	B	Na	C	K	D	Rb

2. Which elements has the lowest electronegativity?

A	Be	B	Mg	C	Ca	D	Sr

3. Which elements has the highest electronegativity?

A	Li	B	Be	C	B	D	C

4. Which group has the highest electronegativity?

A	I-A	B	II-A	C	III-A	D	IV-A

Give reasons for the following:

1. The electronegativity of Na is more than K.

Ans. Sodium contains a smaller number of shells so that its shared pair will be nearer to nucleus and nucleus can attract it with a stronger force.

Electrical Conductivity

The ability of an element to conduct electric current is called electrical conductivity.

Table 1.5 **Electrical conductivity trends of representative elements**

Group Number	Trend of Electrical Conductivity
Group I and IIA	High electrical conductivity
Group IIIA	Moderate electrical conductivity
Group IVA	Variable electrical conductivity (Carbon: poor, Silicon: moderate, Germanium: moderate, Tin: moderate, Lead: poor)
Group VA	Moderate electrical conductivity
Group VIA	Poor electrical conductivity
Group VIIA (Halogens)	Poor electrical conductivity
Group VIIIA (Noble gases)	Extremely low electrical conductivity

Oxidation State

“An oxidation number is a value assigned to an element in a chemical compound or combined state.

Table 1.6 **Oxidation states of representative elements**

Group	Elements	Oxidation States
IA (Alkali Metals)	Li, Na, K, Rb, Cs	+1
IIA (Alkaline Earth Metals)	Be, Mg, Ca, Sr, Ba	+2
IIIA	B, Al, Ga, In, Tl	+3
IVA	C, Si, Ge, Sn, Pb	-4, -2, +2, +4
VA	N, P, As, Sb, Bi	-3, -2, +3, +5
VIA	O, S, Se, Te, Po	-2, +2, +4, +6
VIIA (Halogens)	F, Cl, Br, I, At	-1, +1, +3, +5, +7
VIIIA (Noble Gases)	He, Ne, Ar, Kr, Xe, Rn	0

Melting and Boiling Point

The temperature at which a solid start converting into liquid is called melting point.

The temperature at which a liquid starts boiling is called boiling point.

Boiling point and melting point are measured in °C or K.

The trend of Melting Point and Boiling Point is irregular in the periodic table.

In group I-A and II-A, MP and BP decrease down the group due to increase in atomic volume which makes the element less dense.

There is no regular pattern of MP and BP in group III-A

From group IV-A to VII-A MP and BP increases down the group due to stronger intermolecular forces.

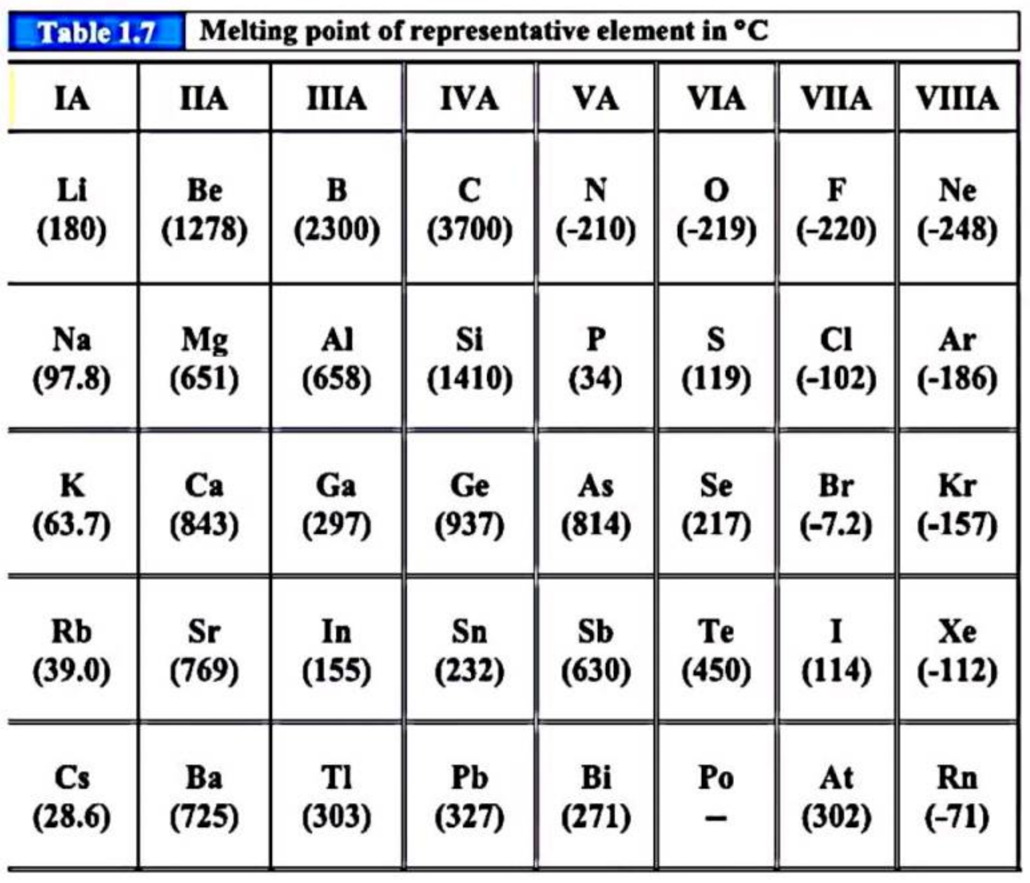


Table 1.7 Melting point of representative element in °C

IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
Li (180)	Be (1278)	B (2300)	C (3700)	N (-210)	O (-219)	F (-220)	Ne (-248)
Na (97.8)	Mg (651)	Al (658)	Si (1410)	P (34)	S (119)	Cl (-102)	Ar (-186)
K (63.7)	Ca (843)	Ga (297)	Ge (937)	As (814)	Se (217)	Br (-7.2)	Kr (-157)
Rb (39.0)	Sr (769)	In (155)	Sn (232)	Sb (630)	Te (450)	I (114)	Xe (-112)
Cs (28.6)	Ba (725)	Tl (303)	Pb (327)	Bi (271)	Po –	At (302)	Rn (-71)

MCQ's:

1. Which element has the highest melting point?

A	Li	B	Na	C	K	D	Rb

2. Which elements has the highest melting point?

A	F	B	Cl	C	Br	D	I

REACTIONS OF REPRESENTATIVE ELEMENTS

s-block elements

1) Reaction with Oxygen:

$$4Li_{(s)} + O_{2(g)} \longrightarrow 2Li_2O_{(s)} \text{ (Normal oxide)}$$

$$2Na_{(s)} + O_{2(g)} \xrightarrow{\text{(Excess)}} Na_2O_{2(s)} \text{ (Per oxide)}$$

$$K_{(s)} + O_{2(g)} \longrightarrow KO_{2(s)} \text{ (Super oxide)}$$

$$Rb_{(s)} + O_{2(g)} \longrightarrow RbO_{2(s)} \text{ (Super oxide)}$$

$$Cs_{(s)} + O_{2(g)} \longrightarrow CsO_{2(s)} \text{ (Super oxide)}$$

$2M + O_2 \longrightarrow 2MO$ (Where M = Be, Mg, Ca)

$M + O_2 \longrightarrow MO_2$ (Where M = Sr, Ba)

2) Reaction with Water:

$$2M_{(s)} + 2H_2O_{(\ell)} \longrightarrow 2MOH_{(aq)} + H_{2(g)}\uparrow$$

(Where M = Li, Na, K, Rb, Cs).

$$M_{(s)} + 2H_2O_{(\ell)} \longrightarrow M(OH)_{2(aq)} + H_2\uparrow$$

(Where M = Mg, Ca, Sr and Ba).

3) Reaction with Halogens:

$$2M_{(s)} + X_{2(g)} \longrightarrow 2MX_{(s)}$$

(Where M = Li, Na, K, Rb, Cs)

$$M_{(s)} + X_{2(g)} \longrightarrow MX_{2(s)}$$

(Where M = Be, Mg, Ca, Sr, Ba)

4) Reaction with Nitrogen:

$6M_{(s)} + N_{2(g)} \longrightarrow 2M_3N_{(s)}$ (M = Li, Na, K, Rb, Cs)

$3M_{(s)} + N_{2(g)} \longrightarrow M_3N_{2(s)}$ (M = Be, Mg, Ca, Sr, Ba)

5) Reaction with Hydrogen:

$2M_{(s)} + H_{2(g)} \longrightarrow 2MH_{(s)}$ (M = Li, Na, K, Rb, Cs)

$M_{(s)} + H_{2(g)} \longrightarrow MH_{2(s)}$ (M = Ca, Sr, Ba)

5) Reaction with Alcohols:

$2M_{(s)} + 2C_2H_5OH_{(aq)} \longrightarrow 2C_2H_5OM_{(aq)} + H_{2(g)}$ (M = Li, Na, K, Rb, Cs)

Alkaline earth metals have a very limited reactivity with alcohols.

6) Reaction with Acids:

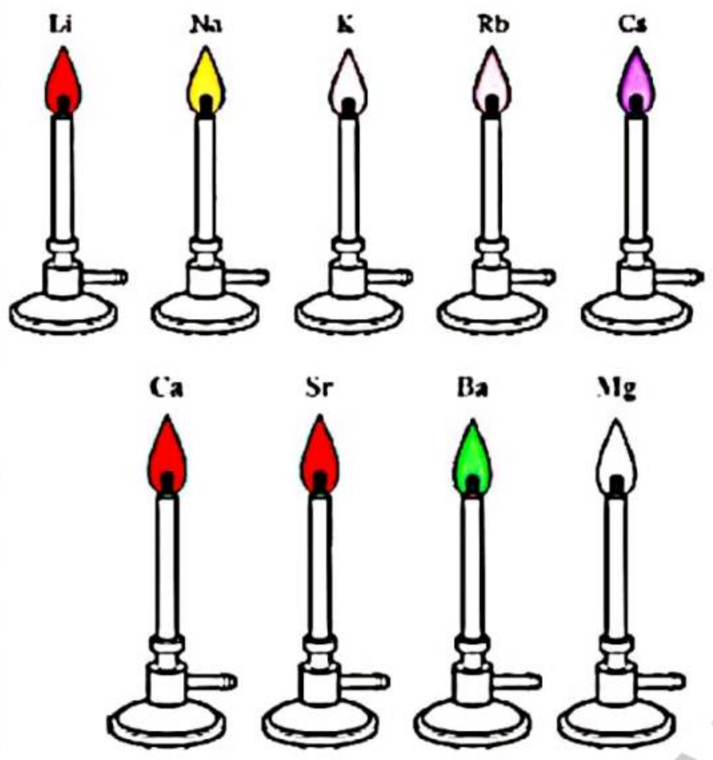
$$2M_{(s)} + 2HCl_{(aq)} \longrightarrow 2MCl_{(s)} + H_{2(g)} \text{ (Where M = Li, Na, K, Rb, Cs)}$$

Alkaline earth metals can react with acids but their reactivity is generally lower compared to alkali metals.

FLAME TEST FOR S-BLOCK ELEMENTS

"Flame test is a qualitative method used to identify the presence of alkali metals based on their characteristic flame colours".

Elements	Flame Colour
Lithium	Red
Sodium	Yellow
Potassium	Violet
Rubidium	Red Violet
Cesium	Blue Violet
Beryllium	No characteristic flame colour
Magnesium	Silver white
Calcium	Orange red
Strontium	Deep Red
Barium	Pale Green



INDUSTRIAL PREPARATION OF SODIUM HYDROXIDE (NaOH)

Castener-Kellner's Cell

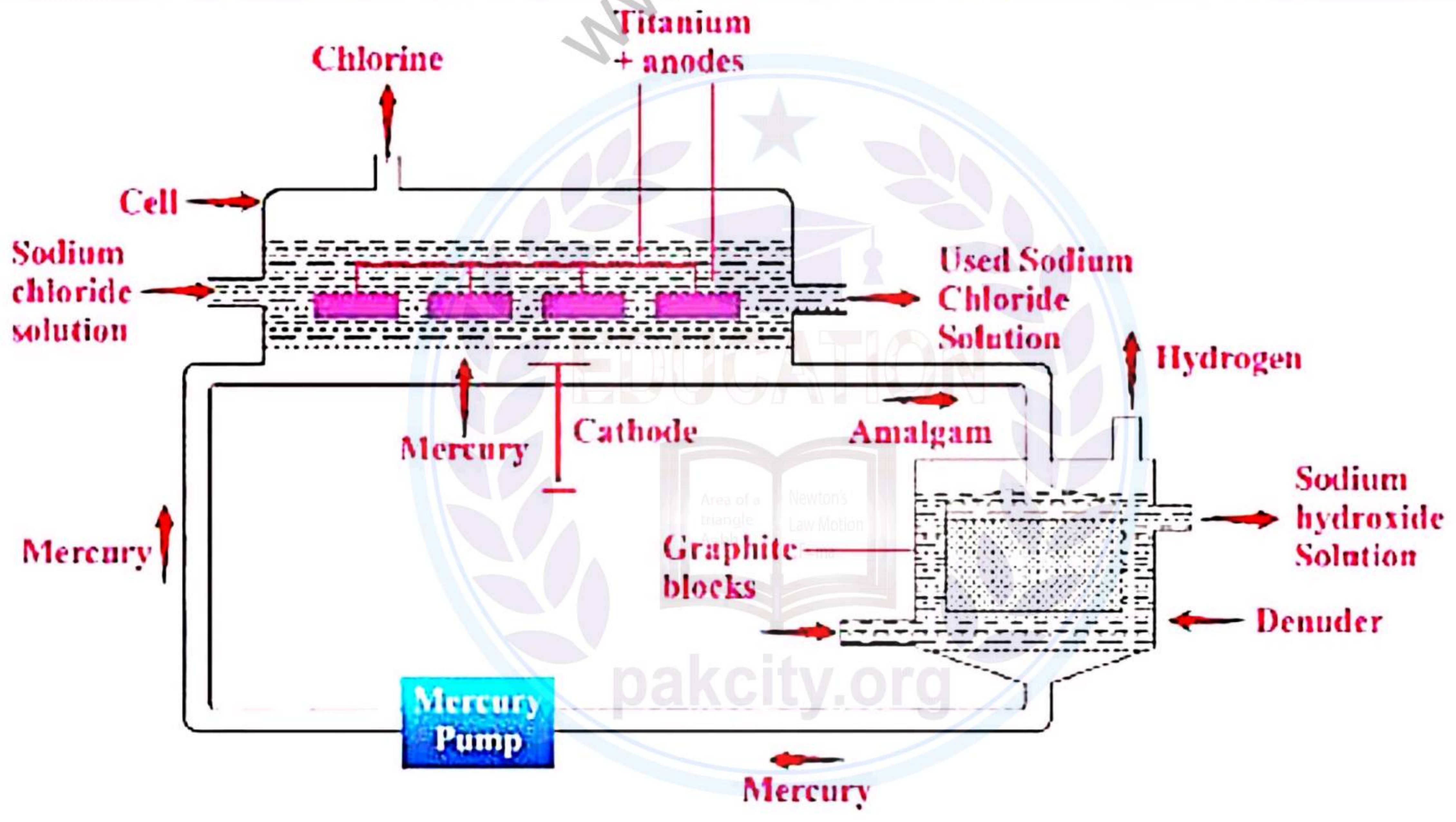


Fig 1.1: Structure of Castner Kellner cell

Introduction

Sodium hydroxide is also known as caustic soda having chemical formula NaOH. It is prepared in industries by the electrolysis of brine in Castener-Kellner's electrolytic cell.

Construction of the Cell:

Castner-Kellner's cell consist of two compartments. The upper compartment contains a tank in which brine is filled. Brine is the saturated solution of sodium chloride and water. Brine is the electrolyte in this process. Titanium (Ti) blocks are dipped in the electrolyte. These blocks are connected to the positive terminal of battery so they are anode.

The lower compartment contains a circular steel pipe in which mercury is circulated by means of a mercury pump. The moving mercury is connected to the negative terminal of battery so it is anode. A denuder is also present in the lower compartment. A graphite block is present in the denuder and water is filled inside the denuder. Sodium hydroxide is produced in the denuder.

Working of the Cell:

When electric current is passed through the cell then chloride ions (Cl^- ions) move towards titanium anode and oxidize into chlorine gas by the loss of two electrons. Chlorine gas is ejected at the top of upper compartment.

Sodium ions (Na^+ ions) move towards moving mercury cathode and reduce into sodium metal by the gain of an electron. Sodium metal mixes with mercury to form sodium amalgam. sodium amalgam is then transferred into the denuder where it reacts with water to produce sodium hydroxide and hydrogen gas. The unreacted mercury metal is separated at denuder for further electrolysis of brine.

Cell Reactions:

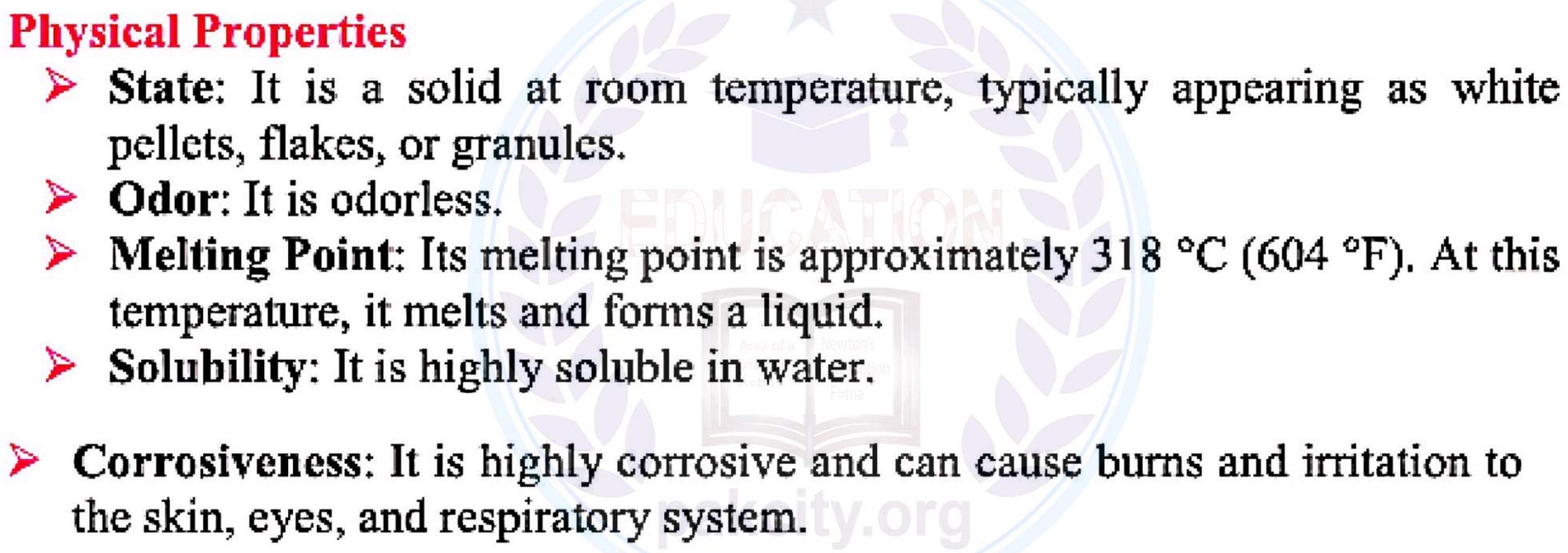
1. Ionization:	$NaCl \rightarrow Na^+ + Cl^-$
2. Reaction at Anode:	$2Cl^- \rightarrow Cl_2 + 2e^-$
3. Reaction at Cathode:	$Na^+ + 1e^- \rightarrow Na/Hg$ (Amalgam)
4. Reaction at Denuder:	$2Na/Hg + 2H_2O \rightarrow 2NaOH + H_2 + 2Hg$

Advantage of the process:

Sodium hydroxide and chlorine gas are produced in different compartments so that the reaction between them is avoided. Otherwise, both the products can react together.

Disadvantage of the process:

This process is not recommended due to the usage of mercury which is toxic in nature. When mercury is discarded into rivers or oceans then it harms fresh water as well as marine life.



Physical Properties

- **State**: It is a solid at room temperature, typically appearing as white pellets, flakes, or granules.
- **Odor**: It is odorless.
- **Melting Point**: Its melting point is approximately 318 °C (604 °F). At this temperature, it melts and forms a liquid.
- **Solubility**: It is highly soluble in water.

- **Corrosiveness**: It is highly corrosive and can cause burns and irritation to the skin, eyes, and respiratory system.

Chemical Properties of NaOH:

Reaction with acids

Being a strong base, it reacts with all acids to produce sodium salt and water.

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(\ell)}$$

$$2NaOH_{(aq)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(\ell)}$$

Reaction with Ferric Chloride

On reaction with aqueous ferric chloride, it gives brown ppt of ferric hydroxide.

$$3NaOH_{(aq)} + FeCl_{3(aq)} \longrightarrow Fe(OH)_{3(s)} + 3NaCl_{(aq)}$$

Reaction with Aluminum and Zinc

Caustic soda can react with aluminum and zinc to form aluminate and zincate salts.

$$2NaOH_{(aq)} + 2Al_{(s)} + 2H_2O_{(\ell)} \longrightarrow 2NaAlO_{2(s)} + 3H_{2(g)}$$

$$2NaOH_{(aq)} + Zn_{(s)} \longrightarrow Na_2ZnO_{2(s)} + H_{2(g)}$$

Reaction with Chlorine

The reaction of hot aqueous sodium hydroxide with chlorine gas gives sodium chloride and sodium chlorate.

$$6NaOH_{(aq)} + 3Cl_{2\,(g)} \longrightarrow NaClO_{3(aq)} + 5NaCl_{(aq)} + 3H_2O_{(l)}$$

Uses of Sodium Hydroxide

- It is a key ingredient in the production of detergents and soaps.
- It is utilized in the production of bleach, such as chlorine bleach, which is commonly used as a disinfectant and stain remover.
- Its strong alkaline nature makes it effective for unclogging drains and pipes by breaking down organic matter.
- It is used to remove heavy metals and adjust pH levels in water, ensuring safe and clean drinking water.
- It is used as a food preservative to prevent bacterial and mold growth, enhancing the shelf life of certain food products.

Bleaching Powder($CaOCl_2$)

Bleaching powder is also known as calcium chloro hypochlorite having chemical formula $CaOCl_2$ or Ca(OCl)Cl. It is a white crystalline powder having chlorine like smell. It is called bleaching powder because it can remove color from any surface. The formula of bleaching powder was suggested by Professor Odling.

Bleaching powder can be prepared in industries by Hasen-Clever's plant. It contains four cast iron pipes fitted with rotating blades. Slaked lime or calcium hydroxide is introduced at the top while chlorine gas is introduced from the bottom. Both the reactants react together to produce bleaching powder.

$$Ca(OH)_{2(aq)} + Cl_{2(aq)} \longrightarrow CaOCl_{2(s)} + H_2O_{(l)}$$

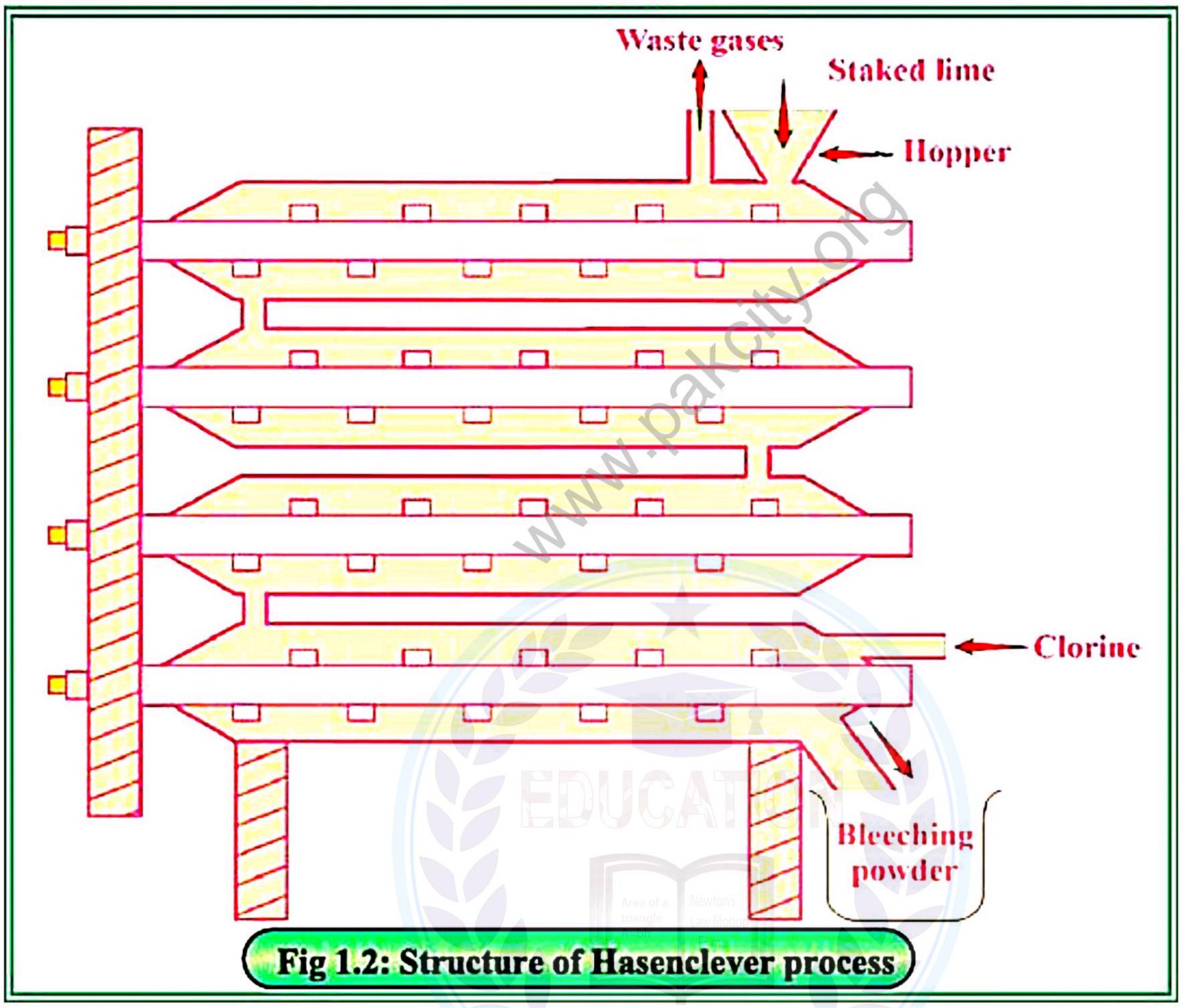


Fig 1.2: Structure of Hasenclever process

Physical Properties of Bleaching Powder

- Bleaching powder has a dirty white appearance.
- It has a distinct chlorine odour.
- It is soluble in water.

Chemical Properties of Bleaching Powder

(i) Reaction with Water

$$CaOCl_2 + H_2O \rightarrow Ca(OH)_2 + Cl_2$$

(ii) Reaction with Acids

$$CaOCl_{2(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(s)} + 2H_2O_{(l)} + Cl_{2(g)}$$

Uses of Bleaching Powder

- It is used for sterilization of water.
- It is used for bleaching of cotton, linen and paper.
- It is used for the preparation of chlorine gas and chloroform.

Selected s-block elements and their compounds	Significant Uses
Sodium (Na)	It helps to regulate the balance of fluids inside and outside our tissues and facilitates the absorption of various nutrients.
Potassium (K)	It helps to balance the pH level in the body.
Calcium (Ca)	It is essential for the growth of bones and teeth.
Common Salt (NaCl)	It is a raw material for the synthesis of various chemicals such as soda ash, caustic soda and chlorine gas etc. It plays a vital role in maintaining electrolyte balance in the body.
Washing Soda ($Na_2CO_3.10H_2O$)	It is used in the manufacturing of glass, soap and borax. It is also used for laundry purpose.
Backing Soda ($NaHCO_3$)	It is used in bakeries to prepare various food items.
Potassium Nitrate (KNO_3)	It is used in fireworks and fertilizer.

REACTIONS OF p-BLOCK ELEMENTS

1) Reaction with Oxygen:

$$4B_{(s)} + 3O_{2(g)} \longrightarrow 2B_2O_{3(s)}$$

$$4Al_{(s)} + 3O_{2(g)} \longrightarrow 2Al_2O_{3(s)}$$

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$

$$N_{2(g)} + O_{2(g)} \xrightarrow{\text{High temp.}} 2NO_{(g)}$$

$$2N_{2(g)} + O_{2(g)} \xrightarrow{\text{Catalyst}} 2N_2O_{(g)}$$

$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

$$2F_{2(g)} + O_{2(g)} \longrightarrow 2OF_{2(g)}$$

2) Reaction with Halogens:

$$2Al_{(s)} + 3Cl_{2(g)} \xrightarrow{\Delta} 2AlCl_{3(s)}$$

$$C_{(s)} + 2Cl_{2(g)} \longrightarrow CCl_{4(l)}$$

$$N_{2(g)} + 3Cl_{2(g)} \longrightarrow 2NCl_{3(g)}$$

$$O_{2(g)} + 2F_{2(g)} \longrightarrow 2OF_{2(g)}$$

3) Reaction with Nitrogen:

$$2B_{(s)} + N_{2(g)} \xrightarrow{\Delta} 2BN_{(s)}$$

$$2Al_{(s)} + N_{2(g)} \xrightarrow{\Delta} 2AlN_{(s)}$$

$$3C_{(s)} + 2N_{2(g)} \xrightarrow{\Delta} C_3N_{4(s)}$$

$$3Si_{(s)} + N_{2(g)} \xrightarrow{\Delta} Si_3N_{4(s)}$$

$$3Cl_{2(g)} + N_{2(g)} \longrightarrow 2NCl_{3(s)}$$

4) Reaction with Hydrogen:

$$Si_{(s)} + 2H_{2(g)} \xrightarrow{\text{High Temperature}} SiH_{4(s)}$$

$$N_{2(g)} + 3H_{2(g)} \xrightarrow{400 - 450°C} 2NH_{3(g)}$$

$$S_{(s)} + H_{2(g)} \xrightarrow{850°C} H_2S_{(g)}$$

$$Cl_{2(g)} + H_{2(g)} \longrightarrow 2HCl_{(g)}$$

CHEMICAL BEHAVIOR OF HALOGENS

Bond enthalpies in halogens

Bond energy in halogens increase down the group due to increasing strength of London dispersion forces but bond energy of fluorine is lesser than chlorine due to the repulsion between electrons of fluorine.

Halogens	Atomic radii (pm)	Bond length (in gaseous phase) (pm)	Bond enthalpies (KJ/mole)
F – F	72	143	159
Cl – Cl	100	199	242
Br – Br	114	228	193
I – I	133	266	151

Acidity of Hydrogen Halides

Hydrogen halides or halogen acids are denoted by HX. Those acids which can loss H^+ ions easily are termed as strong acids. H-I has the weakest bond that's why it is the strongest acid while H-F has the strongest bond that's why it is the weakest acid.

The decreasing order of acidic strength can be given by:

$(HF < HCl < HBr < HI)$

Strength of Halogens as oxidizing agent

Halogens are good oxidizing agents due to their high electronegativities and ability to readily accept electrons. The strength of halogens as oxidizing agent decreases from top to bottom in group VIIA.

$$F_2 > Cl_2 > Br_2 > I_2$$

Halide ions as a reducing agent

Halide ions $(\bar{Cl}, \ \bar{Br}, \bar{I})$ can serve as reducing agents in chemical reactions due to their ability to readily donate electron to an oxidizing species thereby undergoing oxidation.

The decreasing strength of reducing strength of halide ions can be given by:

$$I^- > Br^- > Cl^- > F^-$$

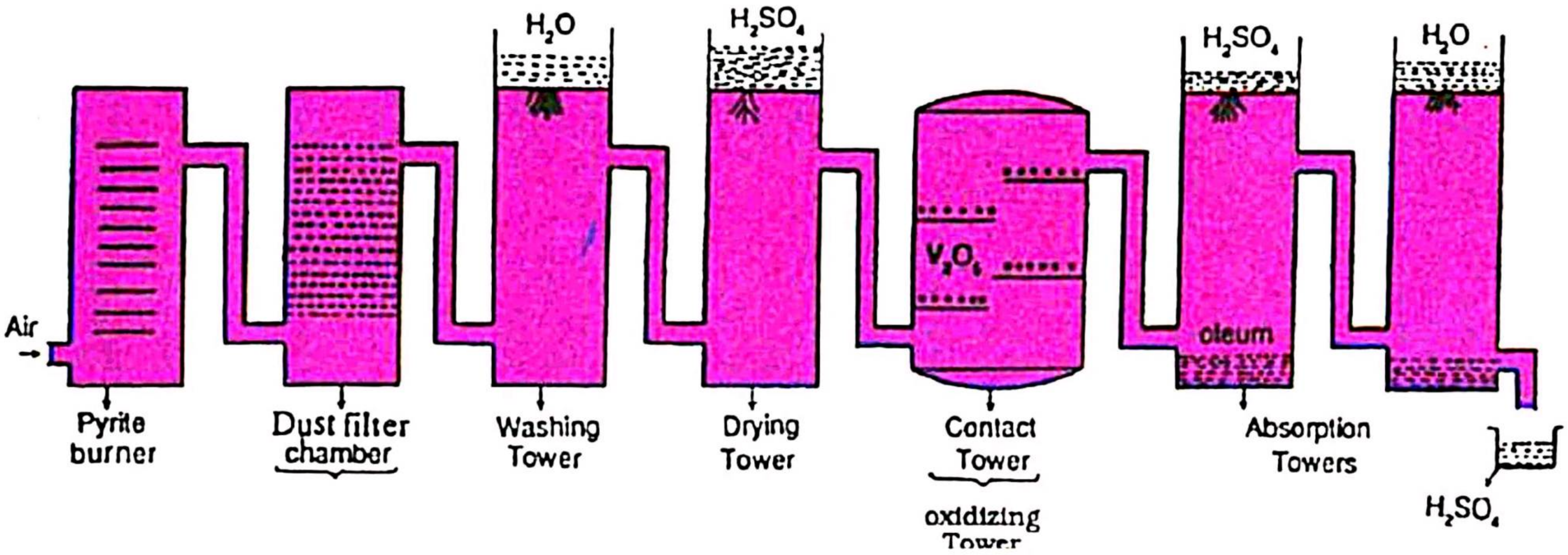
Chlorine as an auto oxidizing and reducing agent

Chlorine reacts with water to form hydrochloric acid and hypochlorous acid. In this reaction chlorine itself reduces into hydrochloric acid and oxidizes into hypochlorous acid and hence serves as auto oxidizing and reducing agent.

$$\underset{\textbf{(Chlorine)}}{Cl_{2(g)}} + H_2O_{(l)} \longrightarrow \underset{\textbf{(Hydrochloric acid)}}{HCl_{(aq)}} + \underset{\textbf{(Hypochlorous acid)}}{HOCl_{(aq)}}$$

INDUSTRIAL PREPARATION OF SULPHURIC ACID (H_2SO_4)

Contact Process



Sulfuric acid is a strong mineral acid having chemical formula H_2SO_4. It is also called oil of vitriol because it was first obtained by green vitriol ($FeSO_4$). Sulfuric acid is known as king of compounds due to its vast industrial usages. Sulfuric acid is prepared in industries in large scale through contact process. This process involves the following five steps:

Step 1: Oxidation of Sulfur to Sulfur Dioxide

First of all, sulfur is burned in the presence of oxygen at high temperature to produce sulfur dioxide gas in sulfur burner.

$$S_{(s)} + O_{2(g)} \xrightarrow{400\text{-}500°C} SO_{2(g)}$$

SO_2 gas produced in sulfur burner is impure. It contains impurities of dust and arsenic oxide (As_2O_3). These impurities must be removed otherwise it could poison the catalyst inside contact tower.

Step 2: Purification of Sulfur Dioxide gas:

The impurities in SO_2 gas are removed in purification chambers. Dust is removed in dust filter. Arsenic oxide is removed in washing chamber by the spray of water. The moisture of SO_2 gas is then removed in dryer. Dryer contains concentrated sulfuric acid which is the dehydrating agent. Pure and dry SO_2 gas is then transferred into contact tower.

Step 3: Oxidation of SO_2 gas:

Contact tower is the most important and biggest tower in this process. Here, SO_2 gas is oxidized into SO_3 gas through a reversible reaction. To obtain the maximum yield of SO_3 gas, Le-Chatelier's principle is applied.

a) Continuous supply of reactants (SO_2 and O_2) is provided

b) Since the reaction is exothermic so maximum yield of SO_3 gas is obtained at low temperature i.e, 500°C.

c) Since the number of moles of reactant are more than the number of moles of product so maximum yield of SO_3 gas is obtained at high pressure i.e, 1-2 atm.

d) A catalyst Vanadium pentoxide (V_2O_5) is used to increase the speed of reaction

$$2SO_{2(g)} + O_{2(g)} \xrightleftharpoons[\text{1-2 atm}]{V_2O_5\ 400\text{-}500^\circ C} 2SO_{3(g)}\ (\Delta H = -45\ \text{Kcal/mol})$$

Step 4: Formation of Oleum ($H_2S_2O_7$)

In the absorption tower, SO_3 gas is absorbed in sulfuric acid to produce oleum. Water cannot be directly added to SO_3 gas for the formation of sulfuric acid because this reaction would be highly exothermic.

$$SO_{3(g)} + H_2SO_{4(l)} \longrightarrow H_2S_2O_{7(l)}$$

Step 5: Formation of Sulfuric Acid (H_2SO_4)

In the dilution tower, water is added to oleum to produce 98% concentrated sulfuric acid.

$$H_2S_2O_{7(l)} + H_2O_{(l)} \longrightarrow 2H_2SO_{4(l)}$$

Physical Properties

- **Boiling Point:** Commercial sulphuric acid has a boiling point of 290ºC. However, the boiling point increases with increasing concentration.
- **Solubility:** Sulphuric acid is highly soluble in water.
- **Corrosive Nature:** Sulphuric acid is a highly corrosive substance and can react with metals and organic compounds etc.

Chemical Properties

An oxidizing agent

In sulphuric acid, sulphur exists in its highest oxidation state of +6. This highest oxidation state of sulphur makes the sulphuric acid to serve as an oxidizing agent when reacts with metals and non metals.

$$C_{(s)} + 2H_2SO_{4(aq)} \longrightarrow CO_{2(g)} + 2SO_{2(g)} + 2H_2O_{(\ell)}$$

$$S_{(s)} + 2H_2SO_{4(aq)} \longrightarrow 3SO_{2(g)} + 2H_2O_{(\ell)}$$

$$Cu_{(s)} + 2H_2SO_{4(aq)} \xrightarrow{\text{(conc.)}} CuSO_{4(aq)} + SO_{2(g)} + 2H_2O_{(\ell)}$$

$$2Al_{(s)} + 6H_2SO_{4(aq)} \xrightarrow{\text{(conc.)}} Al_2(SO_4)_3 + 3SO_{2(g)} + 6H_2O_{(\ell)}$$

A dehydrating agent

The dehydrating ability of sulphuric acid can be attributed to its capability to extract water molecules from other substances.

$$\underset{\text{(glucose)}}{C_6H_{12}O_{6\,(s)}} \xrightarrow{H_2SO_{4(conc.)}} 6C_{(s)} + 6H_2O_{(l)}$$

$$\underset{\text{(sugar)}}{C_{12}H_{22}O_{11(S)}} \xrightarrow{H_2SO_{4(conc.)}} 12C_{(s)} + 11H_2O_{(\ell)}$$

$$\underset{\text{(wood)}}{(C_6H_{12}O_5)_n} \xrightarrow{H_2SO_{4(conc.)}} 6nC_{(s)} + 5nH_2O_{(\ell)}$$

A sulphonating agent

$$\underset{\text{(Benzene)}}{C_6H_{6(l)}} + H_2SO_{4(aq)(conc.)} \longrightarrow \underset{\text{(Benzene sulphonic acid)}}{C_6H_5SO_3H_{(l)}} + H_2O_{(l)}$$

$$\underset{\text{(Toluene)}}{C_7H_{8(l)}} + H_2SO_{4(conc.)} \longrightarrow \underset{\text{(p-toluene sulphonic acid)}}{C_6H_4(CH_3)SO_3H_{(l)}} + H_2O_{(l)}$$

A dibasic acid

Sulphuric acid has the ability to donate two protons in water in two dissociation steps and serves as dibasic acid.

$$H_2SO_{4(aq)} \rightleftharpoons H_3O^+ + HSO^-_{4(aq)}$$

$$HSO^-_{4(aq)} \rightleftharpoons H_3O^+ + SO^{-2}_{4(aq)}$$

Uses of Sulphuric acid

Sulphuric acid is used in various industries for:

- Producing fertilizers, dyes, pigments, detergents, pharmaceuticals, and synthetic fibers.
- Refining petroleum to make high-octane gasoline additives.
- Processing and purifying metals, including removing rust and scale.
- Etching and electroplating processes.
- Manufacturing lead-acid batteries.
- Cleaning and descaling due to its strong acidic properties.

DIAGONAL RELATIONSHIP OF REPRESENTATIVE ELEMENTS

The diagonal relationship refers to the resemblance in the properties exhibited by certain pairs of elements that are located diagonally to each other within the periodic table.

Periods	**Groups**			
	IA	**IIA**	**IIIA**	**IVA**
Second	Li ↘	Be ↘	B ↘	C
Third	Na	Mg	Al	Si

Important functions of selected elements and compounds of representative elements

Element/Compound	Significant Uses
Aluminum	It is used in making coils, alloys, kitchen utensils, window frames, chocolate foils etc.
Sulphur	It is used in the manufacturing of sulphuric acid, hydrogen sulphide and pesticides.
Chlorine	It is used in the manufacturing of plastic, bleaching powder and in the purification of drinking water.
Borax ($Na_2B_4O_7.10H_2O$)	It is used in cleaning, laundry, cosmetics and as flux in welding.
Alum ($K_2SO_4.Al_2SO_4.24H_2O$)	It is used for the purification of water, tanning of leather, fire extinguishers and as an antiseptic for minor cuts and wounds.
Ammonia (NH_3)	It is used in the manufacturing of fertilizers, nitric acid and refrigeration.