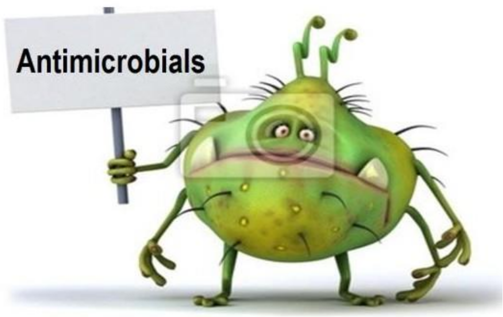
Antimicrobials: Mechanism, classification, Potassium permanganate, Boric acid, Hydrogen peroxide*, Chlorinated lime*, Iodine and its preparations

- An antimicrobial is an agent that kills microorganisms or stops their growth.
- The most common targets for antimicrobial drug actions fall into 5 basic categories:
  i. Inhibition of Cell Wall Synthesis
  ii. Inhibition of Protein Synthesis
  iii. Inhibition of Nucleic Acid Synthesis
  iv. Effects on cell membrane sterols (antifungal agents)
  v. Inhibition of unique metabolic steps
- ***Control of Microbial Growth:***
  - ***Sterilizing Agents***:
  - ***Disinfectants:*** Disinfectants are antimicrobial agents that are applied to the surface of non-living objects to destroy microorganisms that are living on the objects. Disinfection does not necessarily kill all microorganisms, especially resistant bacterial spores; it is less effective than sterilization.
  - ***Antiseptics:*** Antiseptic(s) (from Greek anti: "against" and sēptikos: "putrefactive") are antimicrobial substances that are applied to living tissue/skin to reduce the possibility of infection, sepsis, or putrefaction.
  - ***Chemotherapeutics:*** The chemical agents which is used in the clinical application of antimicrobial agents to treat infectious disease.
- ***Medicines with an antimicrobial activity are divided into two groups***:
  i. Non-selective antimicrobial agents, causes most destructive effect on the majority of microorganisms (antiseptics and disinfectants).
  ii. Selective antimicrobial drugs (chemotherapeutic agents)
- ***Requirements for antiseptics and disinfectants***
  - Must have a broad spectrum of action;
  - Rapid onset of action;
  - Should have a small latency period;
  - Should have a high activity;
  - Must be chemically resistant;
  - High availability and low cost;
  - Lack of local irritant or allergic effects on tissues;
  - Minimal absorption from the place of their application;
  - Low toxicity.



- ***Classification of Antiseptics and Disinfectants (according chemical structure)***

1. Inorganic substances

(i) *Halogens*
- Iodine (2%, 3%, 5% alcohol solution)
- Povidon-Iodine
- Lugol's solution
- Chlorhexidine

(ii) *Oxidizing agents*
- Hydrogen peroxide
- Potassium permanganate

(iii) *Acids and alkalis*
- Boric acid
- Salicylic acid
- Solution of ammonia

(iv) *Metallic salts*
- Silver nitrate
- Copper sulfate
- Zinc sulfate
- Zinc oxide

2. Organic substances

(i) *Aldehydes*
- Formaldehyde
- Glutaraldehyde
- Hexamethylentetraminum

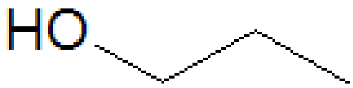
(ii) *Alcohols*
- Ethyl alcohol

(iii) *Phenol derivatives*
- Phenol
- Cresol
- Resorcinol
- Thymol

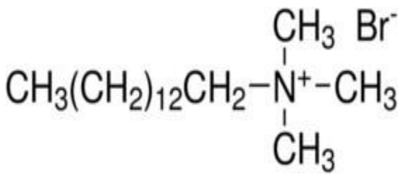
(iv) *Dyes*
- Methylene blue
- Brilliant green

- **SAVLON ANTISEPTIC (Solution)**

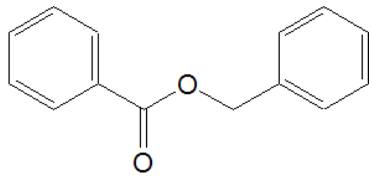
Composition: An aqueous solution containing 0,3 g Chlorhexidine gluconate and 3,0 g Cetrimide as active ingredients per 100 mL and 2,84% m/v n-propyl alcohol and 0,056% m/v Benzyl benzoate as preservatives.



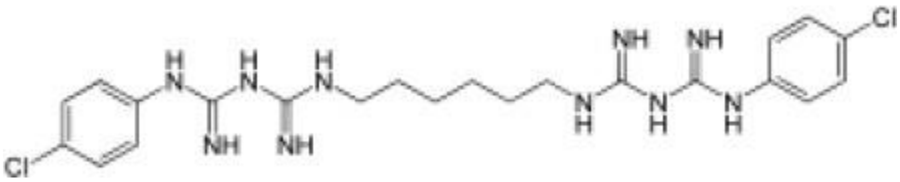
n-propyl alcohol



Cetrimide

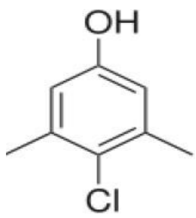


Benzyl benzoate

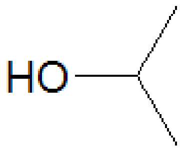


Chlorhexidine

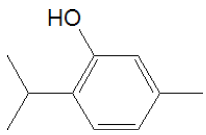
- **Composition of DETTOL:** Chloroxylenol comprises 4.8% of Dettol's total admixture, with the rest made up by pine oil, isopropanol, castor oil, soap and water



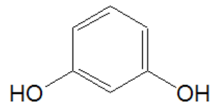
Chloroxylenol,
[also known as para-chloro-meta xylenol (PCMX)]



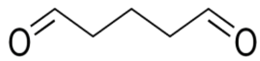
isopropanol



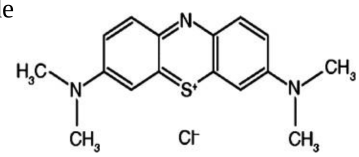
Thymol



Resorcinol

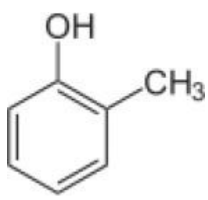


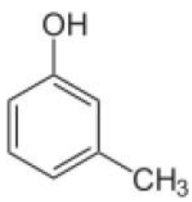
Glutaraldehyde

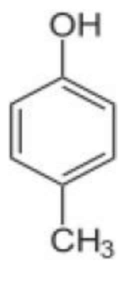


Methylene blue

- **CRESOLS** (also hydroxytoluene) are organic compounds which are methyl phenols.





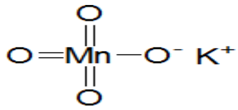


Common name	*o*-cresol	*m*-cresol	*p*-cresol
Systematic name	2-methylphenol	3-methylphenol	4-methylphenol
Other names	ortho-cresol	meta-cresol	para-cresol
Appearance	colorless crystals	thicker liquid	greasy-looking solid
Density	1.05 g/cm^3 (solid)	1.03 g/cm^3 (liquid)	1.02 g/cm^3 (liquid)
Molecular formula		**C_7H_8O**	

❖ Potassium permanganate

Other names: Condy's crystals; Permanganate of potash; Hypermangan

Chemical formula: $KMnO_4$ **Molar mass:** 158.034 g/mol



- **Properties**

Appearance: purplish-bronze-gray needles **Odor:** odorless **Density:** 2.703 g/cm^3 **Melting point:** 240^0 C
Solubility: Freely soluble in water and alcohol **Refractive index:** 1.59 **Taste:** Better with metallic taste

- **Preparation**

- **Industrially Method:** The MnO_2 is fused with potassium hydroxide and heated in air.

$$2\ MnO_2 + 4\ KOH + O_2 \rightarrow 2\ K_2MnO_4 \text{ (potassium manganate) } + 2\ H_2O$$

$$2\ K_2MnO_4 + 2\ H_2O \rightarrow 2\ KMnO_4 + 2\ KOH + H_2$$

- Potassium manganate can be oxidized by chlorine

$$2\ K_2MnO_4 + Cl_2 \rightarrow 2\ KMnO_4 + 2\ KCl$$

- Potassium manganate when treated with Hydrochloric acid

$$3\ K_2MnO_4 + 4\ HCl \rightarrow 2\ KMnO_4 + MnO_2 + 2\ H_2O + 4\ KCl$$

- Potassium manganate when treated with Carbon dioxide

$$3\ K_2MnO_4 + 2\ CO_2 \rightarrow 2\ KMnO_4 + 2\ K_2CO_3 + MnO_2$$

- **Reaction**

- Potassium acts as strong oxidizing agents

$$KMnO_4 + H_2O + KI \rightarrow 2\ MnO_2 + KIO_3 + KOH$$

$$2\ KMnO_4 + 10\ KI + 8\ H_2SO_4 \rightarrow 6\ K_2SO_4 + 2\ MnSO_4 + 5\ I_2 + 8\ H_2O$$

- Potassium permanganate oxidizes aldehydes to carboxylic acids

$$5\ C_6H_{13}CHO + 2\ KMnO_4 + 3\ H_2SO_4 \rightarrow 5\ C_6H_{13}COOH + 3\ H_2O + K_2SO_4 + 2\ MnSO_4$$

(n-heptanal) (heptanoic acid)

- Even an alkyl group (with benzylic hydrogen) on an aromatic ring is oxidized, e.g. toluene to benzoic acid.

$$5\ C_6H_5CH_3 + 6\ KMnO_4 + 9\ H_2SO_4 \rightarrow 5\ C_6H_5COOH + 14\ H_2O + 3\ K_2SO_4 + 6\ MnSO_4$$

(Toluene) (Benzoic acid)

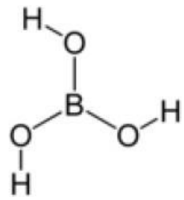
- Solid potassium permanganate decomposes when heated: $2KMnO_4 \rightarrow K_2MnO_4 + MnO_2(s) + O_2$

- **Uses**

- Due to its strong oxidising properties it is used as disinfectant and deodorant.
- It is also used as astringents, anti-infective and bactericidal.
- 1-5% hydroalcholic solution of potassium permanganate used as wet dressing.
- Potassium permanganate has been used in attempts to induce abortions at home. But it is legal restrictions on the chemical in response to its use as an abortifacient.
- Potassium permanganate was used as a bleaching agent.
- Potassium permanganate is used extensively in the water treatment.

- **Storage:** Store in well closed container and kept in a cool place

❖ Boric acid



Synonym : Hydrogen borate, Boracic acid, Orthoboric acid, Acidum boricum

Chemical formula : H_3BO_3 or BH_3O_3 or $B(OH)_3$ **Mol. Weight** : 61.83 g/mol

- **Physical Properties**

Appearance : White crystalline solid or granular **Density** : 1.435 g/cm^3

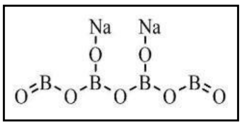
Melting point : 170.9 °C **Odor** : Odorless **Tasteless** : Sweetish after taste

Solubility : Sparingly soluble in water [2.52 g/100 mL (0^0 C); 5.7 g/100 mL (25^{0}C); 27.53 g/100 mL (100^{0}C)] Freely soluble glycerine; Slightly soluble in Alcohol.

- **Preparation**

- Boric acid may be prepared by reacting borax (sodium tetraborate decahydrate) with a mineral acid, such as hydrochloric acid:

$$\mathbf{Na_2B_4O_7{\cdot}10H_2O + 2\ HCl \rightarrow 4\ B(OH)_3\ [or\ H_3BO_3] + 2\ NaCl + 5\ H_2O}$$



Borax

- It is also formed as a byproduct of hydrolysis of boron trihalides and diborane:

$$B_2H_6 \text{ (diborane)} + 6\ H_2O \rightarrow 2\ B(OH)_3 + 6\ H_2$$

$$BX_3 \text{ (boron trihalides)} + 3\ H_2O \rightarrow B(OH)_3 + 3\ HX \qquad (X = Cl, Br, I)$$

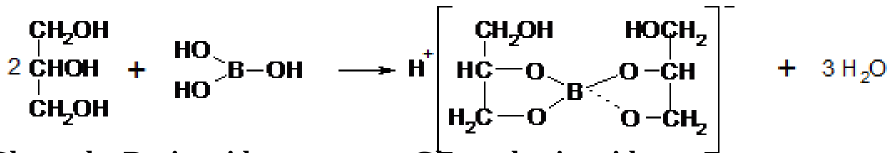
- **Reaction**

- Boric acid is soluble in boiling water. When heated above 100^0 C, it dehydrates, forming ***metaboric acid*** (HBO_2) and when ***metaboric acid*** heated at 160^0 C it converted into ***tetraboric acid*** or ***pyroboric acid*** ($H_2B_4O_7$) and when ***pyroboric acid*** is heated above 200^{0}C it decompose into ***boron trioxide*** (**B_2O_3**):

$$\underset{\text{(Boric acid)}}{H_3BO_3} \xrightarrow[-\ H_2O]{100^0\ C} \underset{\text{(Metaboric acid)}}{HBO_2} \xrightarrow[-\ H_2O]{160^0\ C} \underset{\text{(Tetraboric acid)}}{H_2B_4O_7} \xrightarrow[-\ H_2O]{200^0C} \underset{\text{(Boron trioxide)}}{B_2O_3}$$

- Boric acid is weak acid but when boric acid dissolve in glycerin it gives glyceroboric acid and has ionization constant is 10,000 times greater than that of boric acid.

$$B(OH)_3 + 2\ H_2O \rightleftharpoons B(OH)_4^- + H_3O^+$$



Glycerol **Boric acid** **Glyceroboric acid**

- Boric acid reacts with alcohols to form borate esters [**$B(OR)_3$**] where **R** is alkyl or aryl.

$$\mathbf{B(OH)_3 + 3\ ROH \rightarrow B(OR)_3 + 3\ H_2O}$$

- **Uses**

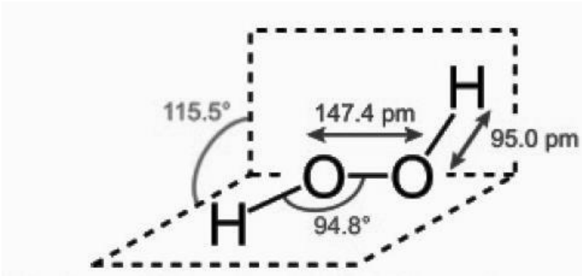
- Boric acid can be used as an antiseptic for minor burns or cuts. it is also used as weak bacteriostatic, fungistatic and astringents.
- Boric acid is applied in a very dilute solution as an eye wash.
- Dilute boric acid can be used as a vaginal douche to treat bacterial vaginosis due to excessive alkalinity.
- It is also used as mouth washes, skin lotion for local anti-infective action.
- Its use as an insecticide.
- The boric acid-borate system can be useful as a primary buffer system.
- Boric acid is used in some nuclear power plants as a neutron poison. The boron in boric acid reduces the probability of thermal fission by absorbing some thermal neutrons.
- It is also used in preservation of grains such as rice and wheat.

- **Storage:** Store in well closed container and kept in a cool place.
- **Adverse effect:** Vomiting, abdominal cramps.

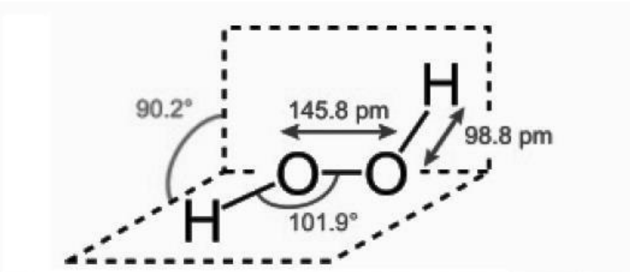
❖ Hydrogen peroxide

Synonym : Dioxidane; Oxidanyl; Perhydroxic acid **Chemical formula** : $\mathbf{H_2O_2}$ **Mol. Weight** : 34 g/mol

- Hydrogen peroxide (H_2O_2) is a nonplanar molecule with twisted symmetry. Although the O−O bond is a single bond, the molecule has a relatively high rotational barrier.
- The molecular structures of gaseous and crystalline H_2O_2 are significantly different. This difference is attributed to the effects of hydrogen bonding, which is absent in the gaseous state.



Structure and dimensions of H_2O_2 in the gas phase



Structure and dimensions of H_2O_2 in the solid (crystalline) phase

- ## Preparation:

  1. ***From Barium peroxide***

- When aqueous cream of barium peroxide treated with cold dilute sulphuric acid forms hydrogen peroxide:

$$\mathbf{BaO_2 + H_2SO_4 \rightarrow BaSO_4 + H_2O_2}$$

- When carbon dioxide is passed slowly through ice-cold paste of barium peroxide, then hydrogen peroxide produced:

$$\mathbf{BaO_2 + H_2O + CO_2 \rightarrow BaCO_3 + H_2O_2}$$

  2. ***From Sodium Peroxide:***

- Sodium peroxide decomposed by addition of cold dilute sulphuric acid forms hydrogen peroxide:

$$\mathbf{Na_2O_2 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O_2}$$

- ## Physical Properties:

Colour : Clear colourless liquid; **Odour** : Odorless; **Taste** : Bitter; **Density** : 1.145 g/cm^3 (20^{0}C, pure)
Boiling point : 150.2^{0}C; **Solubility in water** : Miscible; **Acidity (pKa)** : 11.75 (slightly acidic)

- ## Chemical Properties:

- **Decomposition:** Pure hydrogen peroxide decompose slowly, but when heated at 100^0 C it liberate oxygen:

$$\mathbf{H_2O_2 \rightarrow 2\ H_2O + O_2}$$

- **Oxidation properties:** Hydrogen peroxide is a strong oxidising agent and react many organic materials.

$$\mathbf{PbS}\text{ (lead sulphide) } \mathbf{+ 4\ H_2O_2 \rightarrow PbSO_4}\text{ (lead sulfate) } \mathbf{+ 4\ H_2O}$$

$$\mathbf{2\ KI}\text{ (potassium iodide) } \mathbf{+ H_2O_2 \rightarrow 2\ KOH + I_2}$$

$$\mathbf{2\ FeSO_4}\text{ (ferrous sulfate) } \mathbf{+ H_2SO_4 + H_2O_2 \rightarrow Fe_2(SO_4)_3}\text{ (ferric sulfate) } \mathbf{+ 2\ H_2O}$$

- **Reduction properties:** Hydrogen peroxide behaves as reducing agents towards other oxidizing agents.

$$\mathbf{Ag_2O}\text{ (silver oxide) } \mathbf{+ H_2O_2 \rightarrow 2\ Ag + 2\ H_2O + O_2}$$

$$\mathbf{2\ KMnO_4 + 3H_2SO_4 + 5\ H_2O_2 \rightarrow K_2SO_4 + 2\ MnSO_4 + 8\ H_2O + 5\ O_2}$$

- **Acidic in nature:** Hydrogen peroxide is slightly acidic in nature through in dilute solution it is neutral towards litmus.

$$\mathbf{2\ NaOH + H_2O_2 \rightarrow Na_2O_2}\text{ (Sodium peroxide) } \mathbf{+ 2\ H_2O}$$

$$\mathbf{Ba(OH)_2}\text{ (Barium hydroxide) } \mathbf{+ H_2O_2 \rightarrow BaO_2}\text{ (Barium peroxide) } \mathbf{+ 2\ H_2O}$$

$$\mathbf{Na_2CO_3 + H_2O_2 \rightarrow Na_2O_2}\text{ (Sodium peroxide) } \mathbf{+ CO_2 + H_2O}$$

- ## Assay of Hydrogen peroxide:

- Assay of hydrogen peroxide depend on the oxidation-reduction titration.
- 10 ml the H_2O_2 is diluted with 10 ml distilled water, then add 10 ml of 5N Sulphuric acid and then titrated with 0.1N potassium permanganate solution, until a faint pink color is obtained.
- Each ml of 0.1N $KMnO_4$ = 0.001701 g of H_2O_2

$$\mathbf{2\ KMnO_4 + 3H_2SO_4 + 5\ H_2O_2 \rightarrow K_2SO_4 + 2\ MnSO_4 + 8\ H_2O + 5\ O_2}$$

- **Uses:**
  - **Medical uses:**

- Hydrogen peroxide used as an antiseptic, germicidal and disinfectant.
- Hydrogen peroxide can be used for the sterilization of various surfaces, including surgical tools and may be deployed as a vapour (VHP) for room sterilization.
- H_2O_2 demonstrates broad-spectrum efficacy against viruses, bacteria, yeasts, and bacterial spores. In general, greater activity is seen against Gram-positive than Gram-negative bacteria.
- Hydrogen peroxide was used for disinfecting wounds.

  - **Cosmetic applications**

- Diluted H_2O_2 (between 1.9% and 12%) mixed with ammonium hydroxide is used to bleach human hair.
- Hydrogen peroxide is also used for tooth whitening. It can be found in most whitening toothpastes.
- Hydrogen peroxide may be used to treat acne.

  - **Propellant**

- High-concentration H_2O_2 is referred to as "high-test peroxide" (HTP). It can be used either as a monopropellant (not mixed with fuel) or as the oxidizer component of a bipropellant rocket.

  - **Explosives**

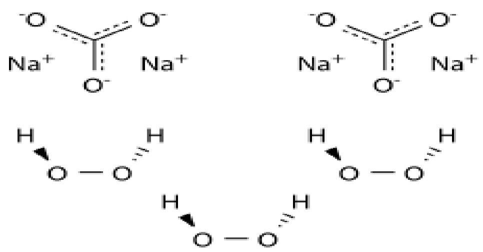
- Hydrogen peroxide has been used for creating organic peroxide-based explosives, such as acetone peroxide, for improvised explosive devices.

  - **Industrial**

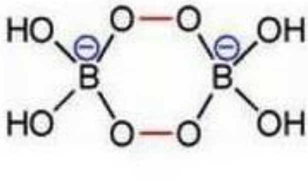
- About 60% of the world's production of hydrogen peroxide is used for pulp and paper-bleaching.
- The second major industrial application is the manufacture of **sodium percarbonate** and **sodium perborate** which are used as mild bleaches in laundry detergents.

- **Storage:** Store in cool & dark place and light resistant container.

SODIUM PERCARBONATE is an adduct of sodium carbonate and hydrogen peroxide, with formula $2Na_2CO_3 \cdot 3H_2O_2$. As an oxidizing agent, sodium percarbonate is an ingredient in a number of home and laundry cleaning products



SODIUM PERBORATE (PBS) is a white, odorless, water-soluble chemical compound with the chemical formula $Na_2B_2O_4(OH)_4$. This salt is widely used in laundry detergents.

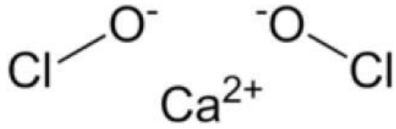


Chlorinated lime

Bleaching powder is not a simple mixture of calcium hypochlorite, calcium chloride, and calcium hydroxide. Instead, it is a mixture consisting principally of **calcium hypochlorite** [**$Ca(OCl)_2$**], **dibasic calcium hypochlorite** [**$Ca_3(OCl)_2(OH)_4$**], and **dibasic calcium chloride** [**$Ca_3Cl_2(OH)_4$**]. It is made from slightly moist slaked lime.

Synonym: Hypochlorous acid; Bleaching powder; Calcium oxychloride; Calcium hypochlorite

Mol. Formula: $Ca(ClO)_2$ **Mol. Weight:** 142.98 g/mol



Appearance: White/gray powder

Density: 2.35 g/cm^3 (20^{0}C)

Melting point: 100^0 C

Solubility in water: 21 g/100 mL **Odour:** It has strong odour of chlorine

Note By: on exposure to air it becomes moist and rapidly decomposes to release Hypochlorous acid.

Preparation:

- Calcium hypochlorite is produced industrially by treating slaked lime [**$Ca(OH)_2$**] with chlorine gas.

$$2\ Cl_2 + 2\ Ca(OH)_2 \rightarrow Ca(OCl)_2 + CaCl_2 + 2\ H_2O$$

Reaction:

- Calcium hypochlorite reacts with **carbon dioxide** to form calcium carbonate and release **dichlorine monoxide**:

$$Ca(ClO)_2 + CO_2 \rightarrow CaCO_3 + Cl_2O\uparrow$$

- A calcium hypochlorite solution is basic. This basicity is due to the hydrolysis performed by the hypochlorite ion, as Hypochlorous acid is weak, but calcium hydroxide is a strong base. As a result, the hypochlorite ion is a strong conjugate base, and the calcium ion is a weak conjugate acid:

$$OCl^- + H_2O \Leftrightarrow HOCl + OH^-$$

- Similarly, calcium hypochlorite reacts with hydrochloric acid to form calcium chloride, water and chlorine:

$$Ca(OCl)_2 + 4\ HCl \rightarrow CaCl_2 + 2\ H_2O + 2\ Cl_2$$

- Treatment of chlorinated lime with dilute sulphuric acids liberates Hypochlorous acid which behaves as oxidising and bleaching agents.

$$2\ Ca(OCl)_2 + 4\ H_2SO_4 \rightarrow CaCl_2 + CaSO_4 + 2HClO$$

$$HClO \rightarrow HCl + [O]$$

- On treatment with excess of dilute acid or CO_2, the whole of chlorine is liberated:

$$Ca(OCl)_2 + H_2SO_4 \rightarrow CaSO_4 + H_2O + Cl_2$$

Uses:

- ***Sanitation***
  - Calcium hypochlorite has rapid bactericidal action. It kills most of bacteria, some fungi, yeast, algae, viruses and protozoa.
  - Calcium hypochlorite is commonly used to sanitize public swimming pools and disinfect drinking water.
  - Calcium hypochlorite is also used in kitchens to disinfect surfaces and equipment.
  - Other common uses include bathroom cleansers, household disinfectant sprays, algaecides, herbicides, and laundry detergents.
- ***Organic chemistry***
  - Calcium hypochlorite is a general oxidizing agent and therefore finds some use in organic chemistry. For instance the compound is used to cleave **glycols**, **α-hydroxy carboxylic acids** and keto acids to yield fragmented **aldehydes** or **carboxylic acids**. Calcium hypochlorite can also be used in the halo form reaction to manufacture chloroform.

$$3\ Ca(OCl)_2 + 2\ (CH_3)_2CO \rightarrow 2\ CHCl_3 + 2\ Ca(OH)_2 + Ca(CH_3COO)_2$$

Storage:

- Calcium hypochlorite is stored dry and cold, away from any organic material and metals. The hydrated form is safer to handle.