Chapter # 1

Chemistry Of Representative Elements

GENERAL GROUP TRENDS OF REPRESENTATIVE ELEMENTS

Elements in the long form of periodic table are arranged according to their increasing atomic number and electronic configuration in such a manner that their general properties are correlated to each other.
They exhibit a regular trend in properties within each group, with some exceptions or anomalies occurring in specific positions.

Group Trend

The regular variations in the properties of elements in a group of periodic table is called group trend

Atomic Radii

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

Group Trends

IA and IIA Groups

- ✓ Elements of group IA are termed as alkali metals.
- ✓ They possess the largest atomic radii in their respective periods.
- ✓ However the atomic radii increase regularly from lithium to francium.
- ✓ It is because the number of energy levels occupied by electrons increases, resulting in an increase in the distance between the nucleus and the outermost electronic shell.
- ✓ The same trend applies to the elements of group IIA (Be to Ra).
- ✓ That means beryllium is the smallest alkaline earth metal (IIA) and barium is the largest.

Alkali Metals (Group IA)	Atomic Radii (pm)
Li	152
Na	186
K	227
Rb	248
Cs	264
Fr	348

Alkaline Earth Metals (Group IIA)	Atomic Radii (pm)
Be	112
Mg	145
Ca	194
Sr	219
Ba	253
Ra	215

IIIA Group

- ✓ Atomic radii of the elements of Boron family (Group IIIA) generally increase down the group (from boron to thallium).
- ✓ There is an exception to the trend between aluminium and gallium. Gallium has slightly smaller atomic radii than aluminium despite being located below it in the group.
- ✓ It is because of poor shielding effect caused by electrons of d-orbitals.

IVA to VIIIA Groups

- ✓ The atomic radii of elements of Group IVA to Group VIlIA follow the similar group trend, increasing regularly from top to bottom within the group.
- ✓ The same reason for this trend is discussed as in the group trend of alkali metals.

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

Ionization Energy

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

Group Trends

IA and IIA Groups

- ✓ The ionization energy of alkali metals (Group IA) and alkaline earth metals (Group IIA) decreases as we move down the group.
- ✓ This is because the outermost electrons of these elements are located farther away from the nucleus as we go from top to bottom, leading to weaker attractive forces between the electrons and the nucleus.
- ✓ As a result, it requires less energy to remove the outer shell electrons from the atom, that is why the ionization energy decreases.

IIIA Group

- ✓ The ionization energy (IE) trend in group IIIA elements has irregularities as we move down the group.
- ✓ Two exceptions highlight this irregularity. Firstly, gallium (Ga) has a higher ionization energy than aluminium (A). Secondly, thallium (TI) exhibits a higher ionization energy than indium (n). These irregularities occur due to insufficient shielding of the nuclear charge in gallium
- ✓ by 3d electrons and in thallium by 4f electrons.

IVA Group

- ✓ The ionization energy of group IVA elements generally decreases from top to bottom in the group. There are irregularities observed between Tin (Sn) and Lead (Pb).
- ✓ This is because both tin and lead have nearly the same atomic radii, which is a result of the lanthanide contraction.
- ✓ Due to this, the attraction between the nucleus and the outer electrons becomes stronger and requires more energy to remove these electrons.

VA, VIA, VIIA and VIIIA Groups

- ✓ The ionization energy of the remaining groups of representative elements (group VÀ, VIA, VIIA, VIIIA) follows a regular pattern.
- ✓ It decreases progressively from top to bottom as the atomic radii increase,

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

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".

Group Trends

IA and IIA Groups

- ✓ The electronegativity (EN) of alkali metals (Group IA) and alkaline earth metals (Group IIA) follows a regular decreasing trend from top to bottom.
- ✓ This trend can be explained by the regular increase in atomic radii as we move down the group.
- ✓ The larger atomic size results in a decreasing tendency for the atom to attract the shared pair of electrons towards itself.

IIIA Group

- ✓ The electronegativity (EN) of group III elements initially decreases from Boron (B) to Aluminium (Al) and then increases from gallium (Ga) to tellurium (Te).
- ✓ This irregular increase in EN can be attributed to the poor shielding effect of the electrons in the d-orbital and f-orbitals, respectively.

IVA, VA, VIA and VIIA Groups

- ✓ The electronegativity of groups IVA, VÀ, VIA, and VIIA decreases regularly from top to bottom.
- ✓ This trend can be explained by the same reason as discussed for alkali metals

IA	IIA	IIA	IVA	VA	VIA	VIIA
Li	**Be**	**B**	**C**	**N**	**O**	**F**
-1	-1.5	-2	-2.5	-3	-3.5	-4
Na	**Mg**	**Al**	**Si**	**P**	**S**	**CI**
-0.9	-1.2	-1.5	-1.9	-2.1	-2.5	-3
K	**Ca**	**Ga**	**Ge**	**As**	**Se**	**Br**
-0.8	-1	-1.6	-1.8	-2	-2.4	-2.8
Rb	**S**	**In**	**Sn**	**Sb**	**Te**	**I**
-0.8	-0.95	-1.7	-1.8	-1.9	-2.1	-2.5
Cs	**Ba**	**TI**	**Pb**	**Bi**	**Po**	**At**
-0.7	-0.9	-1.8	-1.8	-1.9	-2	-2.2

Electrical Conductivity

"Electrical conductivity is the measurement of a material's capability to conduct electric current".

- ✓ Materials with high electrical conductivity allow electric current to pass through them easily, while materials with low electrical conductivity hinder the flow of electric charges.
- ✓ The electrical conductivity of representative elements can vary widely. Alkali metals and alkaline earth metals generally exhibit high electrical conductivity due to their ability to easily transfer electrons.
- ✓ Group IIA elements display moderate electrical conductivity, while elements in Group IVA can have variable conductivity ranging from poor (e.g., carbon and lead) to moderate (e.g., silicon and tin). Group VA, VIA, and VILA elements typically have poor electrical conductivity.

- ✓ Noble gases, on the other hand, have extremely low electrical conductivity as shown in Table

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".

The oxidation states of representative elements depend on their position in a particular group of periodic table.

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, t6
VIIA (Halogens)	F, CI, Br, I, At	-1, +1, +3, +5, +7
VIIIA (Noble Gases)	He, Ne, Ar, Kr, Xe, Rn	0

Melting and Boiling Point

- ✓ The melting and boiling points of representative elements can vary widely across the periodic table.
- ✓ Alkali metals have low melting and boiling points due to weak metallic bonding,
- ✓ while alkaline earth metals have higher melting and boiling points due to stronger metallic bonding
- ✓ Moving across the p-block elements, the melting and boiling points generally increase gradually.

- ✓ However, there are exceptions in groups IVA and VA. Carbon has a high melting point due to strong covalent bonds, while nitrogen has low melting and boiling points because it exists as diatomic molecules with weak intermolecular forces.
- ✓ Halogens have low melting and boiling points due to weak intermolecular forces, and noble gases have extremely low melting and boiling points due to weak interatomic forces.
- ✓ The melting and boiling points of representative elements reflect the different bonding types and intermolecular forces within each group, resulting in a wide range of physical properties.

Melting point of representative element in °C

IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
Li	**Be**	**B**	**C**	**N**	**O**	**F**	**Ne**
-180	-1278	-2300	-3700	-210	-219	-220	-248
Na	**Mg**	**Al**	**Si**	**P**	**S**	**CI**	**Ar**
-97.8	-651	-658	-1410	-34	-119	-102	-186
K	**Ca**	**Ga**	**Ge**	**As**	**Se**	**Br**	**Kr**
-63.7	-843	-297	-937	-814	-217	-7.2	-157
Rb	**Sr**	**In**	**Sn**	**Sb**	**Te**	**I**	**Xe**
-39	-769	-155	-232	-630	-450	-114	-112
Cs	**Ba**	**TI**	**Pb**	**Bi**	**Po**	**At**	**Rn**
-28.6	-725	-303	-327	-271	-	-302	-71

Unique behaviour of Beryllium in group IIA

- ✓ Beryllium differs markedly from its other members because of its smaller atomic radii and high electronegativity.
- ✓ Some unique characteristics shown by beryllium in comparison to other elements of group IIA are given as:
- ✓ Beryllium is harder and more rigid than other members of group IIA.
- ✓ Beryllium has relatively low density and high melting point compared with other group members.
- ✓ Beryllium exhibits chemical stability due to the formation of protective oxide layer on its surface which prevents further oxidation and corrosion.
- ✓ Beryllium has tendency to form covalent bonds with other elements due to its smaller atomic size while other members of the group form ionic bonds.

REACTIONS OF REPRESENTATIVE ELEMENTS

s-block elements

Some common reactions of the elements of group IA and IIA are given as.

1. With oxygen

Alkali metals rapidly react with oxygen to produce oxides. Lithium forms normal oxide (oxidation state of oxygen -2), sodium forms peroxide (oxidation state of oxygen is -1) in excess of air while the rest of the elements of group IA form superoxides (oxidation state of oxygen is).

$4Li + O_2 \longrightarrow 2Li_2O$ (Normal Oxide)
$2Na + O_2 \longrightarrow Na_2O_2$ (Per Oxide)
$4K + O_2 \longrightarrow 2KO_2$ (Super Oxide)
$4Rb + O_2 \longrightarrow RbO_2$ (Super Oxide)
$4Cs + O_2 \longrightarrow CsO_2$ (Super Oxide)

The reaction of alkaline earth metals with oxygen takes place at high temperature. However, on oxidation, beryllium, magnesium and calcium form normal oxides while strontium and barium form peroxides.

General Reactions

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

General Reactions

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

2. With Water

Alkali metals react with water to produce metal hydroxides with the liberation of hydrogen gas.

General Reaction

$2M + 2H_2O \longrightarrow 2MOH + H_2$
(Where M= Li, Na, K, Rb, Cs).

$2Li + 2H_2O \longrightarrow 2LiOH + H_2$
$2Na + 2H_2O \longrightarrow 2NaOH + H_2$
$2K + 2H_2O \longrightarrow 2KOH + H_2$
$2Rb + 2H_2O \longrightarrow 2RbOH + H_2$
$2Cs + 2H_2O \longrightarrow 2CsOH + H_2$

Among alkaline earth metals beryllium does not react with either cold or steam, but magnesium reacts with steam.

General Reactions

$M + 2H_2O \longrightarrow M(OH)_2 + H_2\uparrow$
(Where M = Mg, Ca, Sr and Ba).

$Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2\uparrow$
$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2\uparrow$
$Sr + 2H_2O \longrightarrow Sr(OH)_2 + H_2\uparrow$
$Ba + 2H_2O \longrightarrow Ba(OH)_2 + H_2\uparrow$

3. With halogens

Alkali metals react vigorously with halogens to form metal halides. The reaction involves the transfer of electron from an alkali metal to a halogen.

General Reaction With Group IA

$2M + X_2 \longrightarrow 2MX$

(Where M= Li, Na, K, Rb, Cs) & (X = Cl, Br I)

General Reaction With Group IIA

$2M + X_2 \longrightarrow MX_2$

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

4. With nitrogen

Nitrides are formed when both alkali metals and alkaline earth metals react with nitrogen. The general formula for the nitrides of alkali metals is M_3N and for the nitrides of alkaline earth metals is the formula M_3N_2.

General Reaction

$6M + N_2 \longrightarrow 2M_3N$ (M= Li, Na, K, Rb, Cs)
$3M + N_2 \longrightarrow M_3N_2$ (M= Be, Mg, Ca, Sr, Ba)

5. With hydrogen

Alkali and alkaline earth metals react with hydrogen at different temperatures to produce ionic hydrides.

General Reaction

$2M + H_2 \longrightarrow 2MH$ (M=Li, Na, K, Rb, Cs)
$M + H_2 \longrightarrow MH_2$ (M = Ca, Sr, Ba)

6. With alcohols

Elements of group IA react vigorously with alcohols to form metal alkoxide with the liberation of hydrogen gas.

General Reaction

$2M + 2C_2H_5OH \longrightarrow 2C_2H_5OM + H_2$ (M= Li, Na, K, Rb, Cs)

Alkaline earth metals have a very limited reactivity with alcohols.

7. With acids

Alkali metals react vigorously with acids to produce salt with the liberation of hydrogen gas. This reaction is highly exothermic and violent.

General Reaction

$2M + 2HCl \longrightarrow$ 2MCl t H2 (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".

Colour flames of alkali and alkaline earth metals

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

CHEMISTRY OF IMPORTANT COMPOUNDS OF S-BLOCK ELEMENTS

Sodium Hydroxide or Caustic Soda (NaOH)

Sodium hydroxide is one of the most important chemicals. Sodium hydroxide is commonly known as 'Caustic Soda' because it is caustic (able to burn) to touch and causes painful burns, therefore it must be handled with care.

Manufacture of Sodium hydroxide by Castner-Kellner's Process:

Sodium hydroxide is manufactured by an electrolytic process, known as Castner-Kellner's process.

Raw Material:

25% (W/W) solution of sodium chloride.

Apparatus:

Castner-Kellner's cell

Construction of Castner-Kellner's Cell:

Castner-Kellner's cell is an electrolytic cell in which anode consist of number of titanium plates dipped in sodium chloride solution. The cathode is a moving mercury layer at the bottom of the cell. Mercury flows from left to right. Saturated solution of NaCl also flows in the same direction. There is another lower chamber known as denuder, which is filled with water and packed with graphite blocks as hydrogen is easily liberated over graphite surface.

Process in the Cell:

Ionization:

$$2NaCl \longrightarrow 2Na^{+} + 2Cl^{-}$$

Reaction at Anode:

On passing electric current Cl- ions migrate towards anode and after oxidation liberated as chlorine gas.

$$2Cl^{-} \longrightarrow Cl_2 + 2e^{-}$$

Reaction at Cathode:

Na+ ions are discharge over mercury surface and dissolved in it forming sodium amalgam.

$$2Na^{+} + 2e^{-} \longrightarrow 2Na$$

$$2Na + 2Hg \longrightarrow 2Na/Hg \text{ (sodium amalgam)}$$

Reaction in Denuder:

The mercury containing dissolved sodium is sent to denuder chamber where sodium reacts with water forming sodium hydroxide and hydrogen gas is liberated.

$$2Na/Hg + 2H_2O \longrightarrow 2NaOH + H_2 + 2Hg$$

The mercury is recycled to upper cell to dissolve more sodium

Advantages of the Process:

- ✓ The process is very efficient.
- ✓ The products are of high purity.

- ✓ The possible reaction between NaOH andCl2 is avoided by obtaining NaOH and Cl_2 in separated compartment.

Disadvantages of the Process:

- ✓ This process consumes large amount of electricity.
- ✓ In spite of strict control some mercury vapors escapes into environment and producing the pollution of food
- ✓ chains.
- ✓ The use of this process has been banned and is being replaced by Gibb's diaphragm cell process which does not use
- ✓ mercury but gives the products of high purity.

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.
- ✓ **Density:** The density of NaOH depends on its concentration and temperature. For a 50% concentration at room temperature, the density is approximately 1.52 g/cm^3.
- ✓ **Corrosiveness:** It is highly corrosive and can cause burns and irritation to the skin, eyes, and respiratory system.

Chemical Properties

1. Reaction with acids

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

$$NaOH + HCl \longrightarrow NaCl + H_2O$$
$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_20$$

2. Reaction with Ferric Chloride

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

$$3NaOH + FeCl_3 \longrightarrow Fe(OH)_3 + 3NaCl$$

3. Reaction with Aluminium and Zinc

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

$$2NaOH + 2Al + 2H_20 \longrightarrow 2NaAlO_2 + 3H_2$$
$$2NaOH + Zn \longrightarrow Na_2ZnO_2 + H_2$$

4. Reaction with Chlorine

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

$$6NaOH + 3Cl_2 \longrightarrow NaClO_3 + 5NaCl + 3H_20$$

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.
- ✓ It is utilized in the canning process to remove the outer skin of fruits and vegetables, ensuring food safety and quality.

Bleaching Powder {Ca(OCl)Cl or CaOCl2}

The chemical formula bleaching powder suggested by Professor Odling is Ca(OCl)Cl or CaOCl2. It is a white amorphous powder with smell of chlorine.

Preparation:

In industrial scale bleaching powder is prepared by "Hasen Clever process". The plant consist of number of iron cylinders in which chlorine is brought in contact with slaked lime {Ca(OH)2} and bleaching powder is formed

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

Reactions:

1. **With Water:**

In aqueous solution it liberates Cl_2 gas

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

2. **With Acids:**

When it reacts with acids, Cl2 gas is liberated.

$$CaOCl_2 + 2HCl \longrightarrow CaCl_2 + Cl_2 + H_2O$$

3. **With atmospheric CO_2 and moisture:**

When it reacts with atmospheric CO_2 and moisture, HOCl is liberated.

$$2CaOCl_2 + CO_2 + H_2O \longrightarrow CaCl_2 + CaCO_3 + 2HOCl$$

Uses:

- ✓ It is used in sterilization of drinking water.
- ✓ It is used for bleaching of cotton, linen and paper pulp.
- ✓ It used for the preparation of Cl_2 gas and Chloroform ($CHCl_3$).
- ✓ It plays a role in the paper making industry, where is used for pulping wood fibers and paper recycling processes.

Selected s-block elements and Significant Uses their compounds

❖ 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.

❖ Magnesium Mg

It helps in muscle contraction and maintain the bones and heart functions.

❖ 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

Some important chemical reactions involving p-block elements are given below.

1. With oxygen

The reactions of p-block elements with oxygen produce either normal Oxides or in some cases peroxides.
Elements of group IIIA react with oxygen to produce oxides of the formula M_2O_3.

$$4B + 3O_2 \longrightarrow 2B_2O_3$$
$$4Al + 3O_2 \longrightarrow 2Al_2O_3$$

In group IVA, carbon forms carbon monoxide and carbon dioxide when it reacts with oxygen while silicon form only one stable silicon oxide(SiO_2).

$$C + O_2 \longrightarrow CO_2$$
$$2C + O_2 \longrightarrow 2CO$$
$$Si + O_2 \xrightarrow{\text{above } 900^\circ C} SiO_2$$

In group VA, nitrogen forms NO, N,O and NO, when reacts with oxygen depending upon the conditions applied. Phosphorus may form P,0, in limited supply of Oxygen whereas P,0, in excess of oxygen.

$$N_2 + O_2 \xrightarrow{\text{High temp}} 2NO$$
$$2N_2 + O_2 \xrightarrow{\text{Catalyst}} 2N_2O$$
$$4P + 3O_2 \xrightarrow{\text{Limited oxygen}} 2P_2O_3$$
$$4P + 5O_2 \xrightarrow{\text{Excess oxygen}} 2P_2O_5$$

A In group VIA, sulphur oxidized in air to give sulphur dioxide.

$$S + O_2 \longrightarrow SO_2$$

Halogens can also react with oxygen however their oxides are mostly highly reactive.

For example the oxide of fluorine is a highly reactive yellow gas.
The oxides of halogens are very unstable.

$$2F_2 + O_2 \longrightarrow 2F_2O$$

2. With water

The reaction of p-block elements with water depends on the nature of element and the group to which it belongs.
Aluminium reacts with water but the reaction is slow due to the presence of a thin oxide film on its surface.

$$2Al + 6H_20 \longrightarrow 2AI(OH)_3 + 3H_2$$

Silicon reacts with steam and forms silicon dioxide.

$$Si + 2H_20 \longrightarrow SiO_2 + 2H_2$$

Phosphorus reacts vigorously with water to produce phosphoric acid and phosphine.

$$2P_4 + 12H_2O \longrightarrow H_3PO_4 + 5PH_3$$

Sulphur reacts if it is heated to a high temperature.

$$S + 2H_2Oo) \xrightarrow{high\ temp} SO_2 + 2H_2$$

Halogens such as chlorine and bromine react with water to form a mixture of two acids.

$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$
$$Br_2 + H_2O \longrightarrow HBr + HOBr$$

3. With halogens

Majority of p-block elements have the capability to react with halogens, resulting in the formation of binary compounds.

$$2Al + 3Cl_2 \longrightarrow 2AlCl_3$$
$$C + 2Cl_2 \longrightarrow CCl_4$$
$$N_2 + 3Cl_2 \longrightarrow 2NCl_3$$
$$O_2 + 2F_2 \longrightarrow 2F_2O$$

4. With nitrogen

The reaction of p-block elements with nitrogen can vary depending on the specific element and the reaction conditions.
Boron and aluminium react with nitrogen to form their nitrides.

$$2B + N_2 \longrightarrow 2BN$$
$$2Al + N_2 \longrightarrow 2AIN$$

Carbon and Silicon can form nitrides when heated with nitrogen at high temperatures.

$$3C + 2N_2 \xrightarrow{\Delta} C_3N_4$$

$$3Si + N_2 \longrightarrow Si_3N_4$$

Phosphorus reacts with nitrogen at high temperatures to form phosphorus nitride (P_3N_5).

$$6P + 5N_2 \longrightarrow 2P_3N_5$$

Halogen (Cl_2 ,Br_2) can react with nitrogen to form nitrogen trihalide.

$$3Cl_2 + N_2 \longrightarrow 2NCl_3$$

5. With hydrogen

Elements of group IIA and IVA do not directly react with hydrogen, however silicon at high temperatures may form silicon hydrides.

$$Si + 2H_2 \xrightarrow{High\ Temperature} SiH_4$$

Nitrogen reacts with hydrogen under high pressure to form ammonia.

$$N_2 + 3H_2 \xrightarrow{400-450^\circ C} 2NH_3$$

Sulphur reacts with hydrogen at high temperatures to form hydrogen sulphide.

$$S + H_2 \xrightarrow{850^\circ C} H_2S$$

The reaction of halogen with hydrogen can result in the formation of hydrogen halides.

$$Cl_2 + H_2 \longrightarrow 2HCl$$

CHEMICAL BEHAVIOR OF HALOGENS

Halogens include fluorine (F), chlorine (CI), bromine (Br), iodine (I) and astatine (At). The reactivity of halogens is determined by their bond enthalpies and their ability to undergo redox reactions.

Bond enthalpies in halogens

The enthalpy is required for the dissociation of halogen-halogen bond in gaseous state and it varies according to size of halogen atom, bond length and the intermolecular attraction.

Halogen	Atomic radii (pm)	Bond Length (in gaseous phase) pm	Bond enthalpies (kj/mol)
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 (HX) are strong mineral acids and their acidity follows an increasing trend from HF to HI (HF < HCl< HBr < HI). The increasing order of acidity of hydrogen halides can be attributed to their bond energies. Since the bond energy of H-I is the smallest, it can easily donate a proton and serves as the strongest acid compared to other halogen acids.

Halogen acids	H – F	H – Cl	H – Br	H – I
Bond energies (KJ/mol)	565	432	366	299

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

Among halide ions, there is a trend in relative strength of reducing agents I> BF >
Cl > F. This means that iodide ion is the strongest reducing agent while fluoride ion is the weakest.

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.

$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$

(Chlorine) (Hydrochloric acid) (Hypochlorous acid)

MANUFACTURING OF SULPHURIC ACID (OIL OF VITRIOL) BY CONCTACT METHOD:

Raw Materials:

- ✓ Sulphur or iron pyrites (FeS_2)
- ✓ Air (O_2)
- ✓ Water (H_2O)
- ✓ Catalyst: Vanadium penta oxide (V_2O_5)

Details of Process:

Formation of 'SO_2':

In first step SO_2 is formed by the combustion of sulphur or iron pyrite in pyrite burner.

$$S + O_2 \longrightarrow SO_2$$

OR

$$4FeS_2 + 11O_2 \longrightarrow 3Fe_2O_3 + 8SO_2$$

Mixture of SO_2 and air is passed through special filters, washing and drying towers. As a result of this impurities are left behind and purified mixture of SO_2 and air is entered into contact tower.

Reaction in contact tower:

In contact tower SO_2 is oxidized to SO_3 in presence of catalyst vanadium penta oxide

$$2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3 \quad \Delta H = -45 \text{ K.cal}$$

Favorable conditions:

Since, reaction is reversible and exothermic so, the favorable conditions for obtaining maximum yield of SO3 are:

a) Low temperature (400^{0}C to 450^{0}C)
b) High pressure (1.5 to 1.7 atm)
c) Excess of oxygen.

Under these conditions, the equilibrium mixture contains 98% of SO_3.

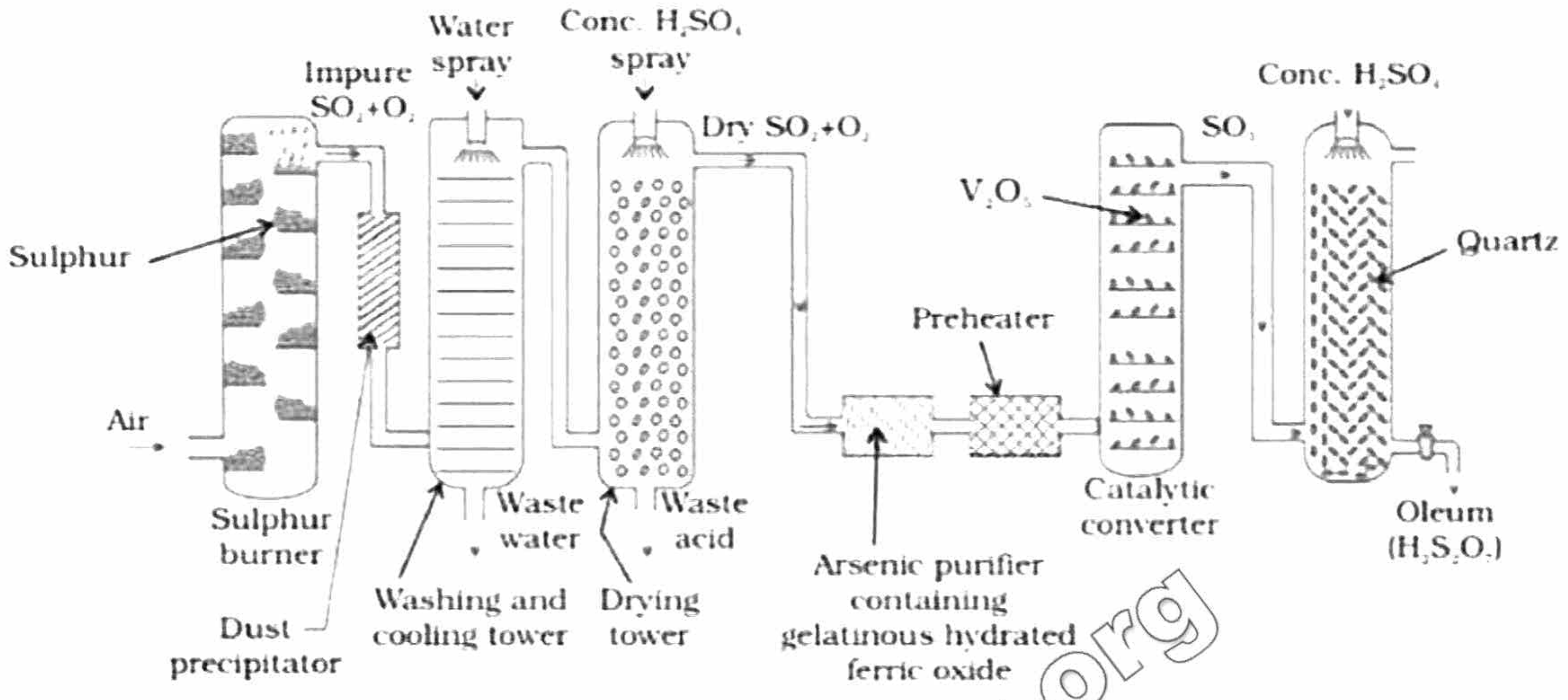
Formation of oleum:

The SO_3 produced in contact tower absorbed H_2SO_4 in absorption tower to form oleum.

$$SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$$

Formation of H_2SO_4:
Oleum absorbed calculated amount of water in last absorption tower to form sulphuric acid of desired concentration.

$$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$$



Flow diagram for the manufacture of sulphuric acid

Physical Properties

- ✓ Density: Sulphuric acid has a high density, typically around 1.84 g/cm^3.
- ✓ Melting Point: Sulphuric acid has no distinct melting point since it can
- ✓ Supercool below its freezing point. The freezing point of sulphuric acid is approximately 10°C but it can vary depending on the concentration.
- ✓ Boiling Point: Commercial sulphuric acid has a boiling point of 290°C. 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 of H_2SO_4

1. 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.

$$C + 2H_2SO_4 \longrightarrow CO_2 + 2SO_2 + 2H_2O$$
$$S + 2H_2SO_4 \longrightarrow 3SO_2 + 2H_2O$$
$$Cu + 2\ H_2SO_4 \xrightarrow{(conc.)} CuSO_4 + SO_2 + 2H_2O$$
$$2Al + 6\ H_2SO_4 \xrightarrow{(conc.)} Al_2(SO_4)_3 + 3SO_2 + 6H_2O$$

2. A dehydrating agent

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

$$C_6H_{12}O_6 \xrightarrow{H_2SO_4(conc)} 6C + 6H_2O$$
(glucose)

$$C_{12}H_{22}O_{11} \xrightarrow{H_2SO_4(conc)} 12C + 11H_2O$$
(sugar)

$$(C_6H_{12}O_5)_n + \xrightarrow{H_2SO_4(conc)} 6nC + 5nH_2O$$
(wood)

3. As sulphonating agent

Sulphonation involves the introduction of sulphonic group (SO_3H) into a molecule. Sulphuric acid serves as a source of sulphonic group which can be added to organic compounds to create new molecules.

$$C_6H_6 + H_2SO_{4\,(conc)} \longrightarrow C_6H_5SO_3H + H_2O$$
(Benzene) (Benzene sulphonic acid)

$$C_7H_8 + H_2SO_{4\,(conc)} \longrightarrow C_6H_4(CH_3)SO_3H + H_2O$$
(Toluene) (p-toluene sulphonic acid)

4. As dibasic acid

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

$$H_2SO_4 \rightarrow H_3O^+ + HSO_4^-$$
$$HSO_4^- \rightarrow H_3O^+ + SO_4^{-2}$$

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.

Diagonal Relationship

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	II A	III A	IV A
Second	Li	Be	B	C
Third	Na	Mg	Al	Si

There are three pairs of elements that exhibit the diagonal relationship in the second and third periods of representative elements.
Diagonal relationship between

- ✓ lithium and magnesium,
- ✓ Beryllium and Aluminium,
- ✓ Boron and Silicon

Li and Mg

- ✓ Both have almost similar atomic radii (Li = 152pm and Mg =160pm).
- ✓ Both have almost similar electronegativities (Li = 1.0 and Mg 1.2)
- ✓ Both are lighter in their respective group.
- ✓ Oxide of both Li and Mg are very less soluble in water compared to other elements of the respective group.

Be and Al

- ✓ Both Be and Mg have same EN (1.5).
- ✓ Both show passivity with conc. Nitric acid.
- ✓ $BeCl_2$ and $AlCl_3$ both acts as Lewis acid.

B and Si

- ✓ Both B and Si have closer EN (B 2.0 and Si 1.8).
- ✓ Both B and Si have nearly same density (B=2.35g/cm3, Si= 2.34g/cm3).
- ✓ Both B and Si are metalloids and both of these do not form cation.

Element/Compound Significant Uses

❖ Aluminium

- ✓ 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.

Short Question Answers

Q1. Give Reasons Of the following.

(i) Ionization energy decreases from top to bottom in s-block elements?

This is because as we move down the group, the valence electrons are added to higher and higher energy shells. As a result, they are further away from the nucleus and are less strongly attracted to it. This makes them easier to remove, which corresponds to a lower ionization energy.

(ii) Boiling point of halogens increase down the group in the periodic table?

This is because the boiling point of a substance is determined by the strength of the intermolecular forces between its molecules. Halogens are non-polar molecules, and the main intermolecular force between them is van der Waals forces. Van der Waals forces are weak forces, but they increase in strength as the size and mass of the molecule increases. As we move down the halogen group, the size and mass of the atoms increase, so the van der Waals forces between them increase. This results in a higher boiling point.

(iii) Gallium has smaller atomic radii than aluminium despite being below the aluminium in group IIIA?

This is because of the lanthanide contraction. The lanthanides are a group of 15 elements that come between lanthanum and lutetium in the periodic table. They have a very similar atomic structure, and as a result, their atomic radii decrease gradually from left to right. This contraction also affects the elements below the lanthanides, causing their atomic radii to be smaller than expected.

(iv) Electronegativities of alkali metals decrease from Li to Cs?

Electronegativity is a measure of how strongly an atom attracts electrons. Alkali metals have a single valence electron in the outermost s shell. This valence electron is relatively loosely held, so alkali metals are not very electronegative. As we move down the alkali metal group, the size of the atom increases. This means that the valence electron is further away from the nucleus, which makes it even less strongly attracted. As a result, the electronegativity of alkali metals decreases from Li to Cs.

(v) Alkali metals are good conductor of electricity.?

Alkali metals are good conductors of electricity because they have a low ionization energy and a large atomic radius. This means that their valence electrons are loosely held and can easily move around. When an electric current is applied, these valence electrons flow towards the positive terminal, creating an electric current.

(vi) Acidity of hydrogen halides increase from HF to HI?

The acidity of a hydrogen halide is determined by the strength of the bond between the hydrogen atom and the halogen atom. As we move down the halogen group, the size of the halogen atom increases. This makes the bond between the hydrogen atom and the halogen atom weaker. As a result, the hydrogen atom is more easily lost, and the hydrogen halide is more acidic.

(vii) Fluorine is the strongest oxidizing agent?
Fluorine is the strongest oxidizing agent because it has the highest electronegativity of all the elements. This means that it has a very strong tendency to attract electrons from other atoms. When fluorine reacts with another atom, it often strips the other atom of its electrons, forming an ion. This is why fluorine is such a powerful oxidizing agent.

Q2. What is flame test? Mention the colour of flame of alkali metals.
"Flame test is a qualitative method used to identify the presence of alkali metals based on their characteristic flame colours".

Colour flames of alkali

Elements	Flame Colour
Lithium	Red
Sodium	Yellow
Potassium	Violet
Rubidium	Red Violet
Cesium	Blue Violet

Q3. Explain the auto oxidizing and reducing properties of chlorine.
Auto-oxidation and reduction of chlorine
Auto-oxidation and reduction is a type of redox reaction in which a substance reacts with itself to produce both oxidized and reduced forms of the substance. Chlorine can undergo auto-oxidation and reduction, as shown in the following equation:

$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$

In this reaction, one chlorine molecule is oxidized to hypochlorous acid (HOCl), while the other chlorine molecule is reduced to chloride ions (Cl-). The hypochlorous acid produced in this reaction is also a strong oxidizing agent, and it can be used to bleach and disinfect.
Examples of the auto-oxidizing and reducing properties of chlorine

- **Auto-oxidation:**
When chlorine gas is bubbled into water, it reacts with water to form hydrochloric acid and hypochlorous acid. The hypochlorous acid is a strong oxidizing agent, and it can be used to bleach and disinfect.
- **Auto-reduction:**
When chlorine gas is reacted with hot sodium hydroxide solution, it is reduced to chloride ions. This reaction is used to produce sodium hypochlorite (NaClO), which is a common bleaching agent and disinfectant.

Q4. What is meant by a diagonal relationship? Mention three pairs of representative elements that show diagonal relationship.
Diagonal Relationship

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.
There are three pairs of elements that exhibit the diagonal relationship in the second and third periods of representative elements.
Diagonal relationship between
- ✓ lithium and magnesium,
- ✓ Beryllium and Aluminium,
- ✓ Boron and Silicon

Q5. Discuss the group trend of Iionization energy in group IIIA of periodic table.
The ionization energy of an element is the amount of energy required to remove the most loosely bound electron from an isolated gaseous atom. The ionization energy of group IIIA elements decreases from top to bottom in the periodic table.
This is because as we move down the group, the valence electrons are added to higher and higher energy shells. As a result, they are further away from the nucleus and are less strongly attracted to it. This makes them easier to remove, which corresponds to a lower ionization energy.
The following table shows the ionization energies of the group IIIA elements:

Element	Ionization energy (kJ/mol)
Boron	800.6
Aluminum	577.6
Gallium	599.9
Indium	558.2
Thallium	589.5

As can be seen from the table, the ionization energy of gallium is slightly higher than that of Aluminum, even though gallium is below Aluminum in the group. This is due to the lanthanide contraction. The lanthanides are a group of 15 elements that come between lanthanum and lutetium in the periodic table. They have a very similar atomic structure, and as a result, their atomic radii decrease gradually from left to right. This contraction also affects the elements below the lanthanides, causing their atomic radii to be smaller than expected.
Gallium is below the lanthanides, so its atomic radius is smaller than expected. This means that the valence electrons in gallium are closer to the nucleus than expected, and they are therefore more strongly attracted to it. This is why the ionization energy of gallium is slightly higher than that of Aluminum.
Overall, the ionization energy of group IIIA elements decreases from top to bottom in the periodic table. This is because the valence electrons are added

to higher and higher energy shells as we move down the group. However, there is a slight anomaly in the trend due to the lanthanide contraction.

Q6. Write down three properties of beryllium that show its unique behaviour in group IIA.

- High ionization energy: Beryllium has the highest ionization energy of all the group IIA elements. This is because beryllium is a very small atom, and its valence electrons are close to the nucleus.
- High melting and boiling points: Beryllium has the highest melting and boiling points of all the group IIA elements. This is because beryllium has a strong covalent character, and its atoms are bonded together very tightly.
- Amphoteric nature: Beryllium is the only group IIA element that is amphoteric. This means that it can react with both acids and bases.

Here are some examples of the unique behaviour of beryllium:

- Ionization energy:

Beryllium has an ionization energy of 899.5 kJ/mol, while the other group IIA elements have ionization energies in the range of 577.6 to 589.5 kJ/mol.

- Melting and boiling points

Beryllium has a melting point of 1278 K and a boiling point of 2970 K, while the other group IIA elements have melting and boiling points in the range of 933 to 1115 K and 1807 to 2795 K, respectively.

- Amphoteric nature

Beryllium can react with acids to form beryllium salts, such as beryllium chloride (BeCl2). It can also react with bases to form beryllate ions, such as beryllate ions (BeO2-).

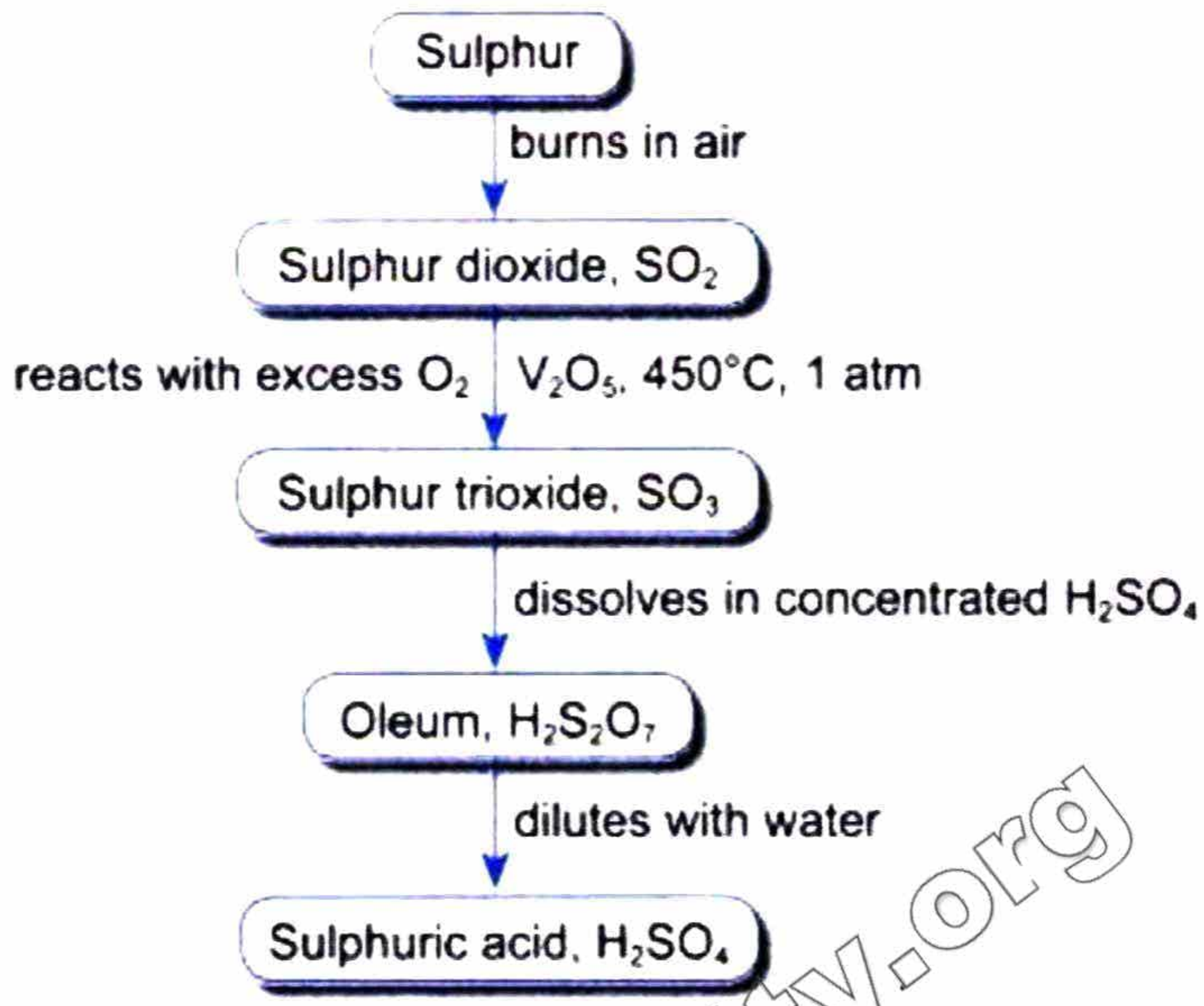
The unique properties of beryllium are due to its small size and high electronegativity. Beryllium is the smallest atom in group IIA, and it has the highest electronegativity of all the group IIA elements. This is because beryllium has a very effective nuclear charge, which attracts its electrons very strongly.

The unique properties of beryllium make it a very useful material. For example, beryllium is used in aerospace applications because of its high melting point and low weight. It is also used in nuclear reactors because of its ability to absorb neutrons.

Descriptive Questions

Q1. Draw a flow diagram of contact process and describe various steps involved in the manufacturing of sulphuric acid.

Flow chart of the Contact process



Q2. Explain with the help of a diagram of Castner Kellner cell, how caustic soda is obtained by the electrolysis of aqueous sodium chloride?

See Answer On Pg #

Q3. Write the balance equations for the following chemical process.

(i) A piece of Aluminum is dipped into concentrated sulphuric acid.

$$Al_{(s)} + 6H_2SO_{4(aq)} \longrightarrow Al_2(SO_4)_{3(aq)} + 3H_{2(g)}$$

(ii) Ferric chloride is mixed with an aqueous solution of caustic soda.

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

(iii) Sodium burns in excess of air.

$$2Na_{(s)} + O_{2(g)} \longrightarrow 2Na2O_{(s)}$$

(iv) Magnesium is heated with nitrogen gas.

$$3Mg_{(s)} + N_{2(g)} \longrightarrow Mg_3N_{2(s)}$$

(v) Potassium is put into ethyl alcohol.

$$2K_{(s)} + 2C_2H_5OH_{(l)} \longrightarrow 2C_2H_5OK_{(l)} + H_{2(g)}$$

(vi) Chlorine gas is passed through an aqueous solution of caustic soda.

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

Q4. What is bleaching powder? How is prepared? Give the reaction of bleaching powder with water and hydrochloric acid.

See Answer On Pg #

Q5. Discuss the group trend of atomic radii, ionization energy and electronegativity of alkali metals.

See Answer On Pg #