# Ratna Sagar

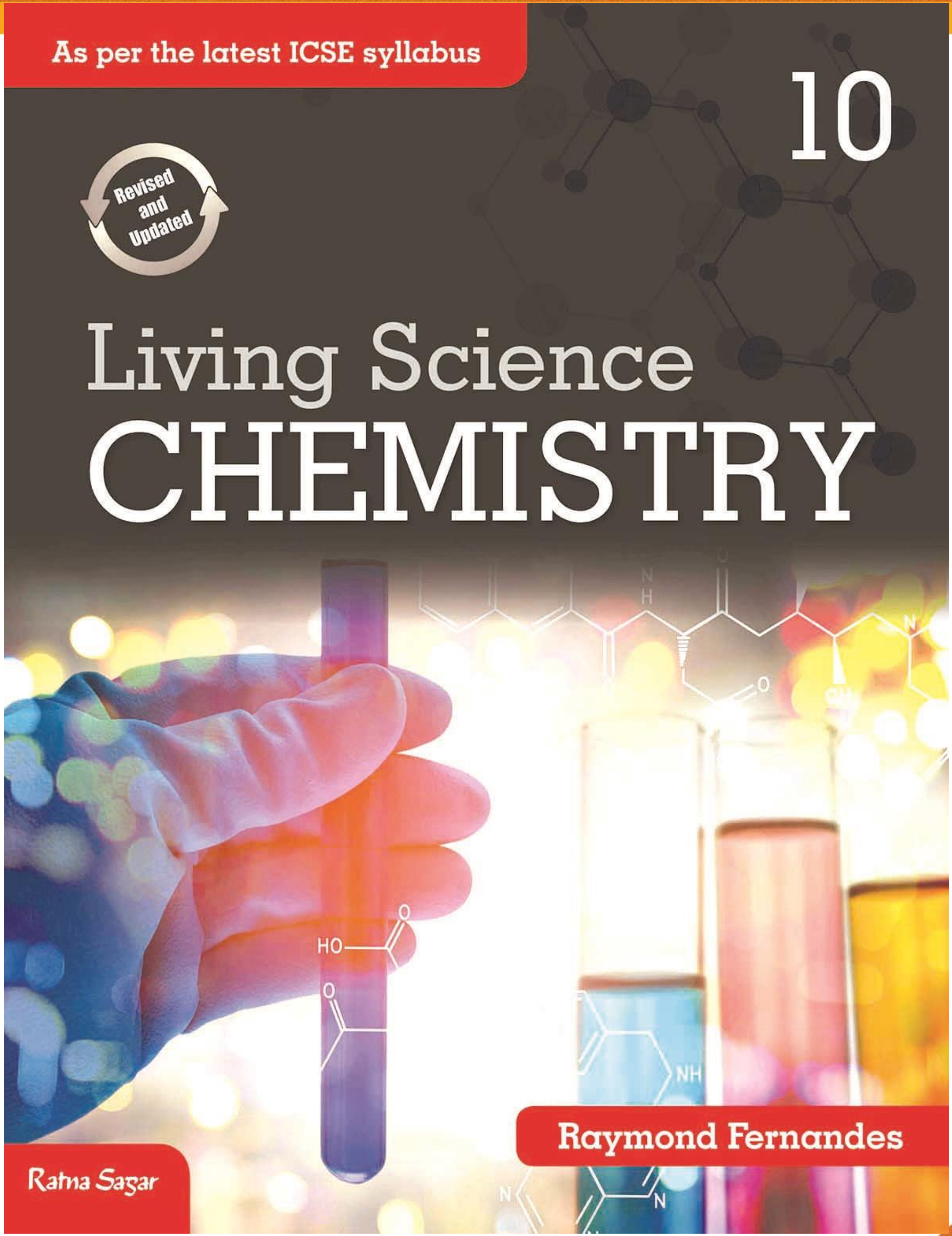
RATNA SAGAR | PRIMUS | BYWORD | E-LIVE

Education, Our Mission

# ICSE
# Living Science
# Chemistry

## Class 10

## Chapter-10 Study of Compounds- Nitric Acid


As per the latest ICSE syllabus
10
Revised and Updated
Living Science
CHEMISTRY
Raymond Fernandes
Ratna Sagar

## LEARNING OBJECTIVES

### Nitric Acid

- ❖Important characteristics of nitric acid
- ❖Occurrence in free state
- ❖Laboratory preparation of nitric acid
- ❖Industrial preparation of nitric acid
- ❖Physical properties of nitric acid
- ❖Chemical properties of nitric acid
- ❖Tests for nitric acid
- ❖Uses of nitric acid

## History of Nitric Acid

The origin of nitric acid can be traced back to the eighth century alchemists due to its property of dissolving silver. In 1658, **Glauber** prepared it by heating saltpeter or nitre (potassium nitrate, KNO3) with concentrated sulphuric acid. In 1785, **Cavendish** established its composition. **Lavoisier** in 1776 proved that oxygen is present in nitric acid.

## Important Characteristics of Nitric Acid

**Molecular formula**: $HNO_3$

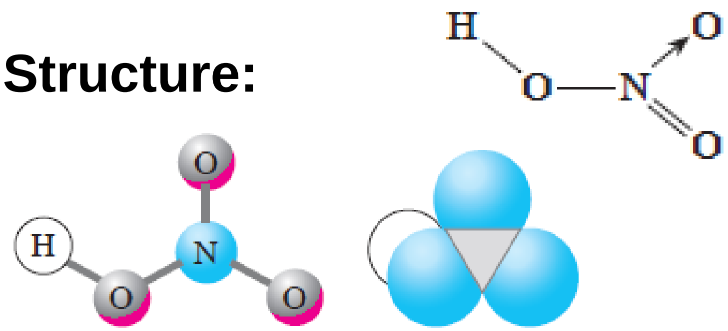
**Molecular mass:** 63 u

**Nature:** Acidic in nature

**Solubility:** Highly soluble in water

**Common name**: Aqua fortis

**Structure:**




## Occurrence in free state

Nitric acid is present in small quantities in the atmosphere after lightning and rain. During lightning discharge, when the temperature is very high, atmospheric nitrogen combines with oxygen of the air to form nitric oxide.

$$N_2 + O_2 \rightleftharpoons 2NO$$

This nitric oxide is further oxidized to form nitrogen dioxide.

$$2NO + O_2 \rightleftharpoons 2NO2$$

Nitrogen dioxide dissolves in rainwater to form nitric acid and comes down as a very dilute solution.

$$4NO_2 + 2H_2O + O_2 \rightleftharpoons 4HNO_3$$

This nitric acid present in the rainwater reacts with the minerals present in the soil to form nitrates.

$$2HNO_3 + CaCO_3 \longrightarrow Ca(NO_3)_2 + H_2O + CO_2$$

## Occurrence in combined state

It is found in the combined state as chile saltpeter (sodium nitrate, $NaNO_3$), saltpetre or nitre (potassium nitrate, $KNO_3$) and lime saltpetre (calcium nitrate [$Ca(NO_3)_2$])

## Laboratory preparation of nitric acid

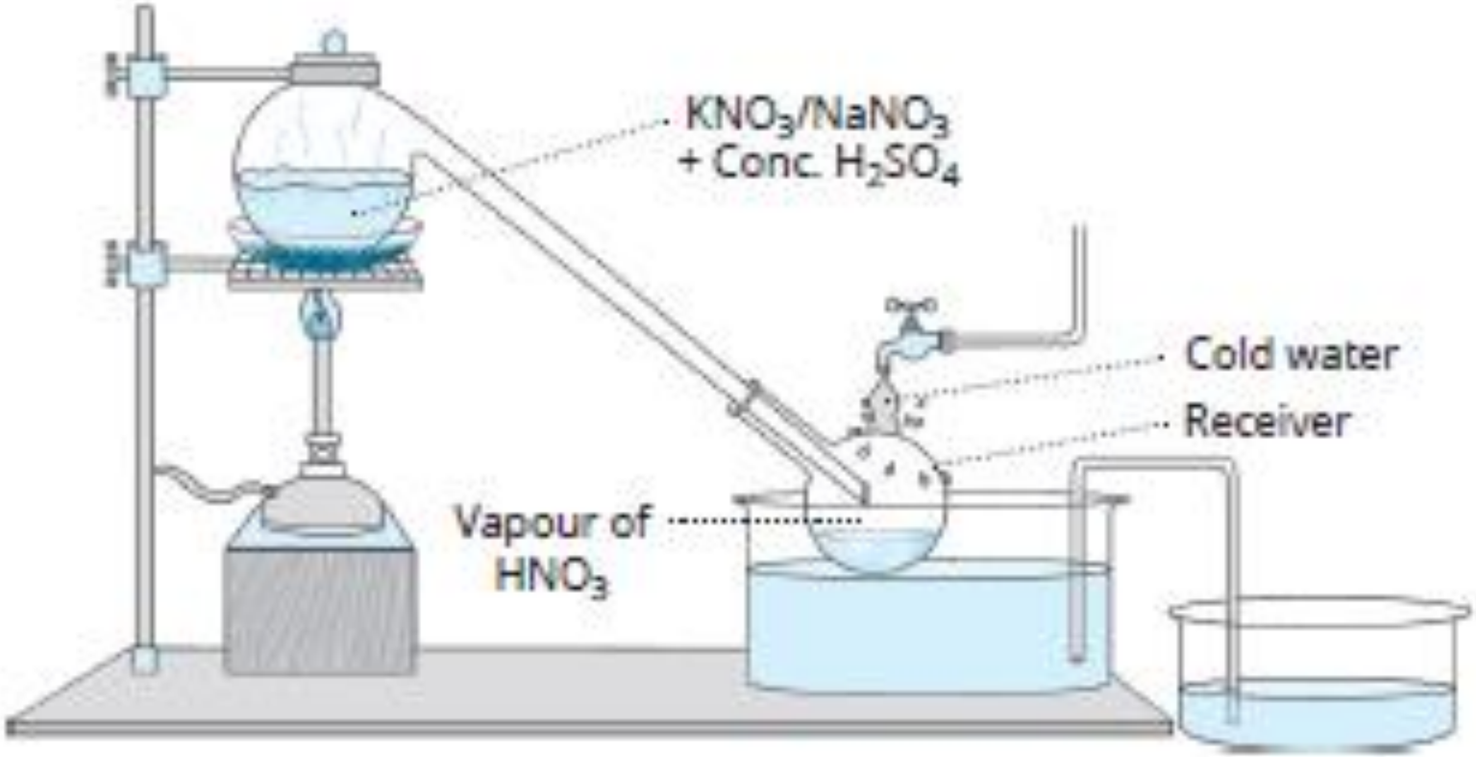
The laboratory preparation of nitric acid is carried out by heating concentrated sulphuric acid with potassium or sodium nitrate.

In the laboratory, nitric acid is prepared by distilling sodium nitrate or potassium nitrate with concentrated sulphuric acid in a glass retort. The flask is heated gently to about 200 °C to initiate the reaction. The vapours of nitric acid are condensed and collected in a watercooled receiver.

$$KNO_3 + H_2SO_4 \longrightarrow KHSO_4 + \underset{\text{(vapours)}}{HNO_3}$$

$$NaNO_3 + H_2SO_4 \longrightarrow NaHSO_4 + \underset{\text{(vapours)}}{HNO_3}$$

The nitric acid prepared in the laboratory is yellow in colour. This colour is due to the decomposition of nitric acid which results in the formation of reddish- brown fumes of nitrogen dioxide, $NO_2$. This nitrogen dioxide gets dissolved in the acid, thereby, imparting yellow colour to the acid.




**Precautions:**

**1.** All apparatus should be made of glass.

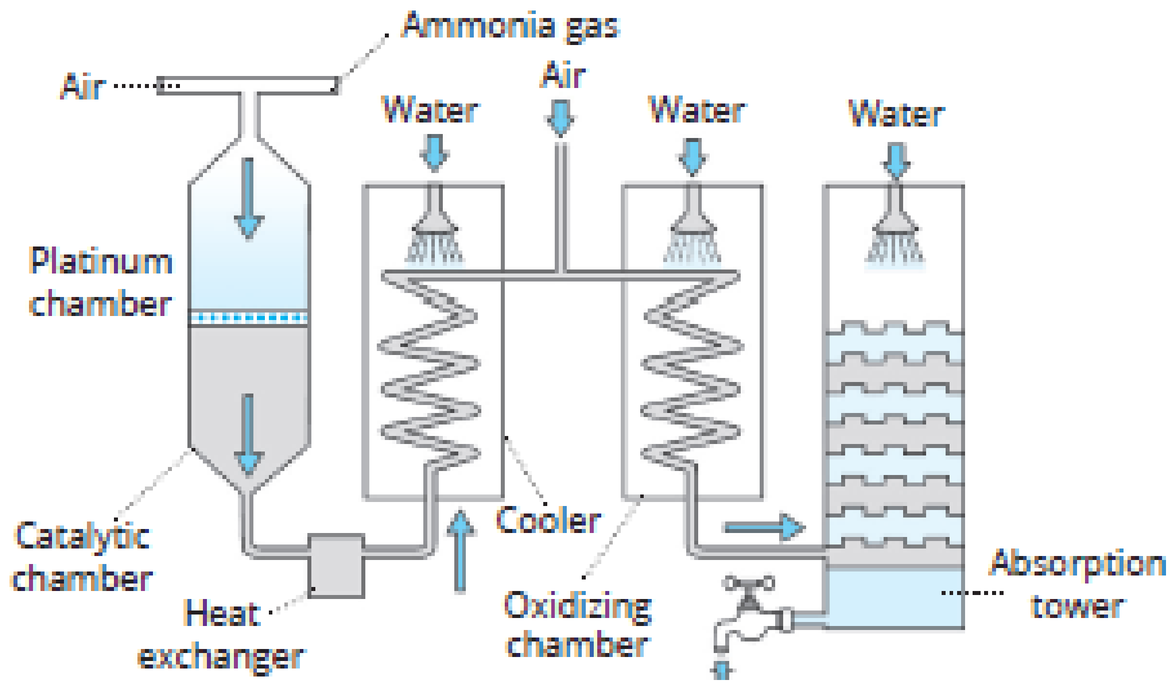
**2.** Use only concentrated sulphuric acid and it cannot be replaced by any other acid like concentrated hydrochloric acid (HCl). This is because concentrated hydrochloric acid is volatile in nature and nitric acid will carry the vapours of HCl also. Therefore, it is not used to displace another volatile acid.

**3.** The temperature of the reaction should be controlled and maintained at 200 $^\circ$ C and should not exceed 200 $^\circ$ C.

## Industrial preparation (or manufacture) of nitric acid

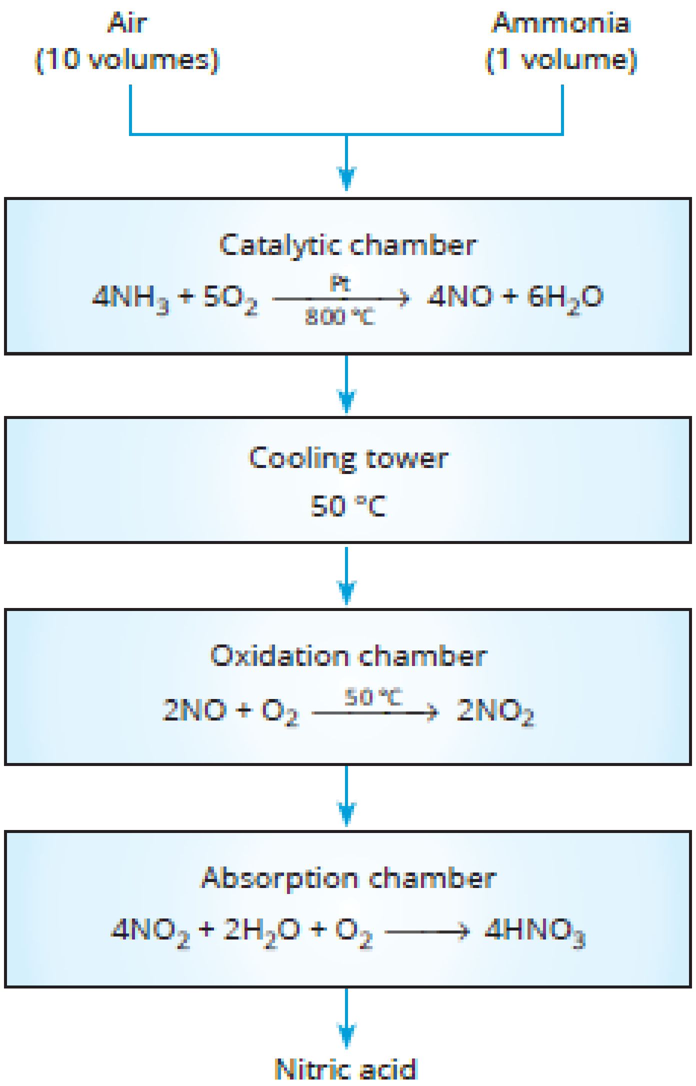
The **Ostwald process** is the single most important process for the manufacture of nitric acid. It has rendered other methods obsolete because of its economic viability and efficiency. The process of producing nitric acid was developed by **Wilhelm Ostwald** in 1914. Around 90% of nitric acid is manufactured bv this method.

This process is based on the catalytic oxidation of ammonia. For this process, ammonia is obtained from Haber's process. Ammonia is oxidized to nitric oxide by oxygen in the presence of platinum gauze as a catalyst when heated to 800 $^\circ$ C.




The reaction is exothermic and the heat released maintains the temperature of the catalyst. This nitric oxide is then oxidized to nitrogen dioxide which is then absorbed in water to give nitric acid.

# Flow diagram of Ostwald's process




**Important characteristics of the process**

**1.** Dust free air is used during the process.

**2.** Excess of air is used in the initial reaction because:

**a.** All stages of the reaction require oxygen.

**b.** All three reactions are reversible, therefore an increase in the concentration of the reactants favours the forward reactions.

**3.** The gases entering the catalytic chamber must be pure. Impurity poisons the catalyst and it loses its efficiency.

**4.** Nitric oxide formed in the catalytic chamber must be cooled because low temperature favours the oxidation of nitric oxide.

## Physical properties of nitric acid

**1. Colour:** Pure nitric acid is a colourless liquid but commercial nitric acid is usually yellow in colour due to the dissolution of nitrogen dioxide.

**2. Odour:** It has a choking odour.

**3. Taste:** Being acidic, it is sour in taste.

**4. Density:** Pure nitric acid is heavier than water and has a density 1.51 g cm–3 at 20 ° C. But commercial nitric acid has a lower density.

**5. Boiling point:** The pure acid boils at 70 ° C. Aqueous or dilute nitric acid containing 68% of the acid boils at 120.5 ° C. Fuming nitric acid containing 98% acid boils at 86 ° C.

**6. Melting point:** When cooled below 0 ° C, it freezes to a white solid, which melts at –42 ° C.

**7. Solubility:** Nitric acid is highly soluble in water.

**8. Physiological action:** It is non-poisonous and has a corrosive action on skin. Nitric acid reacts with the proteins of the skin and forms a yellow compound called **xanthoproteic acid**. Hence, when it comes in contact with skin, it becomes yellow.

## Chemical properties of nitric acid

**1. Stability:** Pure nitric acid is unstable at room temperature and even decomposes at room temperature as well as in the presence of light. Nitric acid decomposes to liberate reddish brown nitrogen dioxide and colourless oxygen gas.

$$4HNO_3 \longrightarrow 2H_2O + 4NO_2 + O_2$$

$NO_2$ remains dissolved in the acid, thus imparting yellow colour to the acid. Therefore, pure nitric acid kept in plain glass reagent bottles turns yellowish brown.

**Note:** The decomposition of nitric acid proves that nitric acid contains oxygen.

**2. Action with indicators:** The hydronium ions formed when nitric acid is dissolved in water are responsible for the colour changes in the indicators.

$$HNO_3 + H_2O \qquad H_3O^+ + NO_3^-$$

The presence of hydronium ions impart acidic properties to nitric acid.

**a. Litmus paper:** From blue to red **b. Methyl orange:** From orange to pink

**c. Phenolphthalein:** Phenolphthalein solution stays colourless. But alkaline phenolphthalein changes from pink to colourless.

**Note: Refer to P- 150-152 of the book for more such properties of Nitric acid**

## Tests for nitric acid

Nitric acid gives the following tests:

**1. Heating test:** Nitric acid on heating gives reddish brown fumes of nitrogen dioxide:

$$4HNO_3 \longrightarrow 2H_2O + 4NO_2\uparrow + O_2$$

(reddish brown fumes)

**2. With copper turnings:** Concentrated nitric acid on heating with copper turnings gives brown fumes of nitrogen dioxide.

$$Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$$

**3. Brown ring test:** Dilute nitric acid gives ring test. Freshly prepared solution of ferrous sulphate is added to dilute nitric acid taken in a test tube. Concentrated sulphuric acid is carefully poured along the sides of the test tube. A dark brown ring is formed at the junction of the two layers.

$$6FeSO_4 + \underset{\text{(conc.)}}{3H_2SO_4} + \underset{\text{(dilute)}}{2HNO_3} \longrightarrow 3Fe_2(SO_4)_3 + 4H_2O + 2NO$$

$$FeSO_4 + NO + 5H_2O \longrightarrow [Fe(NO)(H_2O)_5]SO_4$$

hydrated nitroso ferrous sulphate (brown ring)

In the brown ring test, the concentrated sulphuric acid being heavier settles down and iron(III) sulphate layer remains above it, resulting in the formation of brown ring at the junction.

## Uses of nitric acid

Nitric acid is used in:

**1.** The production of explosives such as TNT, gun cotton and dynamite.

**2.** Making plastics like cellulose nitrate fibres.

**3.** Pickling of stainless steel.

**4.** Etching of metals like copper.

**5.** As an oxidizer in rocket fuels as it gives large amount of oxygen on oxidation.

**6.** Making dye stuff.

**7.** The manufacture of fertilizers, especially ammonium nitrate.

**8.** The purification of gold, silver and platinum because it dissolves impurities of other metals

**9.** The manufacturing of nitrates like silver nitrate and calcium nitrate. Silver nitrate is used in making photographic films.

# SUMMARY

1. **Laboratory preparation of nitric acid**

$$KNO_3 + H_2SO_4 \longrightarrow KHSO_4 + HNO_3 \ (T < 200\ °C)$$
$$NaNO_3 + H_2SO_4 \longrightarrow NaHSO_4 + HNO_3 \ (T < 200\ °C)$$
$$KNO_3 + KHSO_4 \longrightarrow K_2SO_4 + HNO_3 \ (T > 200\ °C)$$
$$NaNO_3 + NaHSO_4 \longrightarrow Na_2SO_4 + HNO_3 \ (T > 200\ °C)$$

2. **Industrial preparation of nitric acid**

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O + 210\ kcal$$
(Pt, 700 °C – 800 °C)
$$2NO + O_2 \longrightarrow 2NO_2$$
$$4NO_2 + O_2 + 2H_2O \longrightarrow 4HNO_3$$

3. **Chemical properties of nitric acid**

- Solubility

$$HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$$

- Thermal decomposition

$$4HNO_3 \longrightarrow 2H_2O + 4NO_2 + O_2$$

4. **Chemical properties of dilute nitric acid**

- With active metals

$$Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2$$
$$Mn + 2HNO_3 \longrightarrow Mn(NO_3)_2 + H_2$$

- With oxides and hydroxides of metals

$$CaO + 2HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O$$
$$ZnO + 2HNO_3 \longrightarrow Zn(NO_3)_2 + H_2O$$
$$NaOH + HNO_3 \longrightarrow NaNO_3 + H_2O$$
$$KOH + HNO_3 \longrightarrow KNO_3 + H_2O$$

- With carbonates and bicarbonates

$$Na_2CO_3 + 2HNO_3 \longrightarrow 2NaNO_3 + H_2O + CO_2$$
$$KHCO_3 + HNO_3 \longrightarrow KNO_3 + H_2O + CO_2$$

- With sulphites and bisulphites

$$K_2SO_3 + 2HNO_3 \longrightarrow 2KNO_3 + H_2O + SO_2$$
$$NaHSO_3 + HNO_3 \longrightarrow NaNO_3 + H_2O + SO_2$$

- With sulphides

$$FeS + 2HNO_3 \longrightarrow Fe(NO_3)_2 + H_2S$$

- With bleaching powder

$$CaOCl_2 + 2HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O + Cl_2$$

5. **Chemical properties of concentrated nitric acid**

- As an oxidizing agent

Reaction mechanism

Concentrated:

$$2HNO_3 \longrightarrow H_2O + 2NO_2 + [O]$$

Moderately concentrated:

$$2HNO_3 \longrightarrow H_2O + 2NO + 3[O]$$

- With compounds having reducing properties

$$2HNO_3 + 6FeSO_4 + 3H_2SO_4 \longrightarrow 3Fe_2(SO_4)_3 + 4H_2O + 2NO$$
$$6HI + 2HNO_3 \longrightarrow 4H_2O + 2NO + 3I_2$$
$$3H_2S + 2HNO_3 \longrightarrow 4H_2O + 2NO + 3S$$
$$3SO_2 + 2HNO_3 + 2H_2O \longrightarrow 3H_2SO_4 + 2NO$$

- With non-metals

$$S + 6HNO_3 \longrightarrow H_2SO_4 + 6NO_2 + 2H_2O$$
$$C + 4HNO_3 \longrightarrow CO_2 + 4NO_2 + 2H_2O$$
$$P + 5HNO_3 \longrightarrow H_3PO_4 + 5NO_2 + H_2O$$

6. **With metals**

- With very dilute acid

$$4Zn + 10HNO_3 \longrightarrow 4Zn(NO_3)_2 + NH_4NO_3 + 3H_2O$$

- With dilute nitric acid

$$3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$$

RATNA SAGAR | PRIMUS | BYWORD | E-LIVE

# THANK YOU