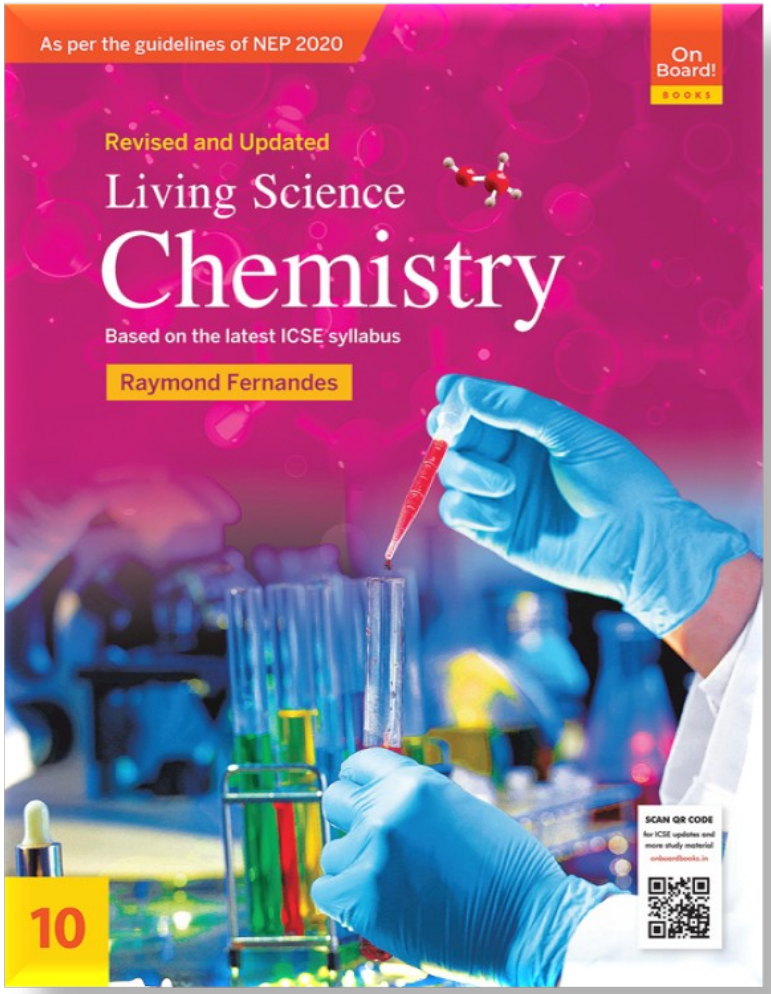
On Board!

ICSE
Living Science
Chemistry

Class 10

Chapter-8 Study of Compounds – Hydrogen Chloride


As per the guidelines of NEP 2020
On Board! BOOKS
Revised and Updated
Living Science
Chemistry
Based on the latest ICSE syllabus
Raymond Fernandes
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LEARNING OBJECTIVES

Hydrogen Chloride Gas

- ❖Preparation of hydrogen chloride gas
- ❖Laboratory preparation of hydrogen chloride gas
- ❖Physical properties of hydrogen chloride gas
- ❖Chemical properties of hydrogen chloride gas

Hydrochloric Acid

- ❖Preparation of hydrochloric acid
- ❖ Physical properties of hydrochloric acid
- ❖Chemical properties of hydrochloric acid
- ❖ Tests for hydrochloric aci
- ❖ Uses of hydrochloric acid

Important characteristics of hydrogen chloride gas

Molecular formula: HCl

Molecular mass: 36.5 u

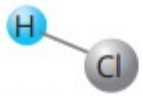
Vapour density: 18.25

Nature: Acidic in nature

Solubility: Highly soluble in water

Common name: Spirit of salts

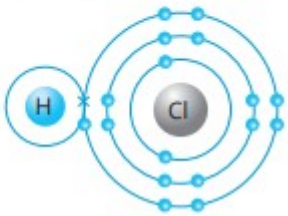
Structure:



Hydrogen chloride is composed of one atom of hydrogen and one ·tom of chlorine joined together · a single covalent bond. It has inear shape. Hydrogen chloride ıs molecular polarity due to the ectronegative difference between e two combining elements.

Electron dot diagram or Lewis structure: H :Cl: or H—Cl

Orbital diagram:



Preparation of hydrogen chloride gas

1. By the direct combination of hydrogen and chlorine

In the presence of diffused sunlight, hydrogen combines with chlorine to form hydrogen chloride gas.

$$H_2 + Cl_2 \longrightarrow 2HCl$$

2. By the reaction of metallic chlorides with concentrated H_2SO_4

When metallic chlorides react with concentrated sulphuric acid, hydrogen chloride gas is liberated.

$$CuCl_2 + H_2SO_4 \longrightarrow CuSO_4 + 2HCl(g)$$

Laboratory preparation of hydrogen chloride gas

In the laboratory, hydrogen chloride gas is prepared by the action of concentrated sulphuric acid on common salt, sodium chloride.

Reactants: Sodium chloride and sulphuric acid

Sodium chloride is preferred only for laboratory preparation of hydrogen chloride gas because it is cheap and easily available. Concentrated H_2SO_4 is used because it is **less volatile** in nature and therefore it can displace a more volatile acid from its corresponding salt.

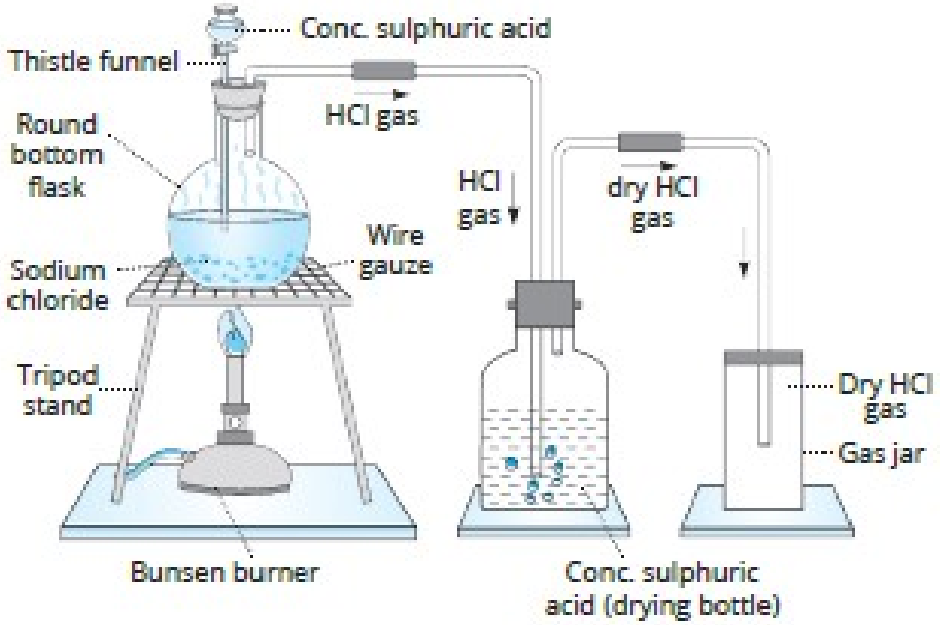
Reaction: The reaction takes place at a temperature of 200 °C as follows:

$NaCl(s) + H_2SO_4\ (l) \xrightarrow{<200°C} NaHSO_4(aq) + HCl(g)$

The temperature is preferably maintained below 200 °C. If the temperature increases beyond 200 °C, sodium sulphate is formed which affects the glass apparatus.

$$NaCl + NaHSO_4 \xrightarrow{T > 200\,°C} \underset{\text{sodium sulphate}}{Na_2SO_4(aq)} + HCl(g)$$

Procedure: Sodium chloride is taken in a round bottom flask and concentrated sulphuric acid is added dropwise to it through the thistle funnel. The flask is heated gently to about 200 °C to initiate the reaction.



Preparation of HCl gas from NaCl and H_2SO_4

Drying and purification of hydrogen chloride gas: The gas obtained is dried and purified by passing it through concentrated H_2SO_4, which acts as a dehydrating and drying agent.
Conventional drying agents like calcium oxide (CaO) and phosphorus pentoxide (P_2O_5 or P_4O_{10}) are not used because they react with hydrogen chloride gas to form their respective chlorides.

$$P_4O_{10} + 3HCl \longrightarrow \underset{\text{phosphorus oxychloride}}{POCl_3} + \underset{\text{metaphosphoric acid}}{3HPO_3}$$

Collection of hydrogen chloride gas: In the laboratory preparation, dry HCl gas is collected by the upward displacement of air, because it is heavier than air. It cannot be collected over water, because it is highly soluble in water.

Identification of the gas: a glass rod dipped in the solution of ammonia is brought near the mouth of the gas jar. The formation of dense white fumes of ammonium chloride at the mouth of the jar shows the presence of hydrogen chloride gas. White fumes are due to the formation of ammonium chloride.

$$HCl(g) + NH_4OH(aq) \longrightarrow \underset{\substack{\text{ammonium chloride}\\ \text{(appears as white fumes)}}}{NH_4Cl(g)} + H_2O(l)$$

Physical properties of hydrogen chloride gas

1. Colour: Colourless gas

2. Smell: Pungent with choking smell. If inhaled, it corrodes the delicate membrane of the respiratory tract.

3. Taste: Sour in taste

4. Density: Its vapour density is 18.25 and that of air is 14.4. Hence, it is 1.28 times heavier than air.

5. Solubility: Highly soluble in water. HCl gas fumes in moist air and forms droplets of HCl acid.

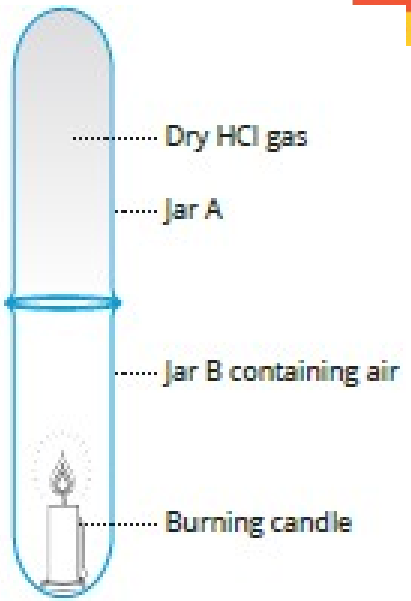
The solubility increases on decreasing the temperature.

6. Liquefaction of gas: Liquefies at 10 °C and 40 atmospheric pressure. On further cooling, liquid hydrogen chloride solidifies to a white solid which

melts at –113 °C.

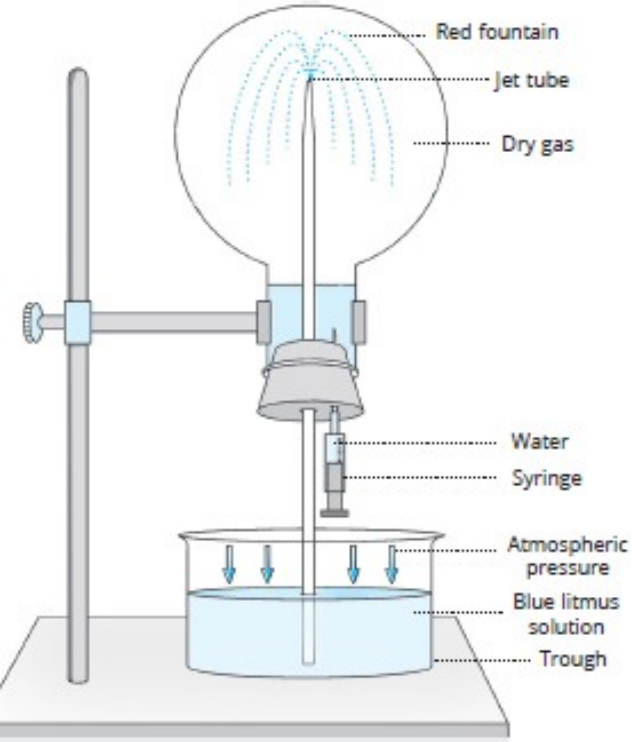
7. Boiling point: Liquid hydrogen chloride boils at –33 °C.

Experiment to show that hydrogen chloride gas is heavier than air



The apparatus to be arranged as shown in the figure. The burning candle gets extinguished because HCl gas in jar A being heavier than air displaces air from jar B. Thus, hydrogen chloride is heavier than air.

Experiment to demonstrate high solubility of hydrogen chloride gas.



The apparatus to be set-up as shown in the figure. When the syringe is squeezed, the water entering the flask dissolves almost the entire hydrogen chloride gas, thus creating a partial vacuum. This happens because hydrogen chloride gas dissolves readily in water. The vacuum draws up the litmus solution, which spurts into the round bottom flask and turns red when it comes in contact with the undissolved hydrogen chloride gas. Blue litmus turning red also shows that the gas is acidic in nature.

Chemical properties of hydrogen chloride gas

1. Combustion

Hydrogen chloride gas is neither combustible nor does it support combustion. It extinguishes a burning candle.

2. Action on indicators

Action on indicators is studied only with moist hydrogen chloride gas. The hydronium ions formed when hydrogen chloride gas is dissolved in water are responsible for the colour changes in the indicators.

$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

3. Thermal dissociation

When heated above 500 °C, less than 0.5% of hydrogen chloride gas dissociates to hydrogen and chlorine.

$$2HCl(g) \overset{>500\,^\circ C}{\rightleftharpoons} H_2(g) + Cl_2(g)$$

Chemical properties of hydrogen chloride gas

4. Reaction with ammonia

Hydrogen chloride gas reacts with ammonia to form dense white fumes of ammonium chloride.

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(g)$$

5. Reaction with metals

Metals react with hydrogen chloride gas at high temperature to form their respective chlorides and liberate hydrogen.

$$Ca(s) + 2HCl(g) \longrightarrow CaCl_2(s) + H_2(g)\uparrow$$
$$2Na(s) + 2HCl(g) \longrightarrow 2NaCl(s) + H_2(g)\uparrow$$
$$Zn(s) + 2HCl(g) \longrightarrow ZnCl_2(s) + H_2(g)\uparrow$$
$$Fe(s) + 2HCl(g) \longrightarrow FeCl_2(s) + H_2(g)\uparrow$$

Iron can form ferrous and ferric compounds, but with hydrogen chloride gas it forms ferrous chloride.

Hydrochloric Acid

Hydrogen chloride gas when dissolved in water produces hydrochloric acid. Hence, hydrochloric acid is a solution of hydrogen chloride in water. The formation of hydronium ions, by HCl is responsible for the acidic character. Hydrochloric acid is a good conductor of electricity.

Preparation of hydrochloric acid

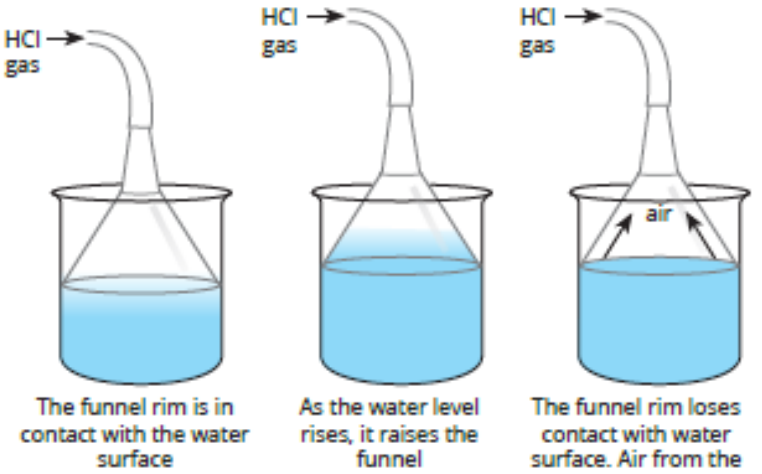
To prepare hydrochloric acid, hydrogen chloride gas is dissolved in water. But it cannot be prepared by directly dissolving HCl gas in water by dipping the delivery tube carrying HCl gas in water. The difficulty encountered in doing so is that hydrogen chloride gas dissolves rapidly in water, thus causing back suction.

Back suction

Hydrogen chloride gas is highly soluble in water. When the delivery tube containing hydrogen chloride gas is directly immersed in water, its rate of dissolution in water is higher than its rate of formation. This creates a partial vacuum inside the delivery tube resulting in low pressure.

To balance this low pressure, the air from outside exerts pressure on the water in a beaker and hence, forces it up through the delivery tube in the flask. As a result, water is sucked back. This effect is called **back suction**.

Prevention of back suction: It is prevented by using the funnel arrangement. The main advantage of this arrangement is that the funnel provides a large surface area which aids in preventing back suction.



Funnel arrangement for the preparation of hydrochloric acid.

Physical properties of hydrochloric acid

1. **Colour:** Pure hydrochloric acid is colourless liquid but commercially available acid is slightly yellow in colour due to the presence of ferric chloride as an impurity.
2. **Taste and odour:** It has a sour taste like most acids and has a slightly pungent odour.
3. **Nature:** It is highly corrosive in nature.
4. **Solubility:** It is highly soluble in water.
5. **Boiling point:** Hydrochloric acid solution forms a constant boiling mixture at around 110 °C. Beyond this temperature, the acid cannot be concentrated by distillation. It is volatile and when exposed to air it fumes, that is, loses hydrogen chloride.

Chemical properties of hydrochloric acid

Reaction with dilute hydrochloric acid

Dilute hydrochloric acid behaves like a typical acid.

1. **Acidic Nature:** Hydrochloric acid is a strong acid. It dissolves in water to generate the hydronium ion. Due to the presence of hydronium ions, it shows acidic properties.

2. **Reaction with active metals:** It reacts with active metals which are placed above hydrogen in the metal reactivity series. Hydrochloric acid reacts with active metals to form metal chlorides and liberates hydrogen gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2\uparrow$$

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2\uparrow$$

3. **Reaction with bases, i.e. oxides and hydroxides of metals:** Hydrochloric acid neutralizes oxides and hydroxides of metals to form their corresponding salts and water.

$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

4. **Reaction with carbonates and bicarbonates:** Hydrochloric acid reacts with metal carbonates and bicarbonates to give the corresponding metal chloride and liberate carbon dioxide.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2\uparrow$$
$$NaHCO_3 + HCl \longrightarrow NaCl + H_2O + CO_2\uparrow$$

5. **Reaction with sulphites and bisulphites:** Hydrochloric acid reacts with metallic sulphites and bisulphites to give metal chlorides and liberate sulphur dioxide.

$$K_2SO_3 + 2HCl \longrightarrow 2KCl + H_2O + SO_2\uparrow$$
$$NaHSO_3 + HCl \longrightarrow NaCl + H_2O + SO_2\uparrow$$

6. **Reaction with sulphides:** Hydrochloric acid reacts with metallic sulphides to form metal chloride and liberates hydrogen sulphide.

$$FeS + 2HCl \longrightarrow FeCl_2 + H_2S\uparrow$$
$$Na_2S + 2HCl \longrightarrow 2NaCl + H_2S\uparrow$$

7. **Reaction with metallic nitrites:** Hydrochloric acid reacts with metallic nitrites on warming to form respective metallic chlorides and oxides of nitrogen.

$$2KNO_2 + 2HCl \longrightarrow 2KCl + H_2O + NO + NO_2$$

8. **Reaction with nitrates:** Normally, hydrochloric acid does not react with nitrates. However, hydrochloric acid reacts with soluble salts of silver and lead like $AgNO_3$ and $Pb(NO_3)_2$ to form their respective insoluble salts in the form of precipitates.

$$AgNO_3 + HCl \longrightarrow AgCl\downarrow + HNO_3$$

curdy white ppt.

9. Reaction with sodium thiosulphate: Dilute hydrochloric acid reacts with sodium thiosulphate to form sodium chloride, liberate sulphur dioxide gas and sulphur.

$$Na_2S_2O_3 + 2HCl \longrightarrow 2NaCl + H_2O + SO_2\uparrow + S\downarrow$$

Specific reactions for concentrated hydrochloric acid

1. Reaction with oxidizing agents: Concentrated hydrochloric acid reduces strong oxidizing agents like MnO_2, PbO_2, Pb_3O_4, $KMnO_4$, $K_2Cr_2O_7$, $CaOCl_2$ (bleaching powder) and in turn gets oxidized to chlorine.

$$MnO_2 + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2$$

$$PbO_2 + 4HCl \longrightarrow PbCl_2 + 2H_2O + Cl_2$$

2. Reaction with concentrated nitric acid (aqua regia formation): When concentrated hydrochloric acid is mixed with concentrated nitric acid in the ratio of 3 : 1, it forms a mixture called **aqua regia**.

$$3HCl + HNO_3 \longrightarrow NOCl_2 + 2H_2O + [Cl]$$

3 parts 1 part — nitrosyl chloride — nascent chlorine

Tests for hydrochloric acid

1. It possesses a characteristic irritating pungent smell.

2. A glass rod dipped in ammonia solution gives dense white fumes with hydrochloric acid.

$$NH_3 + HCl \longrightarrow NH_4Cl$$

3. Hydrochloric acid forms a curdy white precipitate with silver nitrate solution. The precipitate is insoluble in nitric acid but soluble in ammonium hydroxide.

$$AgNO_3 + HCl \longrightarrow AgCl\downarrow + HNO_3$$

4. Concentrated hydrochloric acid when reacts with manganese dioxide liberates greenish-yellow chlorine gas. The liberated gas turns starch iodide paper blue-black.

$$MnO_2 + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2\uparrow$$

Uses of hydrochloric acid

Hydrochloric acid is used

1. in the manufacture of drugs, dyes and paints.

2. in the manufacture of silver chloride for photography.

3. in the manufacture of glucose from starch.

4. in cleaning of metal surfaces before galvanizing, painting, electroplating, soldering, etc.

5. in the preparation of aqua regia.

6. in the extraction of glue from bones.

7. in removing rust from iron sheets.

SUMMARY

1. **Preparation of hydrogen chloride gas**
   - By the synthesis of hydrogen and chlorine:

     $$H_2 + Cl_2 \longrightarrow 2HCl$$

   - By reacting metallic chlorides with concentrated H_2SO_4:

     $$CuCl_2 + H_2SO_4 \longrightarrow CuSO_4 + 2HCl$$

     $$CaCl_2 + H_2SO_4 \longrightarrow CaSO_4 + 2HCl$$

2. **Laboratory preparation of hydrogen chloride**
   - By the action of conc. H_2SO_4 on NaCl below 200 °C:

     $$NaCl + H_2SO_4 \xrightarrow{< 200\ ^\circ C} NaHSO_4 + HCl(g)$$

     $$NaCl + NaHSO_4 \xrightarrow{> 200\ ^\circ C} Na_2SO_4(aq) + HCl(g)$$

   - HCl gas is dried by conc. H_2SO_4 and not by CaO or P_4O_{10} as they react with HCl:

     $$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$

     $$P_4O_{10} + 3HCl \longrightarrow POCl_3 + 3HPO_3$$

   - HCl gas is collected by the upward displacement of air, as it is heavier than air.

3. **Properties of hydrogen chloride gas:** HCl gas is colourless, pungent smelling, sour in taste, heavier than air, highly soluble in water and acidic in nature.

SUMMARY

4. **Preparation of hydrochloric acid:** Hydrochloric acid is prepared by dissolving hydrogen chloride gas through funnel arrangement. Funnel arrangement is used because it
   a. prevents back suction of water.
   b. provides large surface area for the absorption of HCl gas.

   The HCl obtained from funnel arrangement contains 36% by mass of hydrogen chloride.
5. **Acidic nature of hydrochloric acid:** HCl is a strong monobasic acid and produces hydronium ions when dissolved in water.

$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

The acidic properties of HCl are exhibited by the following reactions.

- Reactions with metals:

$$2HCl + 2Na \longrightarrow 2NaCl + H_2$$
$$2HCl + Mg \longrightarrow MgCl_2 + H_2$$

- Reaction with bases (oxides and hydroxides): neutralization reactions:

$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$
$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$
$$NaOH + HCl \longrightarrow NaCl + H_2O$$
$$KOH + HCl \longrightarrow KCl + H_2O$$

- Reaction with carbonates and bicarbonates:

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2\uparrow$$
$$KHCO_3 + HCl \longrightarrow KCl + H_2O + CO_2\uparrow$$

- Reaction with sulphites and bisulphites:

$$K_2SO_3 + 2HCl \longrightarrow 2KCl + H_2O + SO_2\uparrow$$
$$NaHSO_3 + HCl \longrightarrow NaCl + H_2O + SO_2\uparrow$$

- Reaction with sulphides:

$$FeS + 2HCl \longrightarrow FeCl_2 + H_2S\uparrow$$

- Reaction with silver nitrate:

$$AgNO_3 + HCl \longrightarrow \underset{\text{curdy white ppt.}}{AgCl\downarrow} + HNO_3$$

$$AgCl + 2NH_4OH \longrightarrow \underset{\text{soluble diamminesilver(I) chloride}}{[Ag(NH_3)_2]Cl} + 2H_2O$$

- Reaction with lead(II) nitrate:

$$Pb(NO_3)_2 + 2HCl \longrightarrow PbCl_2\downarrow + 2HNO_3$$

- Reaction with oxidizing agents: Chlorine gas is produced.

$$MnO_2 + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2\uparrow$$

$$PbO_2 + 4HCl \longrightarrow PbCl_2 + 2H_2O + Cl_2\uparrow$$
$$Pb_3O_4 + 8HCl \longrightarrow 3PbCl_2 + 4H_2O + Cl_2\uparrow$$

SUMMARY

- Reaction with nitric acid (formation of aqua regia): Aqua regia is a mixture of three parts by volume of concentrated hydrochloric acid and one part by volume of conc. nitric acid. It can dissolve noble metals like Pt and Au.

$$3HCl + HNO_3 \longrightarrow NOCl_2 + 2H_2O + [Cl]$$

$$Au + 3[Cl] \longrightarrow AuCl_3$$

$$Pt + 4[Cl] \longrightarrow PtCl_4$$

6. **Uses of hydrochloric acid:** It is used in manufacture of drugs, dyes, paints, in tanning industry and as a laboratory reagent.

THANK YOU