

## **CONTENTS**

**A. Chlorine.**

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## A. CHLORINE

Chlorine is a non-metallic element in group VII (Group 17) of the periodic table. It has electronic configuration 2:8:7. It gains one valence electron to form stable  $\text{Cl}^-$  ion, it belongs to the chemical family of halogens.

### Occurrence

-As Brine-concentration sodium chloride solution dissolved in salty seas water, oceans and lakes e.g. Lake Magadi in Kenya is very salty.

-As rock-salt solid sodium chloride crystals in the earth's crust all over the world.

### B) Preparation

Chlorine gas may be prepared in the school laboratory from the following:

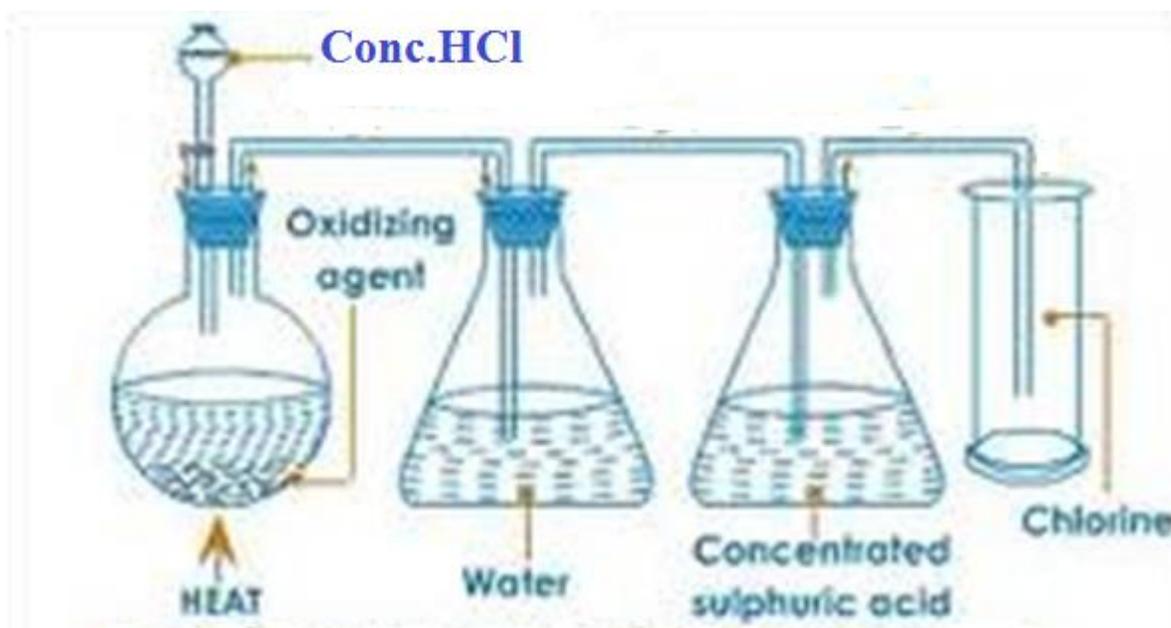
a) Heating solid Manganese (IV) Oxide and Concentrated Hydrochloric acid.

b) Heating Lead (IV) Oxide and concentrated hydrochloric acid.

c) Reacting Potassium Manganate (VII) with concentrated Hydrochloric acid

d) Reacting Potassium /sodium Dichromate (VI) Acid with Concentrated Hydrochloric acid.

Set up of school laboratory preparation of chlorine.



Preparation of Chlorine from Conc. HCl and Oxidizing agent

### **c) Properties of chlorine. (Questions)**

1. What is the colour of chlorine?

**Pale green.**

2. Describe the smell of chlorine.

**Pungent irritating smell.**

3. What method is used in collection of chlorine gas explain.

**-Downward delivery.**

**-Chlorine is 1½ denser than air.**

4.(i) What is the purpose of concentrated sulphuric (VI) acid.

**-To dry the gas.**

(ii) Name two other substances that can be used in place of concentrated sulphuric (VI) acid.

**-Calcium chloride**

**-Silica gel**

(iii) Name a substance that cannot be used in place of concentrated sulphuric (VI) acid explain.

**-Calcium oxide reacts with chlorine.**

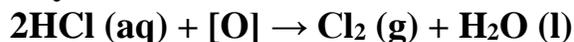
5.(a) Write three possible reactions between concentrated hydrochloric acid and the oxidizing agents.



(b) Why is Hydrochloric acid used in all the above cases?

**Oxidizing agents  $\text{KMnO}_4/\text{PbO}_2/\text{MnO}_2/\text{K}_2\text{Cr}_2\text{O}_7/\text{Na}_2\text{Cr}_2\text{O}_7$  readily oxidize hydrochloric acid to chlorine themselves reduced to their chlorides.**

**Generally:**



**(From oxidizing agent)**

6. State and explain the observation made when chlorine is bubbled in water.

Observation

**-Pale yellow colour of chlorine fades.**

**-yellow solution formed.**

Explanation

**Chlorine dissolves then reacts with water to form yellow chlorine water. Chlorine water is chemically a mixture of hydrochloric acid and chloric(I)acid (hypochlorous acid).**

**A mixture of hydrochloric acid and chloric(I)acid (hypochlorous acid) is commonly called Chlorine water**

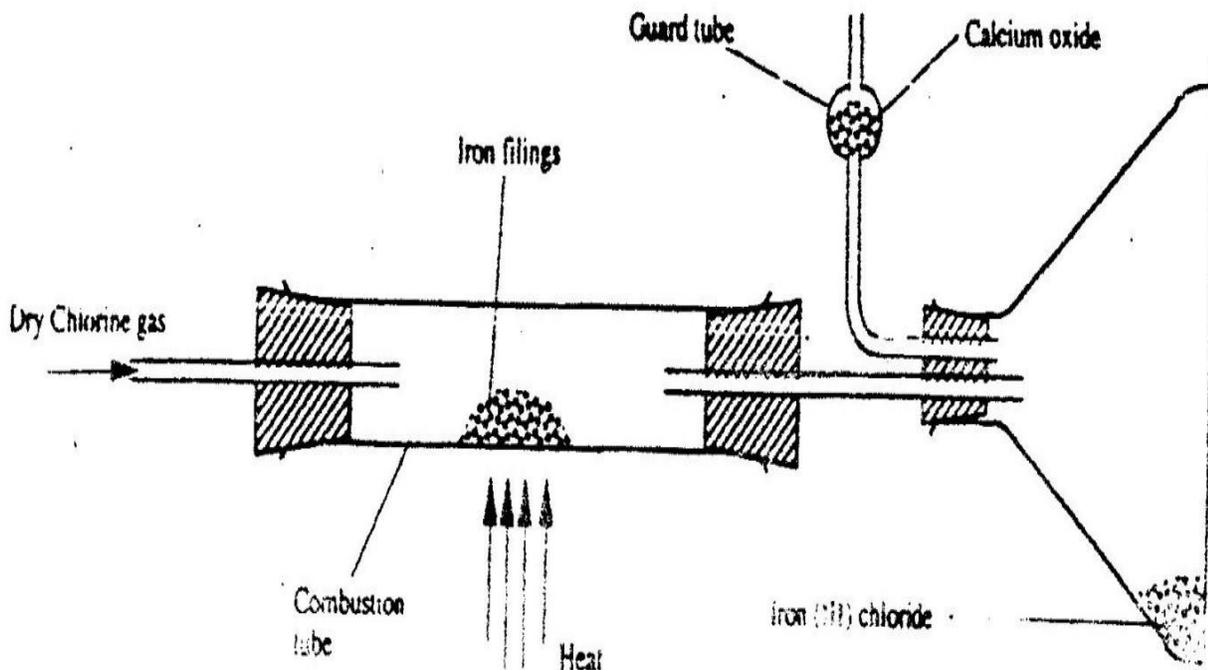




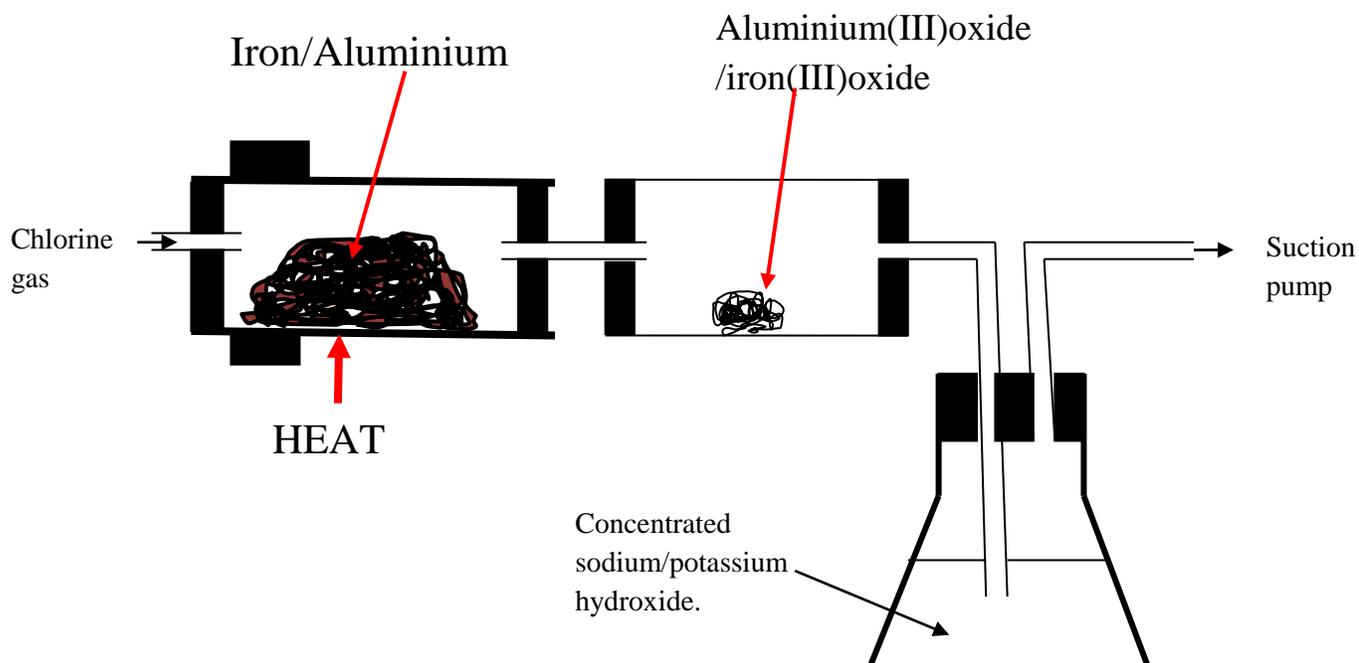
- Manufacture of bleaching agents
- Chlorination of water to kill germs.

12. The diagram below shows the effect of chlorine on heated iron wool.

**Method I**



**Method II**



a) Identify a suitable drying agent to dry chlorine gas.

**-Conc. H<sub>2</sub>SO<sub>4</sub> / Concentrated sulphuric (VI) acid.**

**-Anhydrous Calcium (II) Chloride.**

**-Silica gel**

b) State and explain the observations made in combustion tube in method I and II

Observation

**Iron glows red hot**

**Brown crystals are formed**

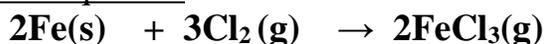
Explanation

**Iron reacts with chlorine to form dark brown crystals of iron (III) Chloride.**

**This reaction is exothermic and requires no farther heating once started.**

**Iron (III) Chloride sublimates away ensuring the unreacted Iron completely reacts with chlorine gas.**

Chemical equation



c) (i) Why is the brown solid collected at the point as shown in method I and II.

**-Heated iron (III) Chloride crystals sublime to gas and solidify on the cooler parts.**

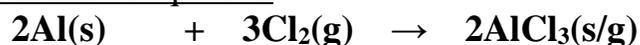
(ii) Name another metal that can be used in place of iron to react with chlorine and collected at similar point on heating explain.

**Metal Aluminum**

Explanation

**Aluminum reacts with chlorine to form a white sublimate of aluminum (III) chloride at the cooler parts**

Chemical equation



d) What is the purpose of suction pump?

**To pull the gaseous products into the set up.**

e) What is the function of:

(i) Sodium hydroxide in method II. Explain.

**To absorb poisonous/toxic excess unreacted chlorine gas.**

**Sodium hydroxide reacts with chlorine to form sodium chloride, Sodium hypochlorite and water.**

Chemical equation:



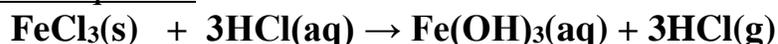
(ii) Anhydrous calcium chloride/calcium oxide in method I. Explain.

**To absorb moisture/water in the set up to prevent it from hydrolyzing iron (III) chloride/aluminium oxide.**

Explanation

**Iron (III) chloride and Aluminium chloride fumes and reacts with small traces of water to form a solution of iron (III) hydroxide/aluminium hydroxide and hydrogen chloride gas.**

Chemical equation



f) Based on e (i) and (ii) above what precaution should be made in:

(i) method II to ensure correct results.

**-Tube B should be completely dry to prevent hydrolysis of iron (III) Chloride to iron (III) hydroxide.**

(ii) Carrying out method I

**-Should be done in a fume chamber or in the open because chlorine gas is poisonous/toxic.**

(g) Name another substance that can be used place of Sodium hydroxide in method I

**Potassium hydroxide**

(h) Calcium oxide cannot be used in place of calcium chloride during preparation of chlorine.

Explain.

**Calcium oxide is a base. It reacts /absorbs water to form calcium hydroxide solution.**

**Calcium hydroxide reacts with chlorine to form a mixture of calcium chloride and calcium hypochlorite.**

Chemical equation



13. (a) State and explain the observation made when a piece of burning magnesium ribbon is lowered in a gas jar containing chlorine gas.

**-Magnesium ribbon continues burning with a bright flame.**

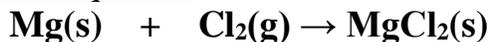
**-White solid formed.**

**-Pale yellow colour of chlorine fades**

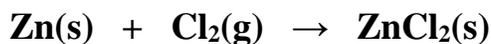
Explanation:

**Magnesium reacts with chlorine forming a white solid of magnesium chloride.**

Chemical equation



(b) Write the equation for the reaction that takes place if zinc is used.

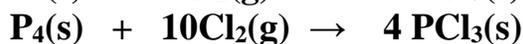
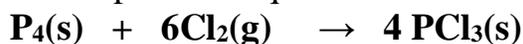


14. Burning phosphorus was lowered in a gas jar containing chlorine gas.

a) State the observations made.

- Phosphorus continues to burn.**
- Dense white fumes formed.**
- Pale green colour of chlorine fades.**

b) Write two possible equations that take place.



(c) State two reasons why the deflagrating spoon with lid/cover should be used.

- Chlorine in the gas jar is poisonous/toxic.**
- Burning phosphorus produces poisonous/toxic phosphorus (III) chloride // phosphorus (V) chloride.**
- Ensure the reaction is not affected by air/oxygen from the atmosphere.**

(d) After the reaction is complete, 2cm<sup>3</sup> of distilled water were added. The solution formed was tested with both blue and red litmus papers.

(i) State the observations made.

- Blue litmus paper turns red**
- Red litmus paper remain red**

(ii) Explain the observation made in d(i) above

- Phosphoric (V) Chloride hydrolyze in water to phosphoric (V) acid and produce hydrogen chloride gas. Both hydrogen chloride and phosphoric (V) acid are acidic.**

Chemical equation



15. State and explain the observations made when gas jar containing chlorine is inverted over another containing hydrogen sulphide gas.

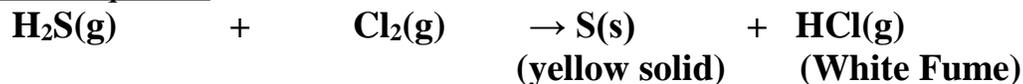
Observation

- Yellow solid formed.**
- Pale colour of chlorine fades**

Explanation

**Chlorine oxidizes hydrogen sulphide to sulphur itself reduced to hydrogen chloride gas. A little water catalyzes the reaction.**

Chemical equation



16. Chlorine was bubbled in aqueous ammonia solution in a beaker state and explain the observation made.

Observation:

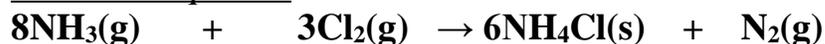
**White fumes evolved.**

**Pale green colour of chlorine fades.**

Explanation

**Chlorine reacts with ammonia gas to form a dense white fume of ammonia chloride and Nitrogen gas is produced.**

Chemical equation



17. (a) Dry gas was bubbled in cold dilute sodium hydroxide solution. Explain the observations made:

Observation

**Pale green colour of chlorine fades.**

**Pale yellow solution is formed.**

Explanation

**Chlorine reacts with hot concentrated sodium hydroxide / Potassium hydroxide solution to form pale yellow solution of metal chlorate (V) and chlorides of the metal**

Chemical equation



(b) The experiment in 17(a) was repeated with hot concentrated sodium hydroxide solution. Explain the observation made.

Observation

**Pale green colour of chlorine fades.**

**Pale yellow solution is formed.**

Explanation

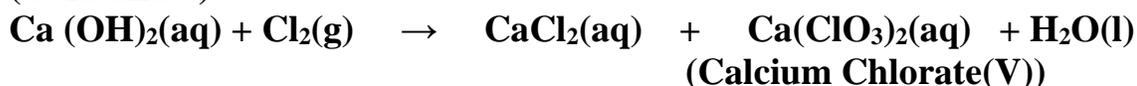
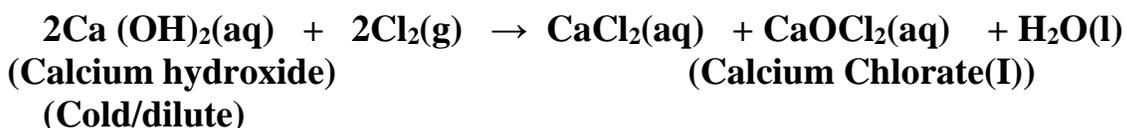
**Chlorine reacts with hot concentrated Sodium hydroxide/Potassium hydroxide solution to form pale yellow solution of metal chlorate (v) and chlorides of metals.**

Chemical equation



**The products formed when chlorine reacts with alkalis depend thus on temperature and the concentration of alkalis.**

(c) (i) Write the equation for the formation of calcium chlorite (I) and calcium chlorate (V).



## **B: THE HALOGENS**

a) What are halogens?

**These are elements in group VII of the periodic table. They include:**

<b>Element</b>	<b>Symbol</b>	<b>Atomic number</b>	<b>Electric configuration</b>	<b>Charge of ion</b>	<b>Valency</b>	<b>State at Room Temperature</b>
<b>Fluorine</b>	<b>F</b>	<b>9</b>	<b>2:7</b>	<b>F<sup>-</sup></b>	<b>1</b>	<b>Pale yellow gas</b>
<b>Chlorine</b>	<b>Cl</b>	<b>17</b>	<b>2:8:7</b>	<b>Cl<sup>-</sup></b>	<b>1</b>	<b>Pale green gas</b>
<b>Bromine</b>	<b>Br</b>	<b>35</b>	<b>2:8:18:7</b>	<b>Br<sup>-</sup></b>	<b>1</b>	<b>Red liquid</b>
<b>Iodine</b>	<b>I</b>	<b>53</b>	<b>2:8:18:18:7</b>	<b>I<sup>-</sup></b>	<b>1</b>	<b>Grey Solid</b>
<b>Astatine</b>	<b>At</b>	<b>85</b>	<b>2:8:18:32:18:7</b>	<b>At<sup>-</sup></b>	<b>1</b>	<b>Radioactive</b>

b) Compare the atomic radius and ionic radius of chloride ion and chlorine. Explain.

**The radius of chlorine is smaller than the ionic radius of the chloride ion.**

**Effective nucleus attraction on outer energy level in chloride ion is less than chlorine atom because of extra gained electron that repelled thus causes the outer energy level to expand/increase.**

c) Compare the atomic radius of chlorine and fluorine Explain.

**Atomic radius of Fluorine is smaller than that of chlorine.**

**Chlorine has more energy levels than fluorine occupied by more electrons.**

d) Chlorine is a gas, Bromine is a liquid, Iodine is a solid. Explain the above observations.

**-Bromine, Chlorine and iodine exists as diatomic molecules bonded by strong covalent bond. Each molecule is joined to the other by weak intermolecular forces/ Van-der-waals forces.**

**-The strength of intermolecular/Van-der-waals forces of attraction increase with increase in molecular size/atomic radius. Iodine has therefore the largest atomic radius and thus strongest intermolecular forces to make it a solid.**

e) (i) What is electronegativity?

**Electronegativity is the tendency/ease of acquiring /gaining electrons by an element during chemical reaction.**

**It is measured using Pauling's scale.**

**Fluorine with Pauling scale 4.0 is the most electronegative element in the periodic table and thus the highest tendency to acquire/gain extra electron.**

(ii) The table below shows the electronegativity of the halogens.

<b>Halogen</b>	<b>F</b>	<b>Cl</b>	<b>Br</b>	<b>I</b>	<b>At</b>
<b>Electronegativity (Pauling's scale)</b>	<b>4.0</b>	<b>3.0</b>	<b>2.8</b>	<b>2.5</b>	<b>2.2</b>

Explain the trend in electronegativity of the halogens.

**Decrease down the group from fluorine to Astatine**

**Atomic radius increase down the group decreasing electron – attracting power down the group from fluorine to astatine.**

(f) (i) What is electron affinity

**Electron affinity is the energy required to gain an electron in an atom of an element in its gaseous state.**

(ii) Study the table below showing the electron affinity of halogens for the process



<b>Halogen</b>	<b>F</b>	<b>Cl</b>	<b>Br</b>	<b>I</b>
<b>Electron affinity kJmole<sup>-1</sup></b>	<b>-333</b>	<b>-364</b>	<b>-342</b>	<b>-295</b>

(iii) Explain the trend in electron affinity of the halogens.

**-Decrease down the group**

**-Atomic radius of halogens increase down the group thus incoming/gained electron is attracted less strongly by the progressively larger atoms with a decreasing effective nuclear charge on outer energy level**

(iv) Which is a more stable ion  $\text{Cl}^-$  or  $\text{Br}^-$  explain?

**- $\text{Cl}^-$  ion.**

**-Has a more negative/exothermic electron affinity than  $\text{Br}^-$**

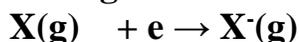
(v) Differentiate between electron affinity and:

I. Ionization energy.

**Ionization energy is the energy required to lose /donate an electron in an atom of an element in its gaseous state while electron affinity is the energy required to gain/acquire extra electron by an atom of an element in its gaseous state. Both are measured in kilojoules per mole.**

II. Electronegativity.

**-Electron affinity is the energy required to gain an electron in an atom of an element in gaseous state. It involves the process:**



**Electronegativity is the ease/tendency of gaining/ acquiring electrons by an element during chemical reactions.**

**It does not involve use of energy but theoretical arbitrary Pauling's scale of measurements.**

(g) (i)  $5\text{cm}^3$  of sodium chloride, Sodium bromide and Sodium iodide solutions were put separately in test tubes. 5 drops of chlorine water was added to each test tube: state and explain the observation made.

Observation

**Yellow colour of chlorine water fades in all test tubes except with sodium chloride.**

**-Coloured Solution formed.**

Explanation

**Chlorine is more electronegative than bromine and iodine. On adding chlorine water, bromine and Iodine are displaced from their solutions by chlorine.**

(ii) The experiment in g (i) was repeated with 5 drops of bromine water instead of chlorine water .explain the observation made.

Observation

- Yellow colour of bromine water fades in test tube containing sodium iodide.**  
**- Brown solution formed in test tube containing sodium iodide**

Explanation

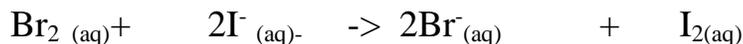
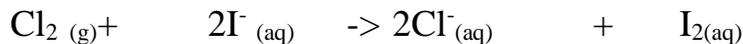
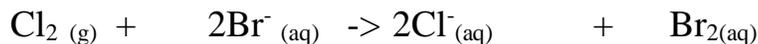
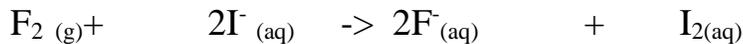
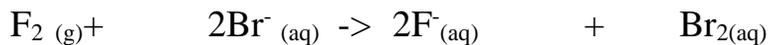
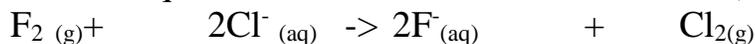
**Bromine is more electronegative than iodide but less than chlorine.**  
**On adding Bromine water, iodide displaced from its solution but not chlorine.**

(iii) Using the knowledge in g(i) and (ii) above,

I. Complete the table below using (X) to show no reaction and (✓) to show a reaction.

Halogen ion in solution Halogen	F <sup>-</sup>	Cl <sup>-</sup>	Br <sup>-</sup>	I <sup>-</sup>
F <sub>2</sub>	X	✓	✓	✓
Cl <sub>2</sub>	X	X	✓	✓
Br <sub>2</sub>	X	X	X	✓
I <sub>2</sub>	X	X	X	✓

Write an ionic equation for the reaction where there is (✓)



(h) State one uses of:

(i) Fluorine

**Manufacture of P.T.F.E (Poly tetra fluoroethene) synthetic fiber.**

**Reduce tooth decay when added in small amounts/equations in tooth paste.**

**Note: large small quantities of fluorine /fluoride ions in water cause browning of teeth/flourosis.**

**Hydrogen fluoride is used to engrave word pictures in glass.**

(ii) Bromine

**Silver bromide is used to make light sensitive photographic paper/films.**

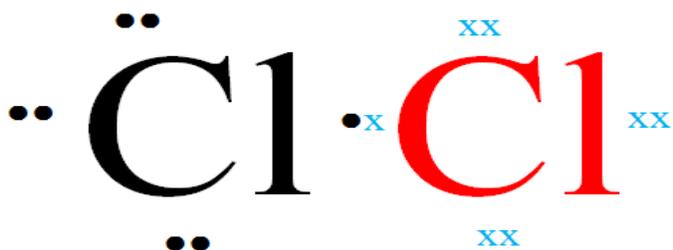
(iii) Iodide

**Iodine dissolved in alcohol is used as medicine to kill bacteria in skin cuts. It is called tincture of iodine.**

(i) The table below to show some compounds of halogens.

Element \ Halogen	H	Na	Mg	Al	Si	C	P
F	HF	NaF	MgH <sub>2</sub>	AlF <sub>3</sub>	SiF <sub>4</sub>	CF <sub>4</sub>	PF <sub>3</sub>
Cl	HCl	NaCl	MgCl	AlCl <sub>3</sub>	SiCl <sub>3</sub>	CCl <sub>4</sub>	PCl <sub>3</sub>
Br	HBr	NaBr	MgBr <sub>2</sub>	AlBr <sub>3</sub>	SiBr <sub>4</sub>	CBr <sub>4</sub>	PBr <sub>3</sub>
I	HI	NaI	MgI <sub>2</sub>	AlI <sub>3</sub>	SiI <sub>4</sub>	Cl <sub>2</sub>	Pb <sub>3</sub>

(j) (i) Using dot (.) and Cross (x) to represent electrons, show the bonding in chlorine molecule.



**Cl<sub>2</sub> (diatomic molecule)**

(ii) Name the type of bond formed.

## Covalent.

(iii) Below is the table showing the bond energy of four halogens.

Bond	Bond energy k J mole <sup>-1</sup>
Cl-Cl	242
Br-Br	193
I-I	151

I. What do you understand by the term “bond energy”

**Bond energy is the energy required to break/ form one mole of chemical bond**

II. Explain the trend in bond Energy of the halogens above:

**-Decrease down the group from chlorine to Iodine**

**-Atomic radius increase down the group decreasing the energy required to break the covalent bonds between the larger atom with reduced effective nuclear charge an outer energy level that take part in bonding.**

(k) Some compounds of chlorine are in the table below the oxidation state of chlorine in each compound.

Compound	Oxidation state	Name of compound
NaClO <sub>3</sub>	<b>+5</b>	<b>Sodium chlorate (V)</b>
ClO <sub>2</sub>	<b>+4</b>	<b>Chloric (IV) oxide</b>
KClO <sub>2</sub>	<b>+3</b>	<b>Potassium chlorate (III)</b>
NaClO	<b>+1</b>	<b>Sodium Chlorite (I)</b>
Cl <sub>2</sub>	<b>0</b>	<b>Chlorine Molecule</b>
NaCl	<b>-1</b>	<b>Sodium Chloride (I)</b>
MgCl <sub>2</sub>	<b>-1</b>	<b>Magnesium Chloride (I)</b>

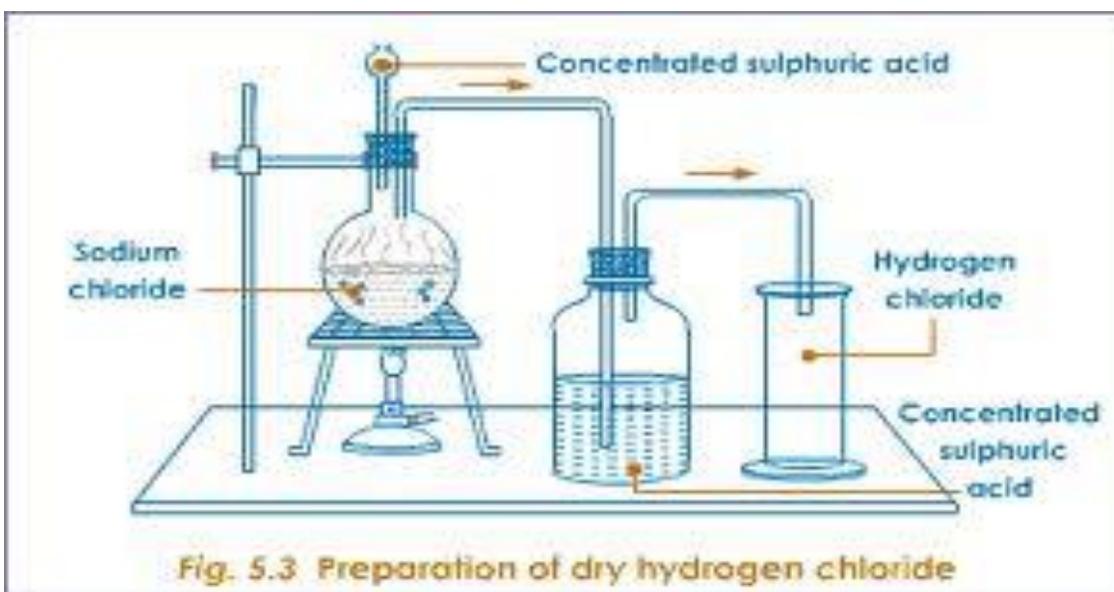
## C. HYDROGEN CHLORIDE

### a) Occurrence

Hydrogen Chloride does not occur free in the atmosphere or in nature

### b) Preparation

Hydrogen chloride may be prepared in the school laboratory by reacting solid sodium/potassium chloride crystals with concentrated sulphuric (VI) acid as in the set up below.



### c) Properties of hydrogen chloride gas(questions)

1. What precautions should be taken when handling concentrated sulphuric acid? Explain.  
**-Wear protective clothing/gloves to avoid accidental contact with skin.**  
**-Concentrated sulphuric (VI) acid is highly corrosive-it causes painful wounds when in contact with skin.**

2. What method of gas collection is used? Explain.  
**-Downward delivery// upward displacement of water**  
**-Hydrogen chloride is denser than air.**

3. a) Write the equation for the reaction that takes place.



**NaCl is commonly used because it is cheaper than KCl**

b) What property of concentrated sulphuric (VI) acid is used during the above reaction  
**-is the least volatile mineral acid, thus displace the more volatile hydrogen chloride from its salt (KCl/NaCl)**

d) i) What is the purpose of concentrated sulphuric (VI) acid.  
**-Drying agent / to dry the gas.**

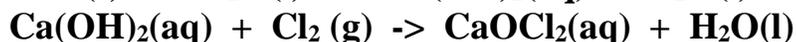
ii) What property of concentrated sulphuric (VI) acid is used during the above use.  
**-Is hygroscopic – absorbs water but do not form solution.**

iii) Name another substance which can be used to dry chlorine gas.  
**-anhydrous Calcium chloride**  
**- silica gel**

iv) Using a chemical equation, explain why anhydrous calcium oxide cannot be used in flask B

**-Calcium oxide reacts with water /moisture to form calcium hydroxide.**  
**The calcium hydroxide formed reacts with chlorine to form calcium hypochlorite.**

**Chemical equations:**



**This reduces the amount of Chlorine produced.**

d) Blue and red litmus papers were dipped in the hydrogen chloride prepared above. The Procedure was repeated with damp/wet/moist litmus papers. Explain the differences in observations made.

- Dry blue litmus papers remain blue
- Dry red litmus papers remain red
- Damp/moist/wet blue litmus papers turn red
- Damp/moist/wet red litmus paper turns red.
- Dry hydrogen chloride is a **molecular** compound that is joined by covalent bonds between the atoms. The gas is **polar** thus dissolves in water and ionize completely to free  $H^+$  that are responsible to turning blue litmus paper red.

e) Dry hydrogen chloride gas was bubbled in two separately beakers containing water and in methylbenzene.

(i) Classify the two solvents as either “polar” or “non-polar”

**Water – polar**

**Methylbenzene – non-polar**

(ii) State and explain the observations made in the beaker containing:

(i) Methylbenzene

**Colour of litmus solution remain.**

**Hydrogen chloride is a molecular substance. When dissolved in non-polar solvent, it does not dissociate / ionize to release  $H^+$  ions that changes the colour of litmus solution.**

(ii) Water

**Colour of litmus solution change to red.**

**Hydrogen chloride is a molecular substance. When dissolved in polar solvent like water, it dissociate/ionize to release  $H^+$  ions that changes litmus solution to red.**

(iii) Why should an inverted filter funnel be used to dissolve hydrogen chloride.

- **The filter funnel is dipped just below the water surface to increase the surface area of dissolving the gas and prevent suck back.**

(iv) Name the solution formed when hydrogen chloride dissolves in water.

**Hydrochloric acid**

(f) Describe the test for presence of hydrogen chloride gas.

- **Dip a glass rod in ammonia. Bring it to the mouth of a gas jar containing a gas suspected to be hydrogen chloride**
- **White fumes of ammonia chloride are formed.**

(g) Place  $5\text{cm}^3$  of dilute hydrochloric acid into a four separate test tubes. To separate test tube add zinc, magnesium iron and copper metals. State and explain the observations made.

Observation

- **Effervescence/bubbles/fizzing in all cases except copper**
- **Colourless solution formed with zinc and magnesium.**

- **Green solution formed with iron.**
- **Gas produced that extinguishes splint with explosion.**

Explanation

**Metals above hydrogen in reactivity series react with hydrochloric acid liberating hydrogen gas.**

Chemical Equation:

**Concentrated hydrochloric acid is a weak oxidizing agent than other concentrated acids i.e Sulphuric (VI) acid and nitric (V) acid that react with all metals even those lower in the reactivity series.**

- (h) Place 5cm<sup>3</sup> of dilute hydrochloric acid into five separate test tubes. To separate test tubes, add calcium carbonate, silver carbonate, copper carbonate, iron (II) carbonate and Sodium hydrogen carbonate. Explain the observations made.

Observation

**Effervescence/bubbles/fizzing vigorously except in silver carbonate and lead (II) carbonate that stop later.**

- **Colourless solution formed except with iron (II) carbonate and copper (II) carbonate**
- **Green solution formed with iron (II) carbonate**
- **Blue solution formed with copper (II) carbonate**

Explanation.

**Carbonates and hydrogen carbonate react with dilute hydrochloric acid to produce carbon (IV) oxide, water and form chlorides.**

**All chlorides formed are soluble Except Lead (II) Chloride (soluble on heating/warming) and silver chloride.**

Chemical equation:



Chemical equation:



Chemical equation:



Chemical equation:



Chemical equation:



- (I) Place 5cm<sup>3</sup> of dilute sodium hydroxide, Potassium hydroxide and aqueous ammonia solution into three separate test tubes. Add one drop of phenolphthalein indicator drop wise, add dilute hydrochloric acid. Explain the observations made.

Observation

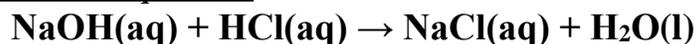
**Colour of Phenolphthalein indicator change from pink to colourless.**

Explanation

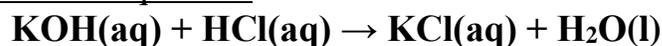
**Hydrochloric acid neutralizes alkalis to salt and water**

**When all the alkali has reacted with the acid, An extra slight **excess** acid turns the indicator used to colourless.**

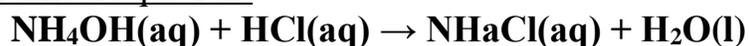
Chemical equation:



Chemical equation:



Chemical equation:



- (j) Place 5cm<sup>3</sup> of hydrochloric acid into four separate test tube tubes Separately add about 1g of each of copper (II) Oxide, Zinc (II) Oxide, Lead (II) Oxide< Calcium (II) Oxide. What happens to each test tube? Explain.

Observation:

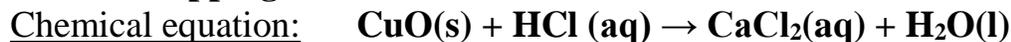
**All Solid dissolves except Lead (II) Oxide**

**Colourless solution formed with zinc Oxide and calcium (II) Oxide blue solution formed with copper (II) Oxide.**

Explanation:

**Metal oxides dissolves in dilute hydrochloric acid to form water and chloride salt**

**Insoluble Lead (II) chloride and silver chloride once formed cover/coat unreacted oxides stopping further reaction.**



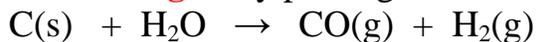
## **(k) Manufacture of Hydrochloric acid.**

**(i) Raw Materials**

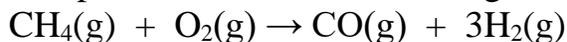
**1. Hydrogen**

(i) During **electrolysis** of Brine from the flowing mercury-cathode cell during the manufacture of sodium hydroxide solution.

(ii) From **water gas** by passing steam in heated charcoal.



(iii) From partial oxidation of natural gas/methane



## 2.Chlorine

(i) From electrolysis of **fused**/solid sodium chloride in the downs process during extraction of sodium

(ii) From electrolysis of **brine**/concentrated sodium chloride solution in the flowing mercury-cathode during the manufacture of sodium hydroxide solution.

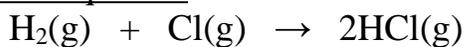
### (ii)Chemical processes.

- Hydrogen and chlorine gases are separately passed through concentrated sulphuric(VI) acid to act as a **drying** agent.
- Small amount of pure hydrogen is continuously ignited in a chamber with **continous** supply of pure dry chlorine.

**Large amount of hydrogen explodes.**

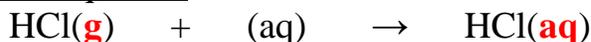
- Hydrogen burns in chlorine to form hydrogen chloride gas.

Chemical Equation



- The hydrogen chloride produced is then passed up to meet a downward flow of water in the **absorbtion** chambers. Hydrogen chloride is very soluble in water and dissolves to form **35%** concentrated hydrochloric acid.

Chemical Equation



The absorption chamber is shelved and packed with broken glass beads to

(i) Slow down the downward flow of water.

(ii) Increase surface area over which the water dissolves

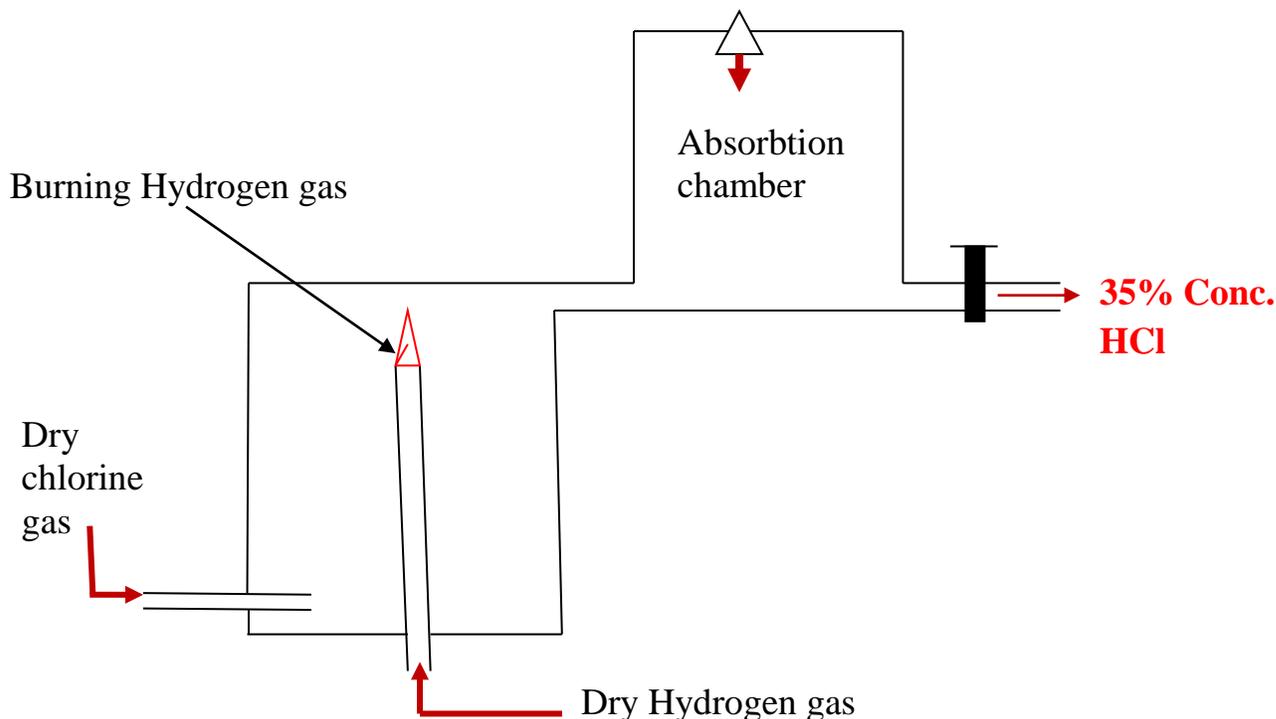
The hydrochloric acid is then transported in steel tanks lined with rubber for market

### (iii)Uses of Hydrochloric Acid

- To standardize the pH of (alcohol and wines)
- Regenerating ion-exchange resin during removal of hardness of water.
- Pickling of metals to remove oxide layers on their surfaces.
- In the manufacture of dyes and drugs.
- Making zinc chloride for making dry cells.

### (iv)Diagram Showing Industrial manufacture.





**(ii) Environmental effects of manufacturing HCl.**

- Hydrochloric acid is acidic. Any leakage from a manufacturing plant to nearby rivers/lake causes excess acidity that lowers pH of water killing marine life.
- Hydrogen chloride leakage into atmosphere dissolves to form “acidic rain” that accelerate corrosion in buildings, Breathing problems to human beings and kill fauna and flora around the plant.
- Chlorine leakage causes breathing and sight problems to human being. It accelerates bleaching of dyed metals.
- Hydrogen leakage can cause an explosion because impure hydrogen explodes on ignition.

**(ii) Factors considered in setting hydrochloric acid manufacturing plant.**

1. Nearness to the manufacturing of sodium hydroxide because the by products of electrolysis of brine are the raw materials for hydrochloric acid plant.
2. Availability of natural gas for extraction of hydrogen.
3. Nearness/Availability of water to dissolve the hydrogen chloride gas.
4. Availability of labour, market, capital and good means of transport.

## D: CHLORIDE (Cl<sup>-</sup>) SALTS

### (a) Occurrence.

1. Chlorides are salts derived from hydrochloric acid. Hydrochloric acid is a monobasic (HX) salt with only one ionizable/replaceable “H” in its molecule. All chlorides are therefore normal salts.
2. All metals exist as chloride salt except platinum and gold as below

Metal	K	Na	Li	Mg	Ca	Al	Zn	Fe	Pb	H.	Cu	Ag	Hg
Formula of chloride	KCl	NaCl	LiCl	MgCl <sub>2</sub>	CaCl <sub>2</sub>	AlCl <sub>3</sub>	ZnCl <sub>2</sub>	FeCl <sub>2</sub> FeCl <sub>3</sub>	PbCl PbCl <sub>4</sub>	HCl	CuCl CuCl <sub>2</sub>	AgCl	Hg <sub>2</sub> Cl <sub>2</sub> HgCl <sub>2</sub>

(i) Both FeCl<sub>2</sub> and FeCl<sub>3</sub> exist but FeCl<sub>2</sub> is readily oxidized to FeCl<sub>3</sub> because it is more stable.

(ii) PbCl<sub>2</sub> and PbCl<sub>4</sub> exist but PbCl<sub>4</sub> is only oxidized to form PbCl<sub>2</sub> by using excess chlorine. It is less stable.

(iii) CuCl and CuCl<sub>2</sub> exist but CuCl<sub>2</sub> is (thermodynamically) more stable than CuCl. CuCl disproportionates to Cu and CuCl<sub>2</sub>.

(iv) HgCl and HgCl<sub>2</sub> exist as molecular compounds.



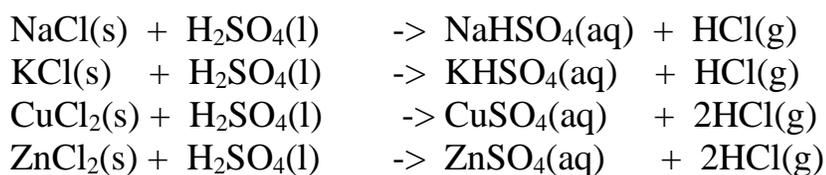
-vigorous effervescence/fizzing /bubbling	Cl <sup>-</sup> ions
-white fumes produced on	HCl gas suspected

**(b)Explanation:**

Concentrated sulphuric (VI) acid is the less volatile mineral acid.

It vigorously displaces chlorine in metal chlorides to evolve acidic hydrogen chloride gas fumes.

Chemical equation



Hydrogen chloride and ammonia gases react and form **white fumes** of ammonium chloride that confirms presence of Cl<sup>-</sup> ions in the **solid** substance.

Chemical equation



2. The following experiment shows the test for the presence of **Cl<sup>-</sup> ions** in **solution** /**aqueous** chloride salts.

**(i)Using aqueous Lead (II) nitrate(V)**

**(a)Procedure:**

I.Place about 5cm<sup>3</sup> of sodium chloride, Iron (III) chloride and copper (II) chloride in separate boiling tubes. Add four drops of Lead (II) nitrate(V) solution to each. Preserve.

Observation	Inference
White precipitate/ppt	SO <sub>4</sub> <sup>2-</sup> , SO <sub>3</sub> <sup>2-</sup> , Cl <sup>-</sup> ,CO <sub>3</sub> <sup>2-</sup>

II.To the preserved sample, add six drops of nitric (V) acid. Preserve.

Observation	Inference
White precipitate/ppt persist	SO <sub>4</sub> <sup>2-</sup> , Cl <sup>-</sup>

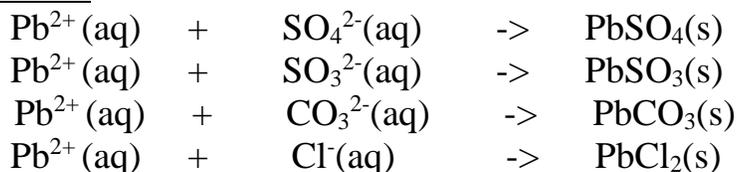
III. To the preserved sample, heat the mixture to boil

Observation	Inference
White precipitate/ppt dissolves on boiling/warming	Cl <sup>-</sup>

**Explanation:**

I. When Lead(II) nitrate(V) solution is added to an unknown salt, a **white precipitate/ppt** of Lead(II) sulphate(VI) Lead(II) carbonate(IV) Lead(II) sulphate(IV) Lead(II) chloride(I) are formed.

Ionic equation:



II. When the white precipitate/ppt formed is acidified with dilute **nitric(V) acid**, the white precipitate of Lead(II) sulphate(VI) and Lead(II) chloride(I) **persist/remain** while that of Lead(II) carbonate(IV) and Lead(II) sulphate(IV) **dissolves**.

III. On **heating/warming** Lead (II) chloride (I) **dissolves** but on cooling it **recrystallizes**. This shows the presence of **Cl<sup>-</sup> ions** in aqueous solutions

**(ii) Using aqueous silver (I) nitrate(V)**

**Procedure**

I. Place about 5cm<sup>3</sup> of sodium chloride, Iron (III) chloride and copper (II) chloride in separate boiling tubes. Add four drops of silver(I) nitrate(V) solution to each. Preserve.

Observation	Inference
White precipitate/ppt	Cl <sup>-</sup> , CO <sub>3</sub> <sup>2-</sup>

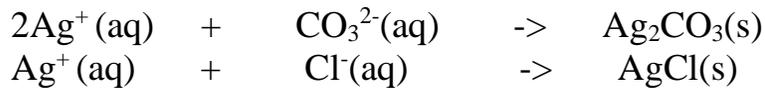
II. To the preserved sample, add six drops of nitric (V) acid. Preserve.

Observation	Inference
White precipitate/ppt persist	Cl <sup>-</sup>

**Explanation:**

I. When silver(I) nitrate(V) solution is added to an unknown salt, a **white precipitate /ppt** of silver(I) carbonate(IV) and silver(I) chloride(I) are formed.

Ionic equation:

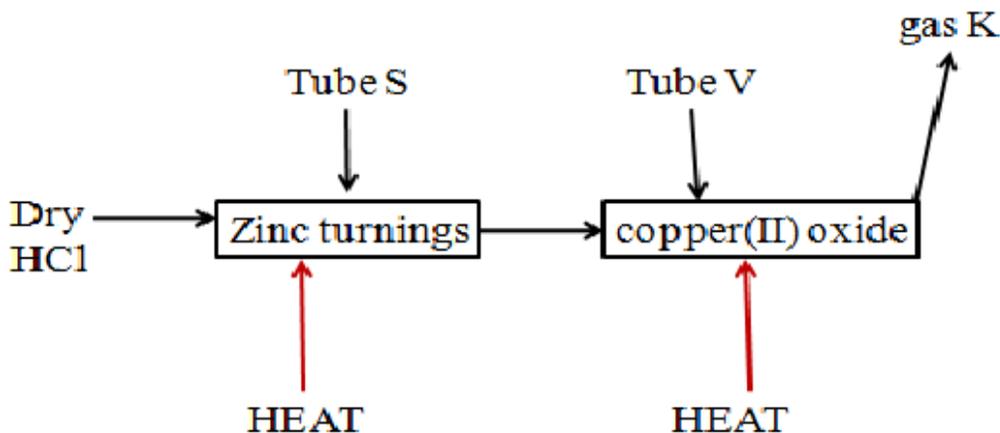


II. When the white precipitate/ppt formed is acidified with dilute **nitric (V) acid**, the white precipitate of silver (I) chloride (I) **persist/remain**. This shows the presence of **Cl<sup>-</sup>** ions in **aqueous solutions**.

Silver (I) carbonate (IV) **dissolves** when reacted with nitric (V) acid.

### COMPREHENSIVE REVISION QUESTIONS

1. In an experiment, dry hydrogen chloride gas was passed through heated zinc turnings as in the set up below. The gas produced was then passed through copper(II) oxide



a) Write the equation for the reaction :

(i) For the school laboratory preparation of hydrogen chloride gas.



(ii) in tube S



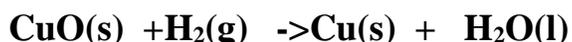
b) State and explain the observation made in tube V.

Observations-**colour of solid changes from black to brown**

**-colourless liquid forms on the cooler parts of tube V**

Explanation-**Hydrogen produced in tube S reduces black copper(II) oxide to brown copper metal and the gas oxidized to water vapour that condense on cooler parts..**

Chemical equation.



(c) How would the total mass of tube S and tube V and their contents compare before and after the experiment.

Tube S- **Mass increase/rise because Zinc combine with chlorine to form heavier Zinc Chloride.**

Tube V- **Mass decrease/falls/lowers because copper (II) oxide is reduced to lighter copper and oxygen combine with hydrogen to form water vapour that escape.**

2. Chlorine is prepared by using solid sodium chloride, concentrated sulphuric(VI) acid and potassium manganate(VII)

a) What is the role of the following in the reaction;

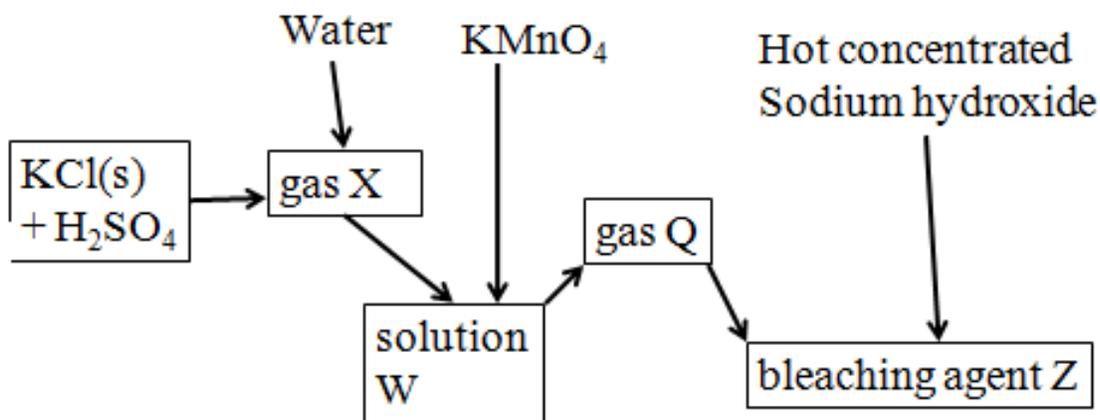
(i) concentrated sulphuric(VI)

**To produce hydrogen chloride gas by reacting with the solid sodium chloride.**

(ii) potassium manganate(VII)

**To oxidize hydrogen chloride gas to chlorine**

3. Use the flow chart below to answer the questions that follow.



a)(i) Name:

gas X

**Hydrogen chloride**

solution W

**hydrochloric acid**

gas Q

**chlorine**

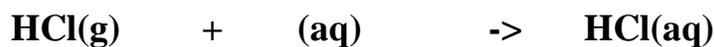
bleaching agent Z **sodium chlorate(V)**

b) Write the chemical equation for the formation of :

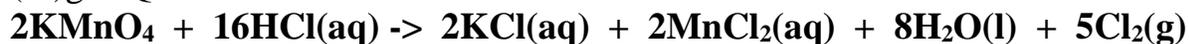
(i) gas X



(ii) solution W



(iii) gas Q



(iv) bleaching agent Z

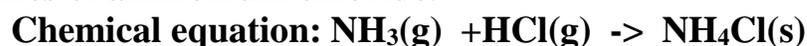


c) State and explain the following observations;

(i) a glass rod dipped in aqueous ammonia is brought near gas X

**Observation: Dense white fumes**

**Explanation: Ammonia gas reacts with hydrogen chloride gas to form dense white fumes of ammonium chloride.**

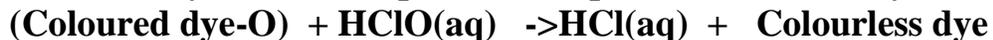


(ii) Wet blue and red litmus papers were dipped into gas Q

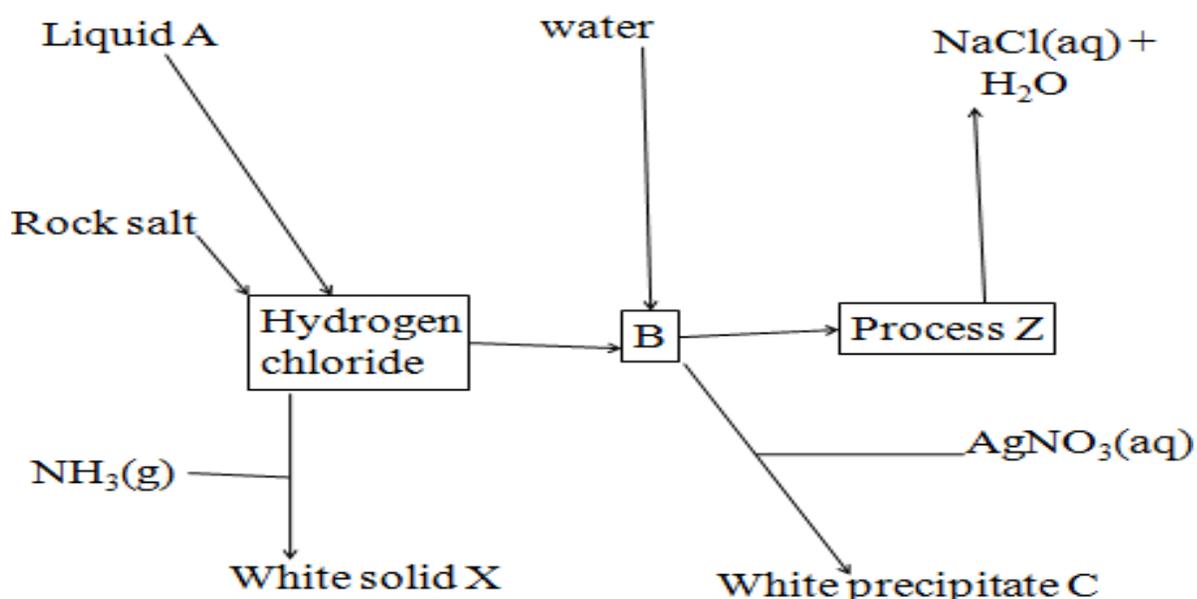
**Observations: Blue litmus paper turned red the both are bleached /decolorized.**

**Explanations:** chlorine reacts with water to form both acidic hydrochloric and chloric (I) acids that turn blue litmus paper red. Unstable chloric (I) acid oxidizes the dye in the papers to colourless.

**Chemical equations**



4. Use the flow chart below to answer the questions that follow



a) Name

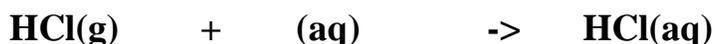
Liquid A	<b>Concentrated sulphuric(VI) acid</b>
Process Z	<b>Neutralization</b>
White solid X	<b>Ammonium chloride</b>

b) Write the equation for the formation of:

(i) Hydrogen chloride



(ii) B



(iii) process Z (using ionic equation)



(iv) C (using ionic equation)



c) Describe how solution B is obtained.

**Bubbling hydrogen chloride gas through inverted funnel into distilled water until no more dissolve.**

5 The results obtained when halogens are bubbled into test tubes containing solutions of halide A, B and C is as in the table below. Tick(v) means a reaction took place. Cross(x) means no reaction took place.

Halogens	Halide ions in solution		
	A	B	C
I <sub>2</sub>	x	-	x
Br <sub>2</sub>	x	v	-
Cl <sub>2</sub>	-	v	v

a) Identify the halide ions represented by letter

A            **Cl<sup>-</sup>**  
B            **I<sup>-</sup>**  
C            **Br<sup>-</sup>**

b) Write the ionic equation for the reaction that take place with halide:

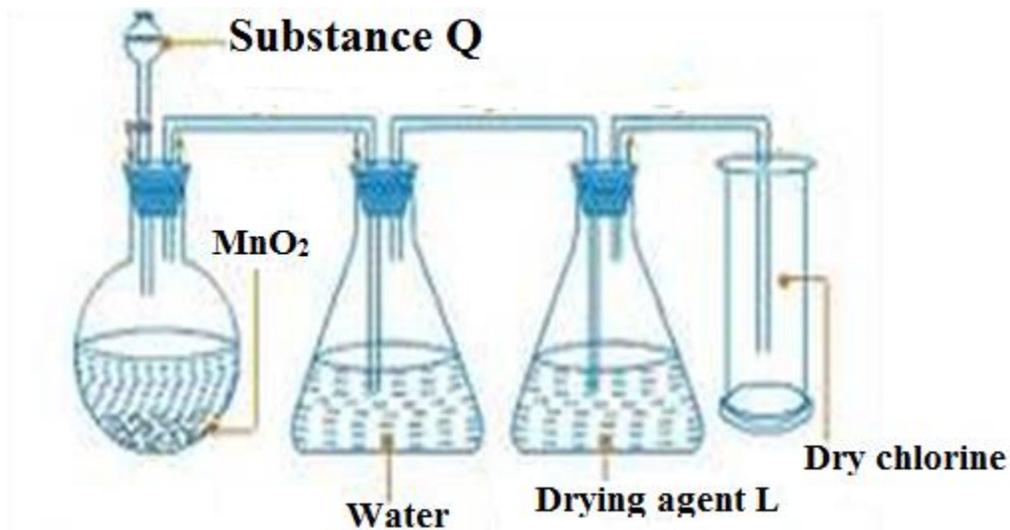
(i) C



(ii) B



6. The diagram below shows a set up of apparatus for the school laboratory collection of dry chlorine gas.



a) Name:

(i) substance Q

**Concentrated hydrochloric acid**

(ii) suitable drying agent L

**-Concentrated sulphuric(VI) acid**

**-anhydrous calcium chloride**

**-silica gel**

b) State a missing condition for the reaction to take place faster.

**-Heat/Heating**

c) Red and blue litmus papers were dipped into the chlorine gas from the above set up. State and explain the observations made.

**Observation: Blue litmus paper remain blue. Red litmus paper remain red.**

**Explanation: Dry chlorine has no effect on dry litmus papers.**

d) Write the equation for the reaction taking place in the conical flask



e) Name two other substances that can be used in place of  $\text{MnO}_2$

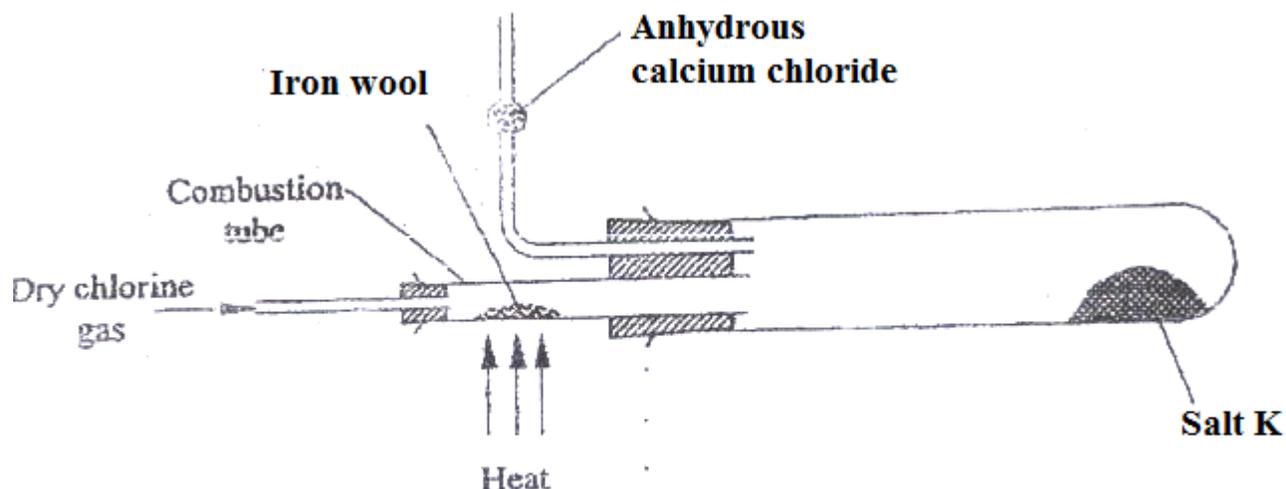
**Lead(IV) oxide ( $\text{PbO}_2$ )**

**Potassium manganate(VI) ( $\text{KMnO}_4$ )**

**Potassium dichromate ( $\text{K}_2\text{Cr}_2\text{O}_4$ )**

**Bleaching powder ( $\text{CaOCl}_2$ )**

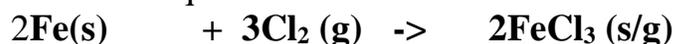
7. The set up below shows the apparatus used to prepare and collect anhydrous iron(III) chloride.



a) Name salt K

**Iron(III) chloride**

b) Write the equation for the reaction for the formation of salt K



c) State and explain the following

(i) Small amount of water is added to iron (II) chloride in a test tube then shaken  
**Solid dissolves to form a green solution. Iron(II) chloride is soluble in water**

(ii) I. Three drops of aqueous sodium hydroxide is added to aqueous iron(II) chloride and then added excess of the alkali.

Observation:

**Green precipitate is formed that persist/remain /insoluble in excess alkali.**

Explanation:

**Iron(II) chloride reacts with aqueous sodium hydroxide to form a green precipitate of iron(II) hydroxide.**

Ionic equation:



II. Six drops of hydrogen peroxide is added to the mixture in d(ii) above.

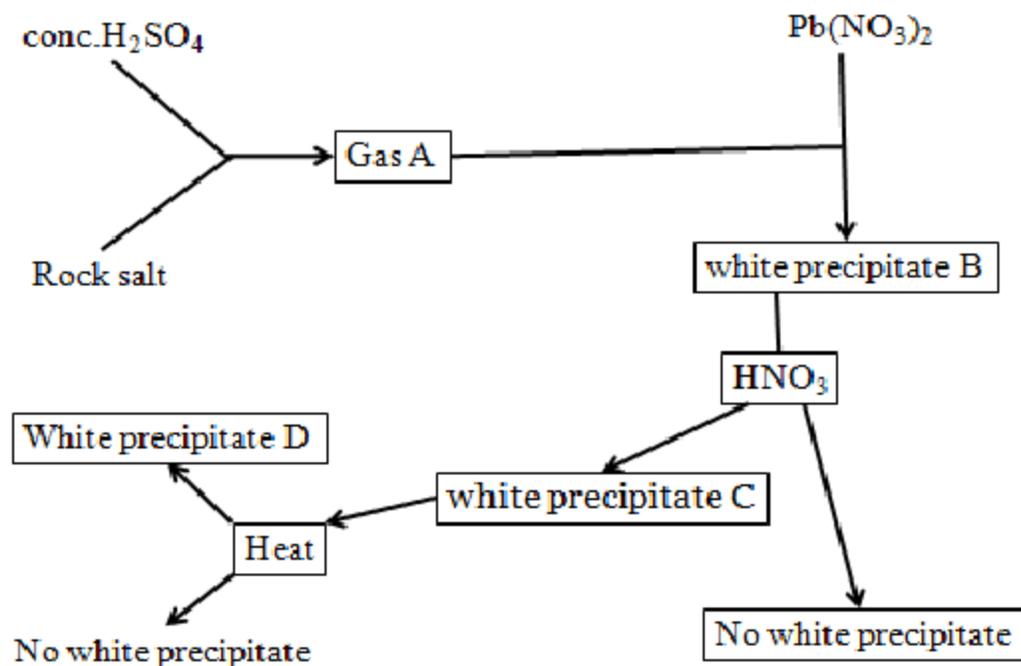
Observation:

**Effervescence/bubbling/fizzing take place and the green precipitate dissolve to form a yellow/brown solution.**

Explanation:

**hydrogen peroxide oxidizes green  $\text{Fe}^{2+}$  to yellow/ brown  $\text{Fe}^{3+}$  solution.**

9. Use the flow chart below to answer the questions that follow.



a) Write the chemical equation for the formation of gas A  
 $\text{NaCl(s)} + \text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{NaHSO}_4(\text{aq}) + \text{HCl(g)}$

b) Identify:

(i) four possible ions that can produce white precipitate B  
 $\text{SO}_4^{2-}, \text{SO}_3^{2-}, \text{CO}_3^{2-}, \text{Cl}^-$

(ii) two possible ions that can produce;

I. White precipitate C

$\text{SO}_4^{2-}, \text{Cl}^-$

II. colourless solution D

$\text{SO}_3^{2-}, \text{CO}_3^{2-}$

(iii) possible ions present in

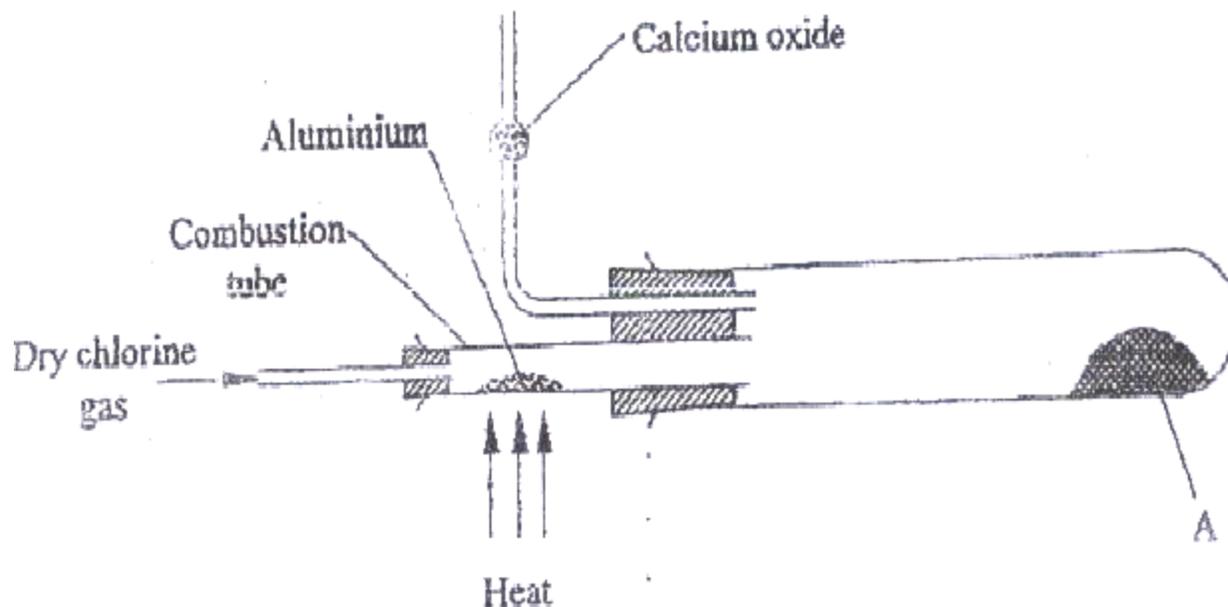
I. White precipitate E



II. colourless solution F



11. Below is a set up in the preparation of a particular salt. Study it and answer the questions that follow.



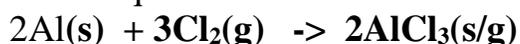
State the observation made when aluminium wool is heated.

**Glows red hot.**

b)(i) Identify salt A

**aluminium(III) chloride//  $\text{AlCl}_3$**

(ii) Write the equation for the formation of salt A



(iii) What property of salt A is exhibited as shown in the experiment.

**It sublimes//sublimation.**

(iv) Calculate the minimum volume of chlorine required to form 700kg of iron(III) chloride at room temperature. (Fe= 56.0, Cl=35.5, 1 mole of a gas =24000cm<sup>3</sup>, 1000g = 1kg)

**Mole ratio Fe : Cl<sub>2</sub> = 2: 3 molar mass FeCl<sub>3</sub> = 162.5g**

**Method 1**

$$2 \times 162.5 \text{ g FeCl}_3 \rightarrow 3 \times 22400 \text{ cm}^3 \text{ Cl}_2$$

$$700 \times 1000 \text{ g FeCl}_3 \rightarrow (700 \times 1000 \times 3 \times 22400) / (2 \times 162.5)$$

$$= \underline{1.4474 \times 10^8 \text{ cm}^3}$$

### Method 2

Moles of FeCl<sub>3</sub> = mass / molar mass

$$\Rightarrow (700 \times 1000) / 162.5 = 4307.6923 \text{ moles}$$

Moles of Cl<sub>2</sub> = 3/2 moles of FeCl<sub>3</sub>

$$\Rightarrow 3/2 \times 4307.6923 = 6461.5385 \text{ moles}$$

Volume of chlorine = moles x molar gas volume

$$\Rightarrow 6461.5385 \times 24000 = \underline{1.5508 \times 10^8 \text{ cm}^3}$$

c) Name another metal that can produce similar results as salt K.

**Iron**

d)(i) What is the purpose of anhydrous calcium chloride.

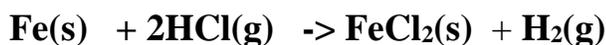
**-ensure the apparatus are water free.**

**-prevent water from the atmosphere from entering and altering/hydrolysing salt A**

(ii) Write the equation for the reaction that take place if anhydrous calcium chloride is not used in the above set up.



(iii) Write the equation for the reaction that take place when Iron metal is reacted with dry hydrogen chloride gas.



(iv) Calculate the mass of Iron(II)chloride formed when 60cm<sup>3</sup> of hydrogen chloride at r.t.p is completely reacted. (1 mole of a gas =24dm<sup>3</sup> at r.t.p, Fe = 56.O, Cl= 35.5)



**Mole ratio HCl: FeCl<sub>2</sub> = 1:1**

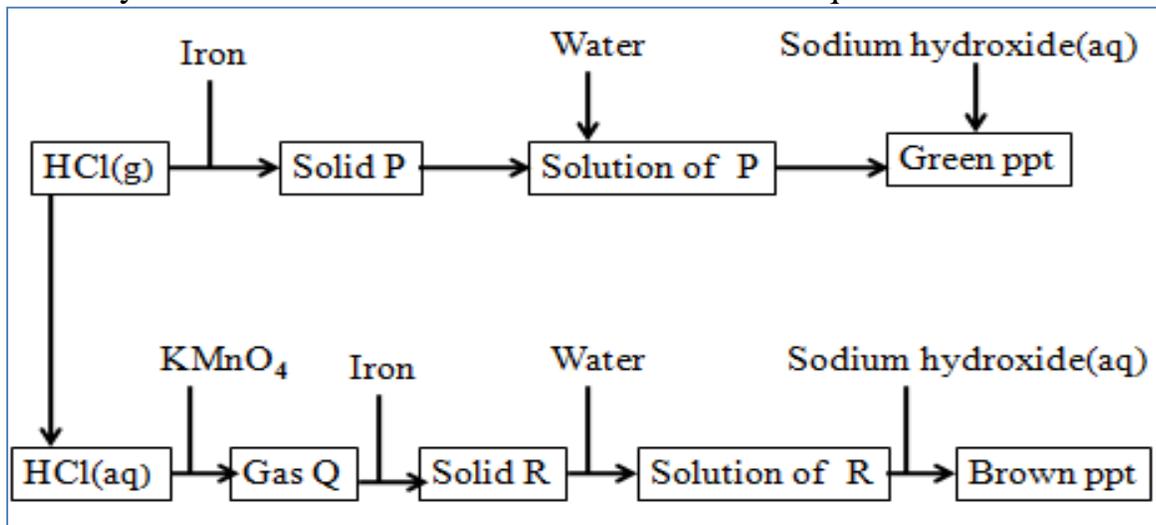
**Molar mass FeCl<sub>2</sub> = 127g**

**Moles of HCl used = 60cm<sup>3</sup> /24000cm<sup>3</sup> = 2.5 x 10<sup>-3</sup> moles**

**Moles of FeCl<sub>2</sub> = Moles of HCl => 2.5 x 10<sup>-3</sup> moles**

**Mass of FeCl<sub>2</sub> = moles x molar mass => 2.5 x 10<sup>-3</sup> x 127 = 0.3175g**

12. Study the flow chart below and use it to answer the questions that follow



a) Identify substance:

- P **Iron(II) chloride//FeCl<sub>2</sub>**  
 Q **Chlorine // Cl<sub>2</sub>**  
 R **Iron(III) chloride//FeCl<sub>3</sub>**

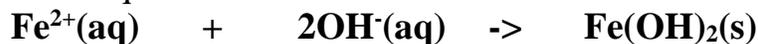
b) Write the equation for the reaction for the formation of:

(i) gas Q



(ii) the green precipitate (using ionic equation)

Ionic equation:



(ii) the brown precipitate (using ionic equation)

Ionic equation:



c) A glass rod was dipped in aqueous ammonia. The rod was then brought near hydrogen chloride. State and explain the observation made.

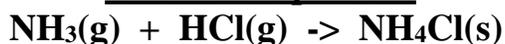
**Observation:**

**White fumes**

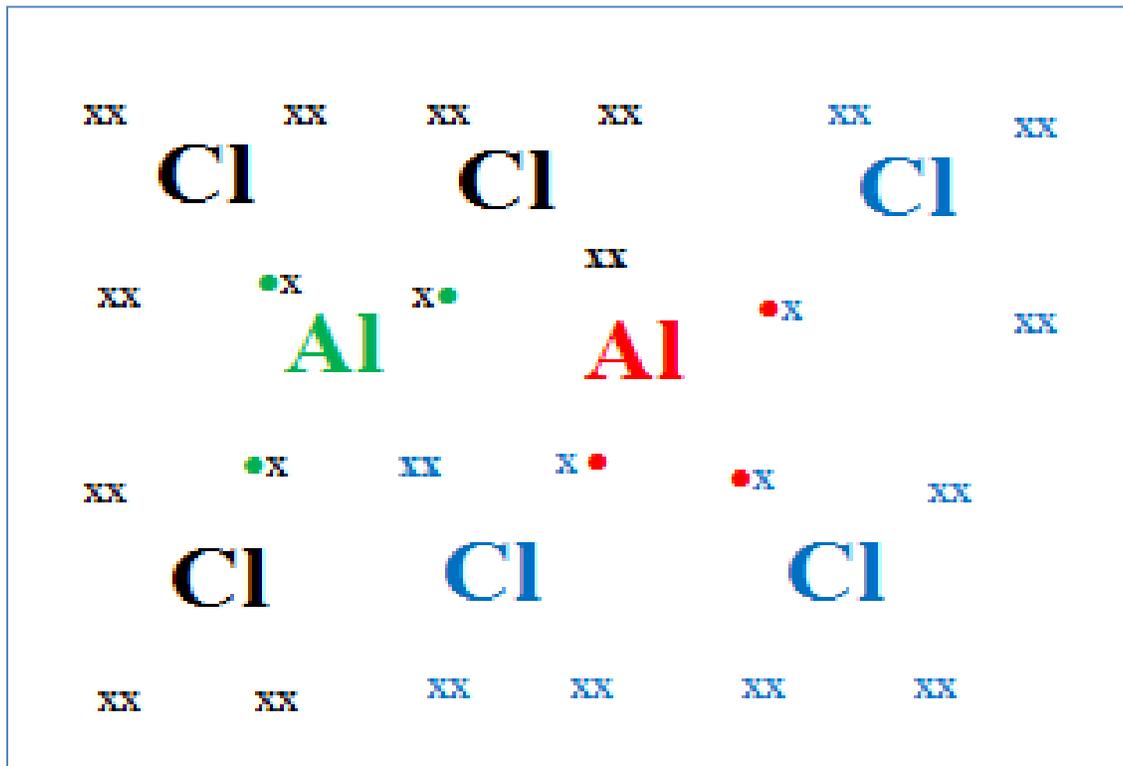
**Explanation:**

**Ammonia gas reacts with hydrogen chloride gas to form white fumes of ammonium chloride.**

**Chemical equation:**



13. Using dot(.)and cross(x)to represent electrons,show the bonding in aluminium chloride in vapour phase.



(b)How many electrons in :

(i)aluminium atoms are used in bonding.

Six electrons(three valence electrons in each aluminium atom)

(ii)chlorine atoms atoms are used in dativebonding.

four electrons(two lone pairs of valence electrons in two chlorine atoms)

(iii)the molecule are used in bonding.

Sixteen electrons

-six valence electrons from aluminium atom through covalent bond

-six valence electrons from chlorine atoms through covalent bond.

- four valence electrons from chlorine atoms through dative bond

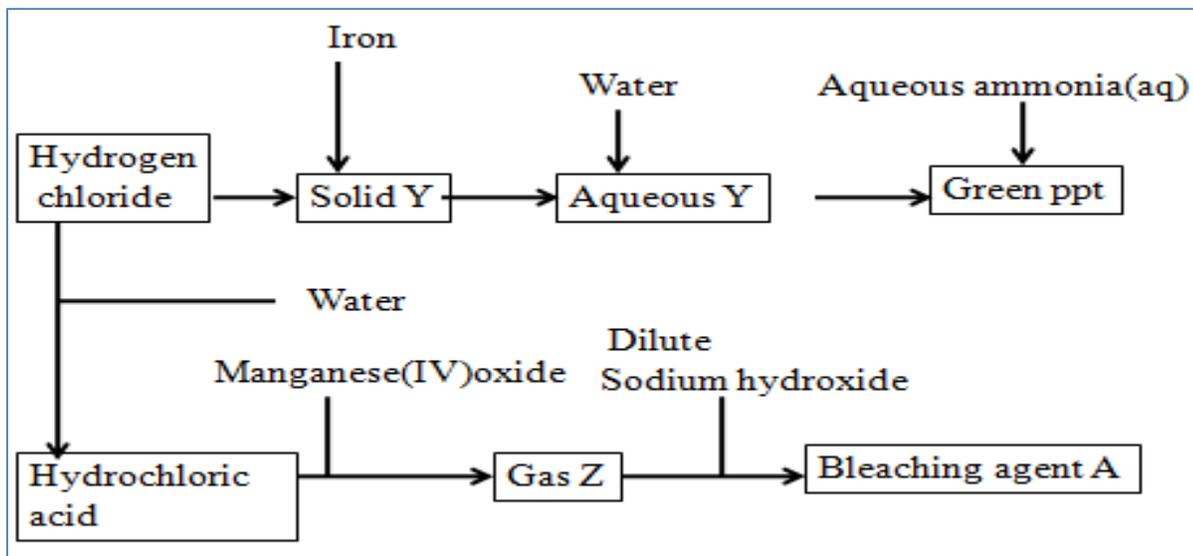
(c)How many lone pair of electrons do not take part in bonding within the molecule.

Sixteen(16) lone pairs from six chlorine atoms(32 electrons)

(d)Aluminium chloride does not conduct electricity in molten state but Magnesium chloride conduct.

Aluminium chloride is a molecular compound that has no free mobile  $\text{Al}^{3+}$  and  $\text{Cl}^-$  ions which are responsible for conducting electricity. Magnesium chloride has free mobile  $\text{Mg}^{2+}$  and  $\text{Cl}^-$  ions because it is an ionic compound.

8. Use the flow chart below to answer the questions that follow:



a) Write an equation for the school laboratory formation of hydrogen chloride gas



b) Name:

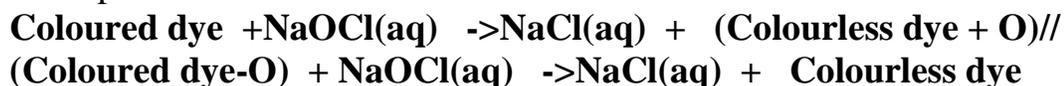
I. solid Y **Iron (II) chloride (FeCl<sub>2</sub>)**

II green precipitate **Iron (II) hydroxide (Fe (OH)<sub>2</sub>)**

III Gas Y **Chlorine (Cl<sub>2</sub>)**

IV. Bleaching agent A **Sodium hypochlorite (NaOCl)**

c) Blue and red litmus papers were dipped into bleaching agent A. Write the equation for the reaction that takes place.



d) State four uses of gas Z

1. Bleaching agent
2. Manufacture of hydrochloric acid
3. Chlorination of water to kill germs
4. Manufacture of PVC pipes

