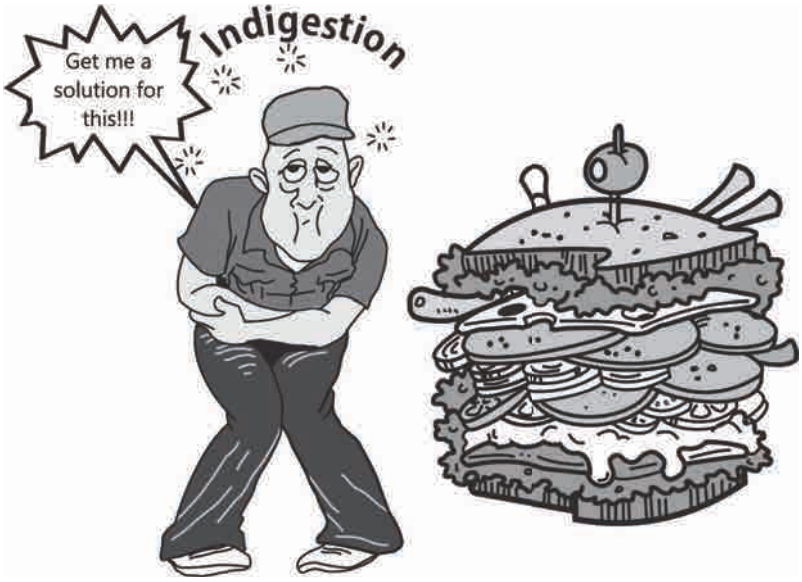
HYDROGEN CHLORIDE

Burping and Burning Stories..!!!



When you eat or drink too much, your digestive system may generate too much acid, a condition is called "heartburn".

Does that "heart" really burn?

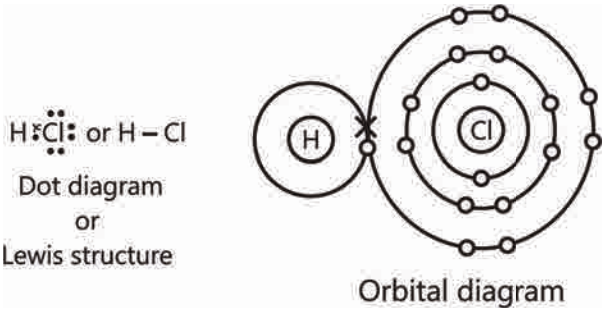
Lets find the reason…

1. Hydrogen Chloride

Molecular formula: HCl

Molecular mass : 36.5

Bond: Covalent



1.1 Occurence

Named as Muriatic acid, which means "pertaining to brine or salt", was commonly prepared by using common salt (NaCl) with concentrated sulphuric acid, .Sir Glauber was involved with the preparation. Sir Antoine Lavoisier named it muriatic acid while Sir Davy gave the name of Hydrochloric acid.

1. Hydrogen chloride gas occurs in free state in volcanic eruption.
2. Digestion is aided by the presence of this 0.2-0.4% acid in the gastric juices of mammals .

1.2 General Preparation of Hydrogen Chloride Gas

The general preparation can be done in 2 ways-

1. **By synthesis (Direct combination).**

   (i) Moist hydrogen gas combines with chlorine in the presence of diffused sunlight.

   $$\text{Hydrogen} + \text{Chlorine} \rightarrow \text{Hydrogen chloride}$$

   $$H_2(g) + Cl_2(g) \xrightarrow[\text{Sunlight}]{\text{Diffused}} 2HCl(g)$$

   Note : The reaction is explosive in direct sunlight but it is negligible in the dark.

   However, in the presence of a catalyst such as activated carbon, the reaction takes place even in the dark. (Activated carbon absorbs hydrogen which increases reactivity).

   (ii) Burning jet of hydrogen also burns in chlorine forming hydrogen chloride.

2. **By heating metallic chloride with conc. sulphuric acid**

Table 6.1: Readction of metal chloride with sulphuric acid

Metal chloride	Sulphuric acid [conc.]	Salt +	Hydrogen chloride
$NaCl + H_2SO_4 \xrightarrow{<200°C} NaHSO_4 + HCl\ [g]$			
$2NaCl + H_2SO_4 \xrightarrow{\text{Above } 200°C} NaSO_4 + HCl\ [g]$			
$CuCl_2 + H_2SO_4 \xrightarrow{\Delta} CuSO_4 + 2HCl\ [g]$			

1.3 Laboratory Preparation of Hydrogen Chloride Gas

The Laboratory preparation is as below-

Reactants : Sodium chloride and concentrated sulphuric acid.

Procedure : Set up the apparatus as shown in Fig.1

1. Place some common salt in a flask and pour concentrated sulphuric acid through the thistle funnel.
2. The reaction proceeds in the cold, although a further yield of the gas is obtained by heating.

3. On heating the mixture gently, there is effervescence and HCl gas is evolved.
4. The gas is dried by passing through concentrated sulphuric acid.

It is collected by upward displacement of air in a gas jar.

Upward Displacement of Air-

1. This method is specially used for gases heavier than air.
2. Thus, for the collection, an empty jar with three-fourth of the delivery tube inside is arranged.
3. The preparation apparatus connected to the tube passess the gas to the jar where it flows in the downward direction displacing the air inside the jar.

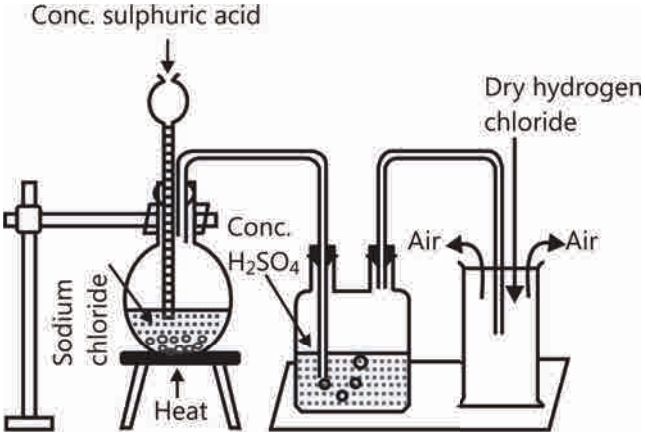


Figure 6.1: Laboratory Preparation of HCl

Reaction:

$$NaCl + H_2SO_4 \xrightarrow{<200^\circ C} NaHSO_4 + HCl\uparrow$$

Though it is a reversible reaction, yet it goes to completion as hydrogen chloride continuously escapes as a gas.

The reaction can occur upto the stage of formation of sodium sulphate on heating above 200°C.

$$NaHSO_4 + NaCl \xrightarrow{\text{above } 200^\circ C} Na_2SO_4 + HCl\uparrow$$

or

$$2NaCl + \underset{(conc.)}{H_2SO_4} \xrightarrow{\text{above } 200^\circ C} Na_2SO_4 + 2HCl$$

Illustration 1: Why do we prefer NaCl over other metal chlorides?

Sol: Sodium chloride is cheap and therefore it is preferred for preparation of HCl over other metal chlorides.

Illustration 2: Conc. nitric acid cannot be used in this preparation. Explain**.**

Sol: Conc. nitric acid is not used during the preparation of HCl because it is volatile and may volatilize out along with hydrogen chloride.

Purification of HCl gas:

1. It is dried by passing through conc. sulphuric acid.
2. The other drying agents like phosphorus pentoxide (P_2O_5) and quick lime (CaO) cannot be used, since they react with hydrogen chloride.

$$2P_2O_5 + 3HCl \rightarrow POCl_3 + 3HPO_3$$
$$CaO + 2HCl \rightarrow CaCl_2 + H_2O$$

Flat bottom flask or round bottom flask can be used. Round bottom flasks are normally used to heat at high temperature.

This reaction indicates clearly the acid nature of sodium hydrogen sulphate.

Collection:

1. Hydrogen chloride gas is collected by the downward delivery (upward displacement of air) as it is 1.28 times heavier than air.
2. It is not collected over water, since it is highly soluble in water.

Identification

1. When the jar is completely filled with hydrogen chloride, fumes appear above the jar's mouth.

   White fumes appear on exposing hydrogen chloride gas to air since it forms hydrochloric acid with atmospheric water vapour.
2. This jar when brought near a rod dipped in ammonium hydroxide gives dense white fumes, which indicate the formation of ammonium chloride, as per the reaction given below-.

$$HCl + NH_4OH \rightarrow NH_4Cl + H_2O$$

1.4 Physical Properties of Hydrogen Chloride Gas

Table 6.2: Physical properties of HCl gas

Colour	colourless gas
Smell	pungent choking smell
Taste	sour (acidic) in taste
Physiological nature	It is corrosive in nature. Causes irritation innose, throat and lungs.

Density	It is about one and a quarter times heavier than air (V.D. of HCl is 18.25 and that of air is 14.4).
Boiling point	-83°C
Melting point	-113°C
Liquefaction and solidification	When subjected to a high pressure (40 atm.) at low. temperature (10°C), it is ,liquefied to a colourless liquid.
Solubility	Hydrogen chloride gas is highly soluble in water (1 volume of water dissolves 452 volumes of the gas at room temperature). HCl being polar covalent compound is soluble in organic, non-polar solvents such as acetone and toluene.

1.5 Experiments

1.5.1 Experiment to Demonstrate Density

To show that HCl gas is heavier than air.

A jar is taken in which a burning candle is kept inside. The HCl gas is poured into this jar, which due to its heaviness, flows downwards, displaces the inside air .

Loss of air, i.e. oxygen, causes the flame to extinguish, proving the presence of HCl gas.

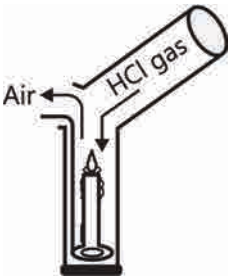


Figure 6.2: Experiment to show density

1.5.2 Experiment to Demonstrate Solubility

To show that HCl gas is highly soluble.

The Fountain Experiment helps in giving the idea of the solubility of the HCl gas.

The experiment is as given below-

Fountain Experiment

A dry, round bottom flask is filled with dry HCl gas and arranged as shown in the Fig. 2.

The mouth of the flask is fitted with a rubber stopper, provided with two holes.

A long jet tube passes through one hole and a dropper, through the other containing few drops of water.

This arrangement(inverted) is set inside a beaker containing blue litmus solution, where the jet tube is inside the solution.

As the dropper is pressed, the blue litmus solution is pulled upwards.

As soon as it comes in contact with the gas, it shows a red fountain.

Reason:

On pressing the dropper, the water , which comes out, dissolves the HCl gas. This creates a low pressure inside

The outside pressure being high, pushes the blue litmus soltion inwards and gives the red colour on coming in contact with the acidic gas.

Note: The high solubility of the HCl gas forms tiny droplets of Hydrochloric acid.

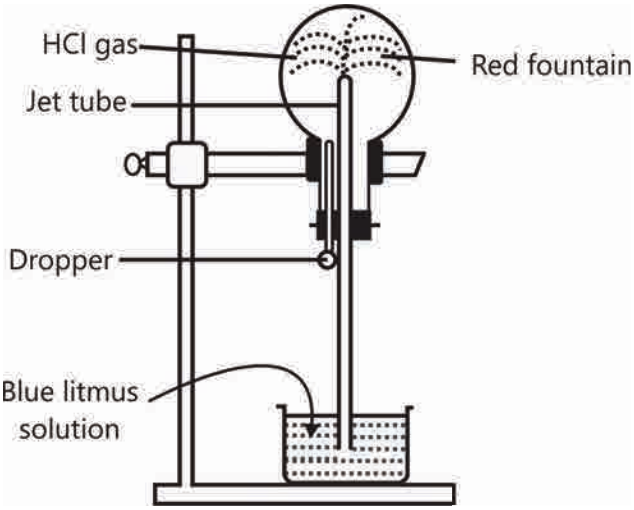


Figure 6.3: Fountain Experiment

1.6 Chemical Properties of Hydrogen Chloride Gas

1. **Combustibility :** The gas is neither combustible nor a supporter of combustion. It does not burn, rather it extinguishes a burning splint.
2. **Thermal dissociation :** Dissociation takes place when heated above 500°C The reaction is as follows:-

$$2HCl \xrightarrow{>500^{\circ}C} \underbrace{H_2}_{\text{Hydrogen}} + \underbrace{Cl_2}_{\text{Chlorine}}$$

3. **With metals :** Metals that come before hydrogen in the electrochemical series form their corresponding chlorides when heated with HCl and liberate hydrogen.

Table 6.3: Reaction of metal with hydrogen chloride acid

Metal + Hydrogen chloride (g) → Metal Chloride + Hydrogen						
$2Na$	+	$2HCl$	→	$2NaCl$	+	H_2
Ca	+	$2HCl$	→	$CaCl_2$	+	H_2
Mg	+	$2HCl$	→	$MgCl_2$	+	H_2
Zn	+	$2HCl$	→	$FeCl_2$	+	H_2

4. **Reaction with ammonia:** It combines with ammonia to form dense white fumes of ammonium chloride.

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

i.e., formation of solid occurs with reaction of gases.

2. Hydrochloric Acid

Hydrogen chloride on dissolving in water gives hydrochloric acid.

Ionisation of the covalent compound takes place due to its polar nature.

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

Polar nature of a compound is due to the unequal sharing of valence electrons between two different atoms which bring in partial charges over the individual atom .Electronegativity values of the specific atoms give us a clear idea of polarity, which is again linked to the number of electrons in the individual atoms.

Important:

(i) Dry hydrogen chloride gas and Liquefied hydrogen chloride do not turn blue litmus paper red, indicating the non-acidic character of the dry gas.

(ii) Liquefied (Pure) hydrogen chloride does not conduct electricity indicating the covalent nature of hydrogen chloride.

Illustration 3: Show the covalent nature of HCl gas.

Sol: The gas is also soluble in toluene, (organic solvent) but in that case, it neither turns blue litmus red nor conducts electricity.

This indicates the absence of H_3O^+ in toluene showing thereby that hydrogen chloride is a covalent compound.

2.1 Laboratory Method of Preparation of Hydrochloric Acid

Hydrochloric acid is the aqueous solution of HCl gas.

This aqueous solution is prepared by dissolving hydrogen chloride gas in water.

Procedure:

A beaker half-filled with water is taken in which an inverted funnel is kept in such a way that the rim of the funnel just touches the water. This funnel is connected to a hydrogen chloride gas supply.

As we know about the high solubility of hydrogen chloride gas in water, the water starts rising in the funnel, back-suction occurs which creates an air gap between the funnel and the water surface.

The pressure outside and inside then becomes equal and the water which had risen in the funnel falls down again.

Continuation of this process goes on till the water inside the beaker is saturated with the hydrogen chloride gas giving the formation of hydrochloric acid.

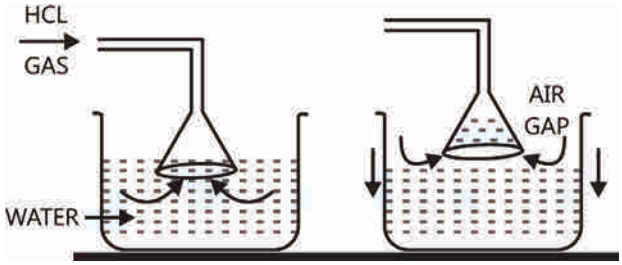


Figure 6.4: The funnel arrangement

Mechanism by which back suction is avoided or minimized

Inverted funnel arrangement serves by-

(a) preventing or minimizing back-suction of water.

(b) providing a large surface area for absorption of HCl gas.

Use of funnel arrangement

The high solubility of hydrogen chloride gas in water gives a large amount of absorption and formation of this acid.

In this case, the pressure in the delivery tube and flask is reduced and the atmospheric pressure from outside forces the water back upto the delivery tube. This effect is called 'back suction'.

If the tube is made of ordinary narrow glass tubing, the water will quickly fill it and pass over into the generating flask. This would stop the reaction and might result in an explosion due to the heat produced when water comes in contact with hot concentrated sulphuric acid.

Precaution: To prevent such an accident, an empty flask (anti-suction device) is put between the generative flask and the water beaker. In case, the back suction occurs, the water will collect in it and will not reach the generating flask.

A dilute aqueous solution of hydrochloric acid gets gradually concentrated on distillation, till the concentration of the acid reaches 22.2% HCl by weight and 77.8% water by weight which boils at 110 °C. No further increase in concentration is possible on boiling, as molecules of HCl (g) get mixed with water vapours.

Illustration 4: Write the main difference in hydrogen chloride gas and hydrochloric acid.

Sol: Hydrogen chloride gas does not conduct electricity but hydrochloric acid is a good conductor.

2.2 Properties of Hydrochloric Acid

2.2.1 Physical Properties

Table 6.4: Physical properties of hydrochloric acid

1. Colour	Colourless
2. Smell	Pungent choking smell
3. Taste	Sour (acidic)
4. Physiological action	Concentrated acid is corrosive and causes blisters on the skin
5. Solubility	Readily soluble in water in all proportions.
6. Boiling point	110°C (volatile acid)

Illustration 5: Explain why dilute hydrochloric acid cannot be concentrated by boiling beyond 22.2%.

Sol: A dilute aqueous solution of hydrochloric acid gets gradually concentrated on distillation, till the concentration of the acid reaches 22.2% HCl by weight which boils at 110°C. When this concentration is reached, no further increase in concentration of the acid becomes possible by boiling [CONSTANT BOILING MIXTURE or AZEOTROPE].

Reason. Vapors evolved before 110°C are vapours of water but at temperature above 110°C vapours consist mostly of molecules of HCl.

2.2.2 Chemical Properties

1. **Nature :** Aqueous solution is strongly acidic, and shows all properties of acids.

   Action on indicators

Table 6.5: Action on indicators

Indicator	Original colour	Change to
Moist litmus	Blue	Red
Methyl orange	Orange	Pink
Phenolphthalein	Colourless	Colourless

2. **Action on metals:** Hydrochloric acid reacts with metals above hydrogen in the activity series forming metallic chlorides and evolving hydrogen.

Table 6.6: Reaction of metal with HCl

Metal + Hydrochloric acid → Metallic chloride + Hydrogen						
Ca	+	2HCl	→	$CaCl_2$	+	$H_2\uparrow$
Mg	+	2HCl	→	$MgCl_2$	+	$H_2\uparrow$
Zn	+	2HCl	→	$ZnCl_2$	+	$H_2\uparrow$

3. **Action on oxides and hydroxides:** It reacts with oxides and hydroxides (bases) to form salt and water only.

Table 6.7: Reaction of metalic oxide Hydrochloric with HCl

Metallic oxide /hydroxide + Hydrochloric acid → Metallic chloride + water						
MgO	+	2HCl	→	$MgCl_2$	+	H_2O
ZnO	+	2HCl	→	$ZnCl_2$	+	H_2O
FeO	+	2HCl	→	$FeCl_2$	+	H_2O
Fe_2O_3	+	6HCl	→	$2FeCl_3$	+	$3H_2O$
CuO	+	2HCl	→	$CuCl_2$	+	H_2O
NaOH	+	HCl	→	NaCl	+	H_2O
$Ca(OH)_2$	+	2HCl	→	$CaCl_2$	+	$2H_2O$
$Zn(OH)_2$	+	2HCl	→	$ZnCl_2$	+	$2H_2O$
$Cu(OH)_2$	+	2HCl	→	$CuCl_2$	+	$2H_2O$

PLANCESS CONCEPTS

All metals are corroded by hydrochloric acid except for mercury, gold, platinum, tantalum and certain alloys. A yellow coloured trace is seen due to the presence of iron, chlorine and organic matter.

Vipul Singh

AIR 1, NSTSE 2009

4. **With salts of weaker acids:** Hydrochloric acid decomposes salts of weaker acids quite easily e.g., carbonates, hydrogen carbonates, sulphites and sulphides.

Table 6.8: Reaction of metal carbonates with HCl

Carbonates / hydrogen carbonates+hydrochloric acid →Metal chloride+Water+Carbondioxide						
Na_2CO_3	+ 2HCl	→	2NaCl	+ H_2O	+	$CO_2\uparrow$
Ca_2CO_3	+ 2HCl	→	$CaCl_2$	+ H_2O	+	$CO_2\uparrow$
$Ca(HCO_3)_2$	+ 2HCl	→	$CaCl_2$	+ $2H_2O$	+	$2CO_2\uparrow$

Table 6.9: Reaction of metal sulphites with HCl

Sulphites/hydrogen sulphites+Hydrochloric acid (dil)→Metal chloride+Water+Sulphur dioxide						
Na_2SO_3	+ 2HCl	→	2NaCl	+ H_2O	+	$SO_2\uparrow$
K_2SO_3	+ 2HCl	→	2KCl	+ H_2O	+	$SO_2\uparrow$
$NaHSO_3$	+ HCl	→	NaCl	+ H_2O	+	$SO_2\uparrow$

Table 6.10: Reaction of metallic sulphide with HCl

Metallic sulphide + Hydrochloric acid (dil) → Metal chloride + Hydrogen sulphide					
Na_2S	+ 2HCl	→	2NaCl	+	$H_2S\uparrow$
FeS	+ 2HCl	→	$FeCl_2$	+	$H_2S\uparrow$

5. **Action on thiosulphates :** Thiosulphates treated with dilute hydrochloric acid give sulphur dioxide gas and precipitate yellow sulphur.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2 + S\downarrow$$

Note: This reaction acts as a distinguishing test for thiosulphates and sulphites as sulphur does not precipitate when sulphites are treated with dilute HCl.

6. **Reaction with nitrates:** Dil. HCl does not normally react with nitrates. However, lead nitrate and mercury (I) nitrate react with hydrochloric acid to give white precipitate of lead and mercury (I) chloride.

$$Pb(NO_3)_2 + 2HCl \rightarrow \underbrace{PbCl_2\downarrow}_{\text{White ppt.}} + 2HNO_3$$

$$Hg_2(NO_3)_2 + 2HCl \rightarrow \underbrace{Hg_2Cl_2\downarrow}_{\text{White ppt.}} + 2HNO_3$$

Silver nitrate solution react with hydrochloric acid to give a thick curdy white precipitate of silver chloride, which is insoluble in nitric acid but soluble in ammonium hydroxide solution, and forms a complex salt called diammine silver (I) chloride.

$$AgNO_3 + HCl \rightarrow \underbrace{AgCl\downarrow}_{\text{Curdy white ppt.}} + HNO_3$$

$$AgCl + 2NH_4OH \rightarrow \underbrace{\left[Ag(NH_3)_2\right]^+ Cl^-}_{\text{diammine silver chloride complex}} + 2H_2O$$

When dilute nitric acid is added to the clear solution of diammine silver (I) chloride, a white precipitate of silver chloride is formed.

$$\left[Ag(NH_3)_2\right]^+ Cl^-(aq) + \text{Nitric acid} \rightarrow \text{White ppt. of silver chloride}$$

When exposed to light, silver (I) chloride blackens since it decomposes into chlorine and metallic silver which is liberated as a fine black powder.

$$2AgCl \rightarrow \underbrace{2Ag}_{\text{Fine Black power}} + Cl_2$$

Extra!!!

$AgNO_3$ is used as a test for hydrochloric acid and also for chloride ion.

PLANCESS CONCEPTS

If gaseous HCl is cooled to about -85°C, it condenses to a liquid that doesn't conduct electricity. Pure liquid HCl does not contain ions.

Uday Kiran G

KVPY Fellow

Note: On warming with metallic nitrites, dilute hydrochloric acid gives metallic chlorides and oxides of nitrogen.

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

7. **Oxidation of hydrochloric acid:** Concentrated hydrochloric acid can readily be oxidised to chlorine by strong oxidising agents such as manganese dioxide, lead dioxide and red lead. Alternately, we can say that hydrochloric acid readily reduces these compounds.

Oxidising agent+Hydrochloric acid → Metallic chloride + Water + Chlorine

$$MnO_2 + \underset{\text{Conc.}}{4HCl} \xrightarrow{\Delta} MnCl_2 + 2H_2O + Cl_2\uparrow$$

$$PbO_2 + \underset{\text{Conc.}}{4HCl} \xrightarrow{\Delta} PbCl_2 + 2H_2O + Cl_2\uparrow$$

$$Pb_3O_4 + \underset{\text{Conc.}}{8HCl} \xrightarrow{\Delta} 3PbCl_2 + 4H_2O + Cl_2\uparrow$$

$$2KMnO_4 + \underset{\text{Conc.}}{16HCl} \longrightarrow 2MnCl_2 + 2KCl + 8H_2O + 5Cl_2$$

$$\underset{\text{(bleaching powder)}}{CaOCl_2} + \underset{\text{dil.}}{2HCl} \xrightarrow{\Delta} CaCl_2 + H_2O + Cl_2$$

Illustration 6: Solution A reacts with an acid B (which gives greenish yellow gas on reacting with oxidizing agents like Pb_3O_4 to give white precipitate C insoluble in nitric acid but soluble in ammonium hydroxide. Name A,B and C.

Sol: A is $AgNO_3$ (Silver nitrate); B is HCl (Hydrochloric acid)

C is AgCl (Silver Chloride)

8. **Formation of aqua regia:** A mixture having three parts of conc. hydrochloric acid and one part of conc. nitric acid is called **aquaregia**.

$$\underset{\text{Conc.}}{3HCl} + \underset{\text{Conc.}}{HNO_3} \rightarrow \underset{\text{Nitrosyl chloride}}{NOCl} + 2H_2O + \underset{\text{Nascent Chlorine}}{2[Cl]}$$

It gives nascent chlorine.

The nascent chlorine reacts with noble metals like gold and platinum, to give their soluble chlorides.

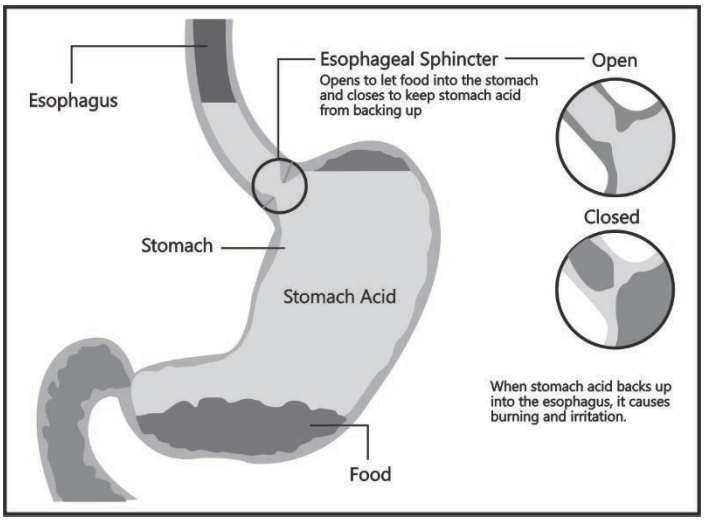
$$\underset{\text{Gold}}{Au} + 3[Cl] \rightarrow \underset{\text{Gold(III) chloride}}{AuCl_3}$$

$$Pt + 4[Cl] \rightarrow \underset{\text{Platinum(IV) chloride}}{PtCl_4}$$

SOLUTION FOR THE BURPING STORY

Protein breakdown is done by the the gastric chief cells of the stomach by secretion of the enzymes(inactive pepsinogen and rennin)

Proteolysis occurs when the amino acids linkage is broken down by the enzyme pepsin in digestion.



The enzyme pepsin is the activated form of pepsinogen, done by hydrochloric acid.

Indigestion is caused by excess acid in the stomach.

Neutralization of this excess acid is done either by antacids, increasing the pH or reversibly reduce or block the secretion of acid by gastric cells.

When gastric hydrochloric acid reaches the nerves in the gastrointestinal mucosa, they signal pain to the central nervous system. This happens when these nerves are exposed.

2.3 Uses of Hydrochloric Acid

I. General uses

Acts as a laboratory reagent and is an active reactant in the preparation of aqua regia.

II. Industrial uses:

(1) In the manufacture of

(a) Chlorine and chlorides, e.g., ammonium chloride used in dry cells.

(b) Dyes, drugs, paints and photographic chemicals (silver chloride).

(c) Glucose from starch.

(2) Used in steel industry to pickle steel (clean metal surface by using acid), since HCl dissolves the oxides. Some inhibitors and HCl is used in pickling of steel before it is plated with tin or chromium, so as to remove impurities.

PLANCESS CONCEPTS

Pickling is a process in which a metal surface is treated to remove impurities, such as stains, inorganic contaminants, rust or scale from ferrous metals, copper, and aluminium alloys.

Makarand Manda

KVPY Fellow

(3) For purifying bone black, because HCl dissolves the calcium phosphate present in bones.

(4) To remove rust from iron sheets.

(5) For cleaning metal surfaces before painting, electroplating, galvanising, soldering, etc.

(6) In the extraction of glue from bones.

(7) In tanning and calico printing industry.

III. Medicine: HCl in a certain concentration, is present in our digestive system which helps to digest the proteins and kill any kind of harmful bacteria which have entered inside, alongwith the food. Thus, in case of decreased activity of gastric juices, dilute HCl is given to patients.

PLANCESS CONCEPTS

Used in activating oil wells: Oil-well acidization is a process involving injecting of acid into the cavities of oil wells which helps to dissolve sections of rock leaving an open column behind. This method accelerates the production of oil from the wells.

Nikhil Khandelwal

KVPY Fellow

Illustration 7: (a) Of the two gases, ammonia and hydrogen chloride, which is more dense? Name the method of collection of this gas.

(b) Give one example of a reaction between the above two gases which produces a solid compound.

Sol: (a) Hydrogen chloride HCl gas is more dense [V.D.-18.25, V.D.of ammonia 8.5]

Hydrogen chloride, it is collected by the upward displacement of air.

(b) $NH_3 + HCl \rightarrow \underset{\text{Ammonium chloride}}{NH_4Cl(s)}$

PLANCESS CONCEPTS

One of the most corrosive of the non-oxidising acids is Hydrochloric acid. When in contact with metals, it gives hydrogen gas which can explode and a poisonous gas, chlorine in a fire.

Chinmay S Purandare

NTSE Scholar

2.4. Tests for Hydrogen Chloride and Hydrochloric Acid

(1) Hydrogen chloride gives an irritating smell.

(2) A rod dipped in hydrochloric acid brought near the test tube of ammonia solution or near a rod dipped in ammonia solution, it gives thick white fumes of ammonium chloride. The below given equation shows the perfect reaction-

$$NH_3 + HCl \rightarrow NH_4Cl$$

Illustration 8: A substance 'A' was heated with slaked lime and a gas 'B' with a pungent smell was is obtained. Name the substances A and B and give balanced equation.

Sol: A is (NH_4Cl) Ammonium chloride B is [NH_3] Ammonia gas.

$$\underset{\text{[Ammonium chloride]}}{2NH_4Cl} + \underset{\text{[Slaked lime]}}{Ca(OH)_2} \xrightarrow{\Delta} CaCl_2(S) + 2H_2O + 2NH_3 \uparrow$$

PLANCESS CONCEPTS

Sal ammoniac is the other name for ammonium chloride(NH_4Cl), the salt of ammonia and hydrogen chloride .

Saurabh Gupta

Level 2, INChO

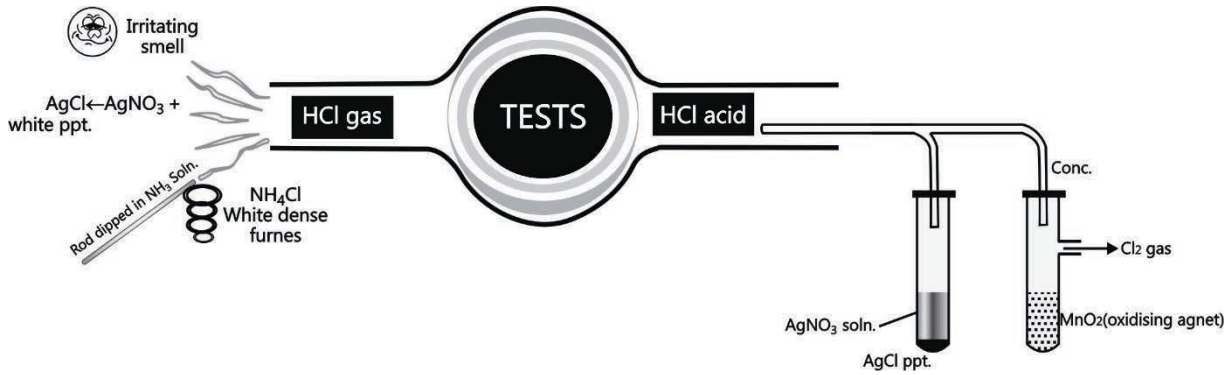
Uses of NH_4Cl:

(1) Its principal use is as an electrolyte in dry cells, and it is also extensively employed as a constituent of galvanizing, tinning, and soldering fluxes to remove oxide coatings from metals and thereby improve the adhesion of the solders. It is a component of many proprietary cold medicines and cough remedies.

(2) The reaction involved in the following diagram

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

The gas liberated turns moist starch iodide paper blue black.



SUMMARY

- Hydrogen chloride: preparation of hydrogen chloride from sodium chloride; refer to the density and solubility of hydrogen chloride (fountain experiment); reaction with ammonia; acidic properties of its solution.
- Preparation of hydrogen chloride from sodium chloride; (the laboratory method of preparation can be learnt in terms of reactants, product, condition, equation, diagram or setting of the apparatus, procedure, observation, precaution, collection of the gas and identification).
- Simple experiment to show the density of the gas (Hydrogen Chloride) – heavier than rain.
- Solubility of hydrogen chloride (fountain experiment): (setting of the apparatus, procedure, observation, interface) – method of preparation of hydrochloric acid by dissolving the gas in water – the special arrangement and the mechanism by which the back suction is avoided should be learnt.
- Reaction with ammonia.
- Acidic properties of its solution – (reaction with metals, their oxides, hydroxides and carbonates to give their chlorides, decomposition of carbonates, hydrogen carbonates, sulphides, sulphites, thiosulphates and nitrates).

SOLVED EXAMPLES

Example 1. What property of hydrogen chloride is demonstrated when it is collected by downward delivery [upward displacement]?

Sol: Hydrogen chloride is 1.28 times heavier than air.

Example 2. Why is hydrogen chloride not collected over water?

Sol: Because hydrogen chloride is highly soluble in water.

Example 3. Write the equation for the following reaction:

(i) Dil. HCl and sodium thiosulphate.

(ii) Dil. HCl and lead nitrate solution.

Sol:

$$\text{(i)}\ Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + SO_2 + S + H_2O$$

$$\text{(ii)}\ Pb(NO_3)_2 + 2HCl \rightarrow PbCl_2\downarrow + 2HNO_3.$$

Example 4.

(i) What must be added to sodium chloride to obtain hydrogen chloride? Write the equation for the reaction.

(ii) Write the equation for the preparation of hydrogen chloride from sodium chloride and sulphuric acid. State whether the sulphuric acid should be concentrated or dilute.

Sol:

(i) Concentrated sulphuric acid.

$$NaCl + H_2SO_4(Conc.) \rightarrow NaHSO_4 + HCl\uparrow$$
$$2NaCl + H_2SO_4(Conc.) \rightarrow Na_2SO_4 + 2HCl\uparrow$$

(ii)
$$NaCl + H_2SO_4(Conc.) \rightarrow NaHSO_4 + HCl\uparrow$$
$$2NaCl + H_2SO_4(Conc.) \rightarrow Na_2SO_4 + 2HCl\uparrow$$

Example 5.

(i) Hydrogen chloride dissolves in water forming an acidic solution. Name the experiment which demonstrates that hydrogen chloride is very soluble in water.

(ii) Name the experiment illustrated by the figure given.

(a) Which property of hydrogen chloride is demonstrated by this experiment?

(b) State the colour of the water that has entered the round-bottomed flask.

Sol:

(i) Fountain Experiment.

(ii) Fountain Experiment.

(a) Hydrogen chloride is highly soluble in water and is acidic in nature.

(b) Blue [Blue litmus solution]

Example 6.

(i) What would you see when hydrogen chloride mixes with ammonia?

(ii) Write the equation for the reaction of hydrogen chloride with ammonia.

(iii) From the following gases – NH_3, Cl_2, HCl, SO_2, select the gas that matches the description given below and answer the questions that follow : When gas C is mixed with gas B, dense white fumes are seen and there is no other product [gas B turns moist red litmus paper blue]. (a) What is the name of gas C. (b) What is the name of the product of the reaction between gas B and gas C ?

Sol:

(i) When hydrogen chloride is mixed with ammonia gas dense white fumes of solid ammonium chloride is formed.

(ii) $NH_3[g] + HCl[g] \rightarrow NH_4Cl[s]$.

(iii) NH_3 and HCl. (a) HCl (ii) Ammonium chloride.

Example 7.

(i) From the following list of substances – ammonium chloride, ammonium nitrate, chlorine, dilute hydrochloric acid, iron, lead nitrate, manganese [IV] oxide, silver nitrate, sodium nitrate, Sulphur – choose two compounds whose aq. solution give white precipitate with dil. HCl.

(ii) Hydrogen chloride dissolves in water forming an acidic solution. Give three distinct tests [apart from using an indicator] you would carry out with this solution to illustrate the typical properties of an acid.

(iii) Write the equation for the reaction of hydrochloric acid with lead nitrate solution.

(iv) Write balanced chemical equation for the reaction of dilute hydrochloric acid with (a) copper oxide (b) zinc (c) calcium bicarbonate.

(v) A solution of hydrogen chloride in water is prepared. The following substances are added to separate portions of the solution:

S. No.	Substances added	Gas evolved	Odour
1.	Calcium carbonate		
2.	Magnesium ribbon		
3.	Manganese (IV) oxide with heating		
4.	Sodium sulphide		

Complete the table by writing the gas evolved in each case and its odour.

Sol:

(i) (a) Silver nitrate

$$AgNO_3 + HCl \rightarrow AgCl\ (white) \downarrow + HNO_3.$$

(b) Lead nitrate

$$Pb(NO_3)_2 + 2HCl \rightarrow PbCl_2 + 2HNO_3.$$

(ii) (a) Hydrochloric acid reacts with active metals to liberate a colourless and odourless gas which burns with a popping sound liberating hydrogen gas.

$$Mg + 2HCl\ (dil.) \rightarrow MgCl_2 + H_2.$$

(b) Dilute hydrochloric acid reacts with metallic carbonate and bicarbonate to liberate a colourless and odourless gas with brisk effervescence which turns lime water milky i.e. CO_2.

$$Na_2CO_3 + 2HCl\ (dil.) \rightarrow 2NaCl + H_2O + CO_2$$

Confirmatory test :

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O.$$

(c) Dilute hydrochloric acid reacts with metallic sulphite and bisulphate to liberate a colourless gas having smell of burning Sulphur which turns acidified potassium dichromate paper from orange to green and potassium permanganate solution from purple to colourless.

$$Na_2SO_3 + 2HCl\ (dil.) \rightarrow 2NaCl + H_2O + SO_2$$
$$K_2Cr_2O_7 + 3SO_2 + H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO4)_2 + H_2O2$$
$$KMnO_4 + 5SO_2 + 2H_2O \rightarrow K_2SO_4 + 2MnSO_4 + 2H_2SO_4.$$

(iii) When dilute HCl is added to lead nitrate solution a white precipitate soluble in hot water but insoluble in cold water is formed.

$Pb(NO_3)2 + 2HCl \rightarrow PbCl_2 \downarrow + 2HNO_3$.

(iv)

(a) $CuO + 2HCl \rightarrow CuCl_2 + H_2O$

(b) $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

(c) $Ca(HCO_3)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O + 2CO_2$.

S. No.	Substances added	Gas evolved	Odour
1.	Calcium carbonate	CO_2	Odourless
2.	Magnesium ribbon	H_2	Odourless
3.	Manganese (IV) oxide with heating	Cl_2	Pungent
4.	Sodium sulphide	H_2S	Rotten eggs

Example 8. Write the equation for the reaction of hydrochloric acid with manganese (IV) oxide.

(i) Name the lead compound that can be used to oxidize hydrogen chloride to chlorine.

(ii) Manganese (IV) oxide, lead (IV) oxide and red lead [Pb_3O_4] react with conc. HCl liberating chlorine. (a) What is the common property being shown by these metal oxides? (b) Write the equation for the reaction of conc. HCl with Pb_3O_4.

(iii) Write balanced equations for the reaction of manganese (IV) oxide and concentrated hydrochloric acid.

(iv) Select the correct compound from the list – Ammonia, Copper oxide, Copper sulphate, Hydrogen chloride, Hydrogen sulphide, Lead bromide – which matches with the description given below: This compound can be oxidized to chlorine.

Sol: (i) $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$.

(ii) Lead dioxide (PbO_2) and Red lead (Pb_3O_4).

(iii) (a) They are oxidizing agent.

(b) $Pb_3O_2 + 8HCl \rightarrow 3PbCl_2 + 4H_2O + Cl_2\uparrow$

(iv) $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$.

(v) Hydrogen chloride.

Example 9.

(i) State what you observe when silver nitrate solution is added to dilute hydrochloric acid?

(ii) From the gases – ammonia, hydrogen chloride, hydrogen sulphide, Sulphur dioxide – Select the following: The gas which gives a white ppt. when reacted with $AgNO_3$ soln. acidified with dilute nitric acid.

Sol:

(i) Curdy white precipitate of silver chloride is obtained which is soluble in NH4OH and insoluble in dil. HNO_3

$$AgNO_3(aq) + HCl \rightarrow AgCl \downarrow + HNO_3$$
$$AgCl + 2NH_4OH \rightarrow Ag(NH_3)2Cl + 2H_2O.$$

(ii) Hydrogen chloride gas.

Example 10.

(i) What must be added to sodium chloride to obtain hydrogen chloride? Write the equation for the reaction.

(ii) Write the equation for the preparation of hydrogen chloride from sodium chloride and sulphuric acid. State whether the sulphuric acid should be concentrated or dilute.

Sol:

(i) Concentrated sulphuric acid.

$$NaCl + H_2SO_4(Conc.) \rightarrow NaHSO_4 + HCl \uparrow$$
$$2NaCl + H_2SO_4(Conc.) \rightarrow Na_2SO_4 + 2HCl\uparrow$$
$$(ii)NaCl + H_2SO_4(Conc.) \rightarrow NaHSO_4 + HCl\uparrow$$
$$2NaCl + H_2SO_4(Conc.) \rightarrow Na_2SO_4 + 2HCl\uparrow$$

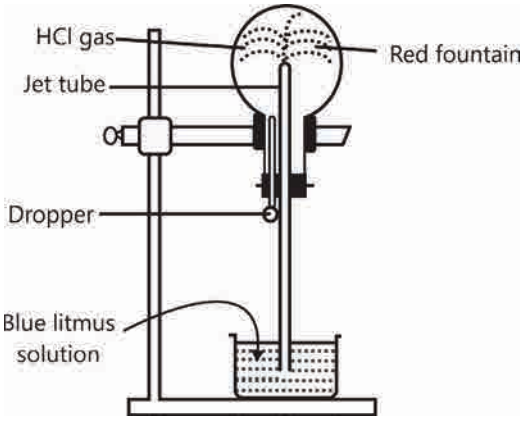
Example 11.

(i) Hydrogen chloride dissolves in water forming an acidic solution. Name the experiment which demonstrates that hydrogen chloride is very soluble in water.

(ii) Name the experiment illustrated by the figure given.

(a) Which property of hydrogen chloride is demonstrated by this experiment?

(b) State the colour of the water that has entered the round-bottomed flask.



Sol:

(i) Fountain Experiment.

(ii) Fountain Experiment.

(a) Hydrogen chloride is highly soluble in water and is acidic in nature.

(b) Blue [Blue litmus solution]

Example 12.

(i) What would you see when hydrogen chloride mixes with ammonia?

(ii) Write the equation for the reaction of hydrogen chloride with ammonia.

(iii) From the following gases – NH_3, Cl_2, HCl, SO_2, select the gas that matches the description given below and answer the questions that follow : When gas C is mixed with gas B, dense white fumes are seen and there is no other product [gas B turns moist red litmus paper blue]. (a) What is the name of gas C. (b) What is the name of the product of the reaction between gas B and gas C.?

Sol:

(i) When hydrogen chloride is mixed with ammonia gas dense white fumes of solid ammonium chloride is formed.

(ii) $NH_3[g]+HCl[g]\rightarrow NH_4Cl[s]$.

(iii) NH_3 and HCl. (a) HCl

(iv) Ammonium chloride

Example 13.

(i) From the following list of substances – ammonium chloride, ammonium nitrate, chlorine, dilute hydrochloric acid, iron, lead nitrate, manganese [IV] oxide, silver nitrate, sodium nitrate, Sulphur – choose two compounds whose aq. solution give white precipitate with dil. HCl.

(ii) Hydrogen chloride dissolves in water forming an acidic solution. Give three distinct tests [apart from using an indicator] you would carry out with this solution to illustrate the typical properties of an acid.

(iii) Write the equation for the reaction of hydrochloric acid with lead nitrate solution.

(iv) Write balanced chemical equation for the reaction of dilute hydrochloric acid with (a) copper oxide (b) zinc (c) calcium bicarbonate.

(v) A solution of hydrogen chloride in water is prepared. The following substances are added to separate portions of the solution:

S. No.	Substances added	Gas evolved	Odour
1.	Calcium carbonate		
2.	Magnesium ribbon		
3.	Manganese (IV) oxide with heating		
4.	Sodium sulphide		

Complete the table by writing the gas evolved in each case and its odour.

Sol:

(i) (a) Silver nitrate

$$AgNO_3 + HCl \rightarrow AgCl\ (white)\ \downarrow + HNO_3.$$

(b) Lead nitrate

$$Pb(NO_3)_2 + 2HCl \rightarrow PbCl_2 + 2HNO_3.$$

(ii) (a) Hydrochloric acid reacts with active metals to liberate a colourless and odourless gas which burns with a popping sound liberating hydrogen gas.

$$Mg + 2HCl\ (dil.) \rightarrow MgCl_2 + H_2.$$

(b) Dilute hydrochloric acid reacts with metallic carbonate and bicarbonate to liberate a colourless and odourless gas with brisk effervescence which turns lime water milky i.e. CO_2.

$$Na_2CO_3 + 2HCl\ (dil.) \rightarrow 2NaCl + H_2O + CO_2$$

Confirmatory test :

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O.$$

(c) Dilute hydrochloric acid reacts with metallic sulphite and bisulphate to liberate a colourless gas having smell of burning Sulphur which turns acidified potassium dichromate paper from orange to green and potassium permanganate solution from purple to colourless.

$$Na_2SO_3 + 2HCl\ (dil.) \rightarrow 2NaCl + H_2O + SO_2$$
$$K_2Cr_2O7 + 3SO_2 + H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_2 + H_2O$$
$$2KMnO_4 + 5SO_2 + 2H_2O \rightarrow K_2SO_4 + 2MnSO_4 + 2H_2SO_4.$$

(iii) When dilute HCl is added to lead nitrate solution, a white precipitate soluble in hot water but insoluble in cold water is formed.

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

(iv) (a) $CuO + 2HCl \rightarrow CuCl_2 + H_2O$

(b) $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

(c) $Ca(HCO_3)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O + 2CO_2$.

(v)

S. No.	Substances added	Gas evolved	Odour
1.	Calcium carbonate	CO_2	Odourless
2.	Magnesium ribbon	H_2	Odourless
3.	Manganese (IV) oxide with heating	Cl_2	Pungent
4.	Sodium sulphide	H_2S	Rotten eggs

Example 14.

(i) Write the equation for the reaction of hydrochloric acid with manganese (IV) oxide.

(ii) Name the lead compound that can be used to oxidize hydrogen chloride to chlorine.

(iii) Manganese (IV) oxide, lead (IV) oxide and red lead [Pb_3O_4] react with conc. HCl liberating chlorine. (a) What is the common property being shown by these metal oxides? (b) Write the equation for the reaction of conc. HCl with Pb_3O_4.

(iv) Write balanced equations for the reaction of manganese (IV) oxide and concentrated hydrochloric acid.

(v) Select the correct compound from the list – Ammonia, Copper oxide, Copper sulphate, Hydrogen chloride, Hydrogen sulphide and Lead bromide – which matches with the description given below: This compound can be oxidized to chlorine.

Sol:

(i) $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$.

(ii) Lead dioxide (PbO_2) and Red lead (Pb_3O_4).

(iii) (a) They are oxidizing agents.

(b) $Pb_3O_4 + 8HCl \rightarrow 3PbCl_2 + 4H_2O + Cl_2 \uparrow$

(iv) $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$.

(v) Hydrogen chloride.

Example 15.

(i) State what you observe when silver nitrate solution is added to dilute hydrochloric acid.

(ii) From the gases – ammonia, hydrogen chloride, hydrogen sulphide, Sulphur dioxide – Select the following: The gas which gives a white ppt. when reacted with $AgNO_3$ soln. acidified with dilute nitric acid.

Sol:

(i) Curdy white precipitate of silver chloride is obtained which is soluble in NH4OH and insoluble in dil. HNO_3

$$AgNO_3(aq) + HCl \rightarrow AgCl \downarrow + HNO_3$$
$$AgCl + 2NH_4OH \rightarrow Ag(NH_3)2Cl + 2H_2O.$$

(ii) Hydrogen chloride gas.

EXERCISE 1 – For School Examinations

Long Answer Questions

Directions: Give answer in four to five sentences.

Q.1. Write equation for the reactions of aqueous hydrochloric acid on:

(a) Silver nitrate solution
(b) Magnesium foil
(c) Caustic soda solution
(d) Zinc carbonate
(e) Lead nitrate solution
(f) Copper oxide

Q.2. Name:

(a) Black metallic oxide which reacts with hydrochloric acid to give coloured solution.

(b) Two colourless gases, which when mixed produce a white solid.

(c) Two gases which chemically combine to form: (i) a liquid (ii) a solid.

(d) A chloride which is soluble in excess of ammonium hydroxide.

(e) The chemical in which gold can be dissolved.

(f) Name the experiment which demonstrates that hydrogen chloride is soluble in water.

(g) Name the gas produced when chlorine water is exposed to sunlight.

Q.3. Complete the following reactions and balanced them.

(a) $NH_4OH + HCl \longrightarrow$

(b) $Pb_3O_4 + HCl \longrightarrow$

(c) $Pb(NO_3)_2 + HCl \longrightarrow$

(d) $Pb_3O_4 + HCl \longrightarrow$

(e) $Zn + HCl \longrightarrow$

(f) $Ca(HCO_3) + HCl \longrightarrow$

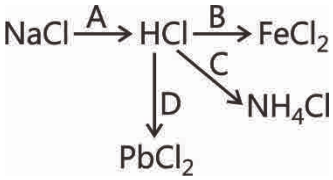
Q.4. MnO_2, PbO_2 and red lead reacts with conc. HCl acid liberates Cl_2. What is the common property being shown by these metals oxides?

Q.5. Convert two soluble metallic nitrates to insoluble metallic chlorides using dil. HCl?

Q.6. State the composition of aqua regia. State which component is the oxidising agent in aqua regia.

Q.7. Convert Hydrochloric acid to nascent chlorine.

Q.8. Study the flow chart and give balanced equations with conditions for conversions A, B, C and D.



Q.9. A solution of hydrogen chloride in water is prepared. The following substances are added to separate portions of the solution:

S.No.	Substance Added	Gas Evolved	Odour
1.	Calcium carbonate	_____	_____
2.	Magnesium ribbon	_____	_____
3.	Manganese (IV) oxide with heating	_____	_____
4.	Sodium sulphide	_____	_____

Q.10. Write balanced equations for the reaction of dilute hydrochloric acid with each of the following: (i) Iron (ii) sodium hydrogencarbonate (iii) iron (II) sulphide (iv) sodium sulphide

(v) sodium thiosulphate solution

Q.11. What property of hydrogen chloride is demonstrated when it is collected by downward delivery (upward displacement)?

Q.12. Why is hydrogen chloride not collected over water?

Q.13. Write equations for the following reactions:

(i) Dilute hydrochloric acid and sodium thiosulphate.

(ii) Dilute hydrochloric acid and lead nitrate solution.

EXERCISE 2 – For Competitive Examinations

Long Answer Questions

Directions: Give answer in four to five sentences.

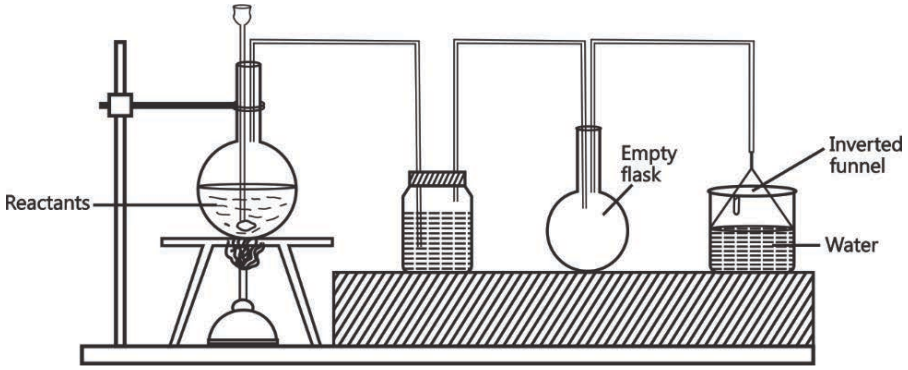
Q.1. Explain the laboratory preparation of hydrogen chloride gas. Give the balanced equation.

Q.2. Name the drying agents:

(a) Used in drying hydrogen chloride gas.

(b) Phosphorous pentoxide and calcium oxide are good drying agent but they cannot be used to dry hydrogen chloride gas. Why?

Q.3. The given set up in the figure is for the preparation of an acid.



(a) Name the acid prepared by this method.

(b) Name the reactants used.

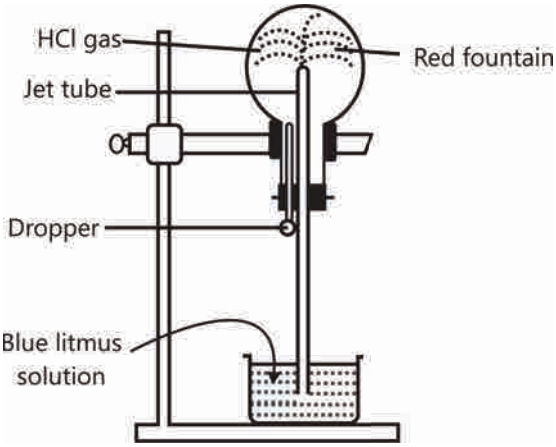
(c) Why empty flask is used.

(d) What is the dying agent used? Why is this drying agent chosen?

(e) What is the role of inverted funnel in the arrangement?

Q.4. Hydrochloric acid contains (i) Hydrogen (ii) Chlorine. Write equations for the reactions.

Q.5. (a) Write balanced equations.



(i) Copper oxide and dilute hydrochloric acid.

(ii) Manganese oxide and concentrated hydrochloric acid

(b) (i) Name the experiment illustrated below.

(ii) Which property of hydrogen chloride is demonstrated by this experiment?

(iii) State the colour of the water that has entered the round bottomed flask.

SOLUTIONS

EXERCISE 1 — For School Examinations

1. (a) Thick white ppt. of AgCl is formed.

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

The white ppt. is insoluble in nitric acid but soluble in NH_4OH solution

$$AgCl + 2NH_4OH \longrightarrow \underset{\text{Diammine silver chloride}}{[Ag(NH_3)_2]^+ Cl^-} + 2H_2O$$

When exposed to light, AgCl blackens. Since it decomposes into Cl_2 and metallic silver which is liberated as a fine black powder

$$2AgCl \longrightarrow 2Ag + Cl_2$$

(b) $$Mg + \underset{\text{(dil.)}}{2HCl} \longrightarrow MgCl_2 + H_2$$

(c) $$NaOH + HCl \longrightarrow NaCl + H_2O$$

(d) Water and chloride and CO_2 are formed.

$$ZnCO_3 + \underset{\text{(dil.)}}{2HCl} \longrightarrow ZnCl_2 + CO_2 + H_2O$$

(e) With lead nitrate solution. Thick white ppt. lead chloride is formed.

$$\underset{\text{(Sol)}}{Pb(NO_3)_2} + \underset{\text{(dil.)}}{2HCl} \longrightarrow \underset{\text{(white ppt)}}{PbCl_2} + 2HNO_3$$

(f) With copper oxide

$$CuO + \underset{\text{(dil.)}}{2HCl} \longrightarrow CuCl_2 + H_2O$$

2. (a) CuO (s) Copper (II) oxide

$$\underset{\text{Black}}{CuO} + \underset{\text{(dil.)}}{2HCl} \longrightarrow \underset{\text{(Blue green)}}{CuCl_2} + H_2O$$

(b) Two colourless gases are:

(1) Ammonia (2) Hydrogen chloride

(c) (i) Liquid (1) Ammonia gas (2) Chlorine gas

$$NH_3 + \underset{\text{(in excess)}}{3Cl_2} \longrightarrow \underset{\substack{\text{(liquid)}\\\text{(Nitogen trichloride)}}}{NCl_3} + 3HCl$$

(ii) To form a solid

(1) Chlorine gas (2) Hydrogen sulphide gas

$$Cl_2 + H_2S \longrightarrow 2HCl + \underset{\text{(solid)}}{S\downarrow}$$

(d) Silver chloride [AgCl]

(e) Aqua Regia [1 part of HNO_3 and 3 parts conc. HCl].

(f) Hydrogen chloride is soluble in water is demonstrated by experiment called Fountain experiment.

(g) HCl gas [Hydrogen Chloride Gas]

3. (a) $NH_4OH + HCl \longrightarrow NH_4Cl + H_2SO_4$

(b) $Pb_3O_4 + HCl \longrightarrow NaCl + SO_2\uparrow + H_2O$

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

(d) $Pb_3O_4 + HCl \longrightarrow 3PbCl_2 + 4H_2O + Cl_2\uparrow$

(e) $Zn + 2HCl \longrightarrow ZnCl_2 + H_2\uparrow$

(f) $Ca(HCO_3)_2 + HCl \longrightarrow CaCl_2 + 2H_2O + 2CO_2\uparrow$

4. MnO_2, Pb_3O_4 and PbO_2 are strong oxidizing agents and hence shown common property Reducing property when reacts with conc. HCl to liberate Cl_2 (gas).

5. $$Pb(NO_3)_2 + \underset{\text{(dil.)}}{2HCl} \longrightarrow \underset{\text{Insoluble}}{PbCl_2\downarrow} + 2HNO_3$$

$$Hg_2(NO_3)_2 + 2HCl \longrightarrow \underset{\text{insoluble}}{Hg_2Cl_2\downarrow} + 2HNO_3$$

$$AgNO_3 + HCl \longrightarrow \underset{\text{insoluble}}{AgCl\downarrow} + HNO_3$$

6. Composition of aqua regia is

3 parts conc. HCl +1 part conc. HNO_3

7.

$$\underset{\text{Conc.}}{3HCl} + \underset{\text{Conc.}}{HNO_3} \longrightarrow \underset{\text{Nitrosyl Chloride}}{NOCl} + 2H_2O + \underset{\text{nascent chlorine}}{2(Cl)}$$

8. A. $NaCl + H_2SO_4 \xrightarrow{< 200^\circ C} NaHSO_4 + HCl\uparrow$

B. $Fe + 2HCl \longrightarrow FeCl_2 + H_2$

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

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

9.

S.No.	Substance Added	Gas Evolved	Odour
1.	Calcium carbonate	CO_2	Odourless
2.	Magnesium ribbon	H_2	Odourless
3.	Manganese (IV) oxide with heating	Cl_2 (Chlorine gas)	Strong Pungent odour
4.	Sodium sulphide	H_2S	Unpleasant like rotten eggs

10. (i) $Fe + \underset{\text{(dil.)}}{2HCl} \longrightarrow FeCl_2 + H_2\uparrow$

(ii) $NaHCO_3 + \underset{\text{(dil.)}}{HCl} \longrightarrow NaCl + H_2O + CO_2\uparrow$

(iii) $FeS + \underset{\text{(dil.)}}{2HCl} \longrightarrow FeCl_2 + H_2S\uparrow$

(iv) $Na_2SO_3 + \underset{\text{(dil.)}}{2HCl} \longrightarrow 2NaCl + H_2O + SO_2\uparrow$

(v) $Na_2S_2O_3 + \underset{\text{(dil.)}}{2HCl} \longrightarrow 2NaCl + H_2O + S\downarrow + SO_2\uparrow$

11. Hydrogen chloride is heavier than air.

12. Because hydrogen chloride is highly soluble in water.

13. (i) $Na_2S_2O_3 + 2HCl \longrightarrow$

Sodium thiosulphate; dilute hydrochloric acid

$2NaCl + H_2O + SO_2 \uparrow + S \downarrow$

Sodium chloride; (Water); Sulphur dioxide; Sulphur

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

Lead Nitrate; dilute hydrochloric acid; Lead chloride; Nitric acid

Exercise 2 — For Competitive Examinations

1. Laboratory preparation of hydrochloric acid. Hydrogen chloride gas when dissolved in water forms hydrochloric acid. The gas is highly soluble in water and thus cannot be passed through water with the help of a delivery tube because it leads to back suction i.e., water may move back into the hot flask through the delivery tube. The delivery tube is connected with funnel as shown and gas is dissolved in water. This prevents back-suction of water.

2. (a) Drying agent used in drying HCl gas is conc. sulphuric acid.

(b) Phosphorous pentoxide (P_2O_5) and calcium oxide (CaO) are not used for drying HCl gas as they react with hydrogen chloride.

$2P_2O_5 + 3HCl \longrightarrow POCl_3 + 3HPO_3$;

$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$

3. (a) Hydrochloric Acid (HCl) is prepared by this method.

(b) The reactants are sodium Chloride and Sulphuric Acid (Conc.)

(c) Empty flask acts as Anti-suction device. In case the back suction occurs, the water will collect in it and will not reach the generating flask. Otherwise if water reaches the flask reaction would stop and might result an explosion due to heat produced.

(d) Drying agent used is conc. H_2SO_4. Since other drying agents like P_2O_5 or quick lime (CaO) react with hydrogen chloride, they cannot be used.

(e) Purpose of inverted funnel is to stop back-suction.

4. We can prove that hydrochloric acid contains both hydrogen and chlorine by the following experiments:

(1) Take a voltmeter used for electrolysis of water, fitted with platinum cathode and graphite anode. Into the voltmeter, pour 4 molar HCl and pass the direct electric current. It is seen that a colourless gas is evolved at cathode and a greenish yellow gas is evolved at anode. When a burning splinter is brought near colourless gas, it bursts into flame thereby proving that it is hydrogen gas. When moist starch iodide paper is held in the greenish yellow gas, it turns blue black, thereby proving that gas is chlorine.

Chemical Equation: $2HCl \longrightarrow H_2 \uparrow + Cl_2 \uparrow$

This experiment proves the hydrochloric acid contains both hydrogen and chlorine.

5. (a) (i)

$$CuO(s) + 2HCl(dil.) \longrightarrow CuCl_2(aq) + H_2O(l)$$

(ii) $MnO_2(s) + 4HCl(conc.) \longrightarrow MnCl_2(aq) + 2H_2O(l) + Cl_2 \uparrow$

(b) (i) Fountain experiment.

(ii) Hydrogen chloride is soluble in water.

(iii) Red.