

ST. LAWRENCE HIGH SCHOOL A JESUIT CHRISTIAN MINORITY INSTITUTION STUDY MATERIAL FOR CHEMISTRY (CLASS-12)



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TOPIC- ALKYL AND ARYL HALIDE

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The replacement of hydrogen atom(s) in hydrocarbon, aliphatic or aromatic, by corresponding number of halogen atom(s) results in the formation of alkyl halide (haloalkane) and aryl halide (haloarene), respectively.

# **Classification of Halogen Derivatives**

On the basis of number of halogen atoms present, halogen derivatives are classified as mono, di, tri, tetra, etc., halogen derivatives, e.g.,



On the basis of the nature of the carbon to which halogen atom is attached, halogen derivatives are classified as 1°, 2°, 3°, allylic, benzylic, vinylic and aryl derivatives, e.g.,



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# **General Methods of Preparation of Haloalkanes**

# 1. From Alcohols:



## POINTS TO BE NOTED:

1. In Groove's method,  $ZnCl_2$  is used to weaken the C-OH bond. In case of 3° alcohols,  $ZnCl_2$  is not required.

2. The reactivity order of halogen acids is HI > HBr > HCl.

3. The mixture (1:1) of concentrated HCl and anhydrous  $ZnCl_2$  is called Lucas reagent, which is used to distinguish 1°, 2° and 3° alcohols.

4. Darzen's procedure is the best method for preparing alkyl halides from alcohols since both the by products (SO<sub>2</sub> and HCl) are gaseous and escape easily.

## 2. Free Radical Halogenation of Alkanes:





## POINTS TO BE NOTED:

1. In presence of sunlight, heat or catalyst (free radical halogenation) gives a mixture of mono, di, tri halogen derivatives, etc.

2. Replacement of H atoms from hydrocarbons follows the order:

Allylic>  $3^{\circ}H > 2^{\circ}H > 1^{\circ}H > CH_4$ 

4. The iodination (Reversible in nature) is carried out in presence of strong oxidizing agents like  $HIO_3$ ,  $HNO_3$  to drive the reaction in the forward direction of maximizing the yield of the final product.

# 3. Addition of Hydrogen Halides on Alkenes:

By the addition of HX with an unsymmetrical and symmetrical alkene. In case of unsymmetrical alknene Markownikoff's and Anti-Markownikoff's addition rule are needed to be considered.

# What is Markownikoff's addition rule?

When a protic acid (HX) is added to an asymmetric alkene, the acidic hydrogen attaches itself to the carbon having a greater number of hydrogen substituents whereas the halide group attaches itself to the carbon atom which has a greater number of alkyl substituents.

To simplify the rule, it can also be stated as – "Hydrogen is added to the carbon with the most hydrogens and the halide is added to the carbon with least hydrogens".

An example of a reaction that observes Markovnikov's rule is the addition of hydrobromic acid (HBr) to propene, which is shown below.



#### Markownikoff's addition rule

#### What is the Mechanism behind Markovnikov's Rule?

To understand this mechanism, let us consider the same example illustrated earlier, i.e. the addition reaction of hydrobromic acid with propene. The Mechanism of Markownikoff's rule can be broken down into the following two steps.

#### <u>Step 1</u>



## The Mechanism behind Markownikoff's Rule (Step 1)

The alkene is protonated and it gives rise to the more stable carbocation as shown below.

From the illustration shown above, we can see that there are two types of carbocations that can be formed from the protonation of the alkene, one is a primary carbocation and the other is a secondary carbocation. However, the secondary carbocation is far more stable and therefore, its formation is preferred over the formation of a primary carbocation.

#### <u>Step 2</u>



## The Mechanism behind Markownikoff's Rule (Step 2)

The halide ion <u>nucleophile</u> now attacks the carbocation. This reaction yields the alkyl halide. Since the formation of the secondary carbocation is preferred, the major product of this reaction would be 2-bromopropane as illustrated below.

It is important to note that the Markovnikov's rule was developed specifically for its application in the addition reaction of hydrogen halides to alkenes. The opposite of 'Markownikoff' addition reactions can be described as Anti-Markownikoff based on the regioselectivity of the reaction.

## What is the Reasoning behind Markovnikov's Rule?

The protonation of the alkene by the protic acid results in the formation of a carbocation. The most stable carbocation is the one in which the positive charge is held by the carbon with the

greatest number of alkyl substituents. Therefore, the majority of the product features the addition of the halide to the carbon having fewer hydrogen substituents.

## What is Anti-Markownikoff's addition rule?

When any polar molecule is added to any unsymmetrical alkene in presence of any organic peroxide, the negative part of molecule is added to that carbon atom which is connected to more Hydrogen atom than the other unsaturated carbon atom . This is known as peroxide effect.

Alkenes belong to the group of unsaturated hydrocarbons, that is, one molecule of alkene contains at least one double bond. Due to the presence of pi electrons, they show addition reactions in which an electrophile attacks the carbon-carbon double bond to form the additional products. When HBr is added to unsymmetrical alkenes in the presence of peroxide, 1-bromopropane is formed contrary to 2-bromopropane (according to Markownikoff's rule). This reaction is better known as anti-Markovnikov addition or Kharasch effect after the name of M. S. Kharash who first observed it. This reaction is also known as Kharasch effect or peroxide effect.

$$CH_{3}\text{-}CH=CH_{2} + HBr \xrightarrow{C_{6}H_{5}O_{2}} CH_{3}\text{-}CH_{2}\text{-}CH_{2}Br$$

Anti Markovnikov addition is also an example of addition reaction of alkenes which is an exception to the Markownikoff's rule. It is one of the few reactions following free radical mechanism in organic chemistry in place of electrophilic addition as suggested by Markownikoff.

## This reaction is observed only with HBr, not with HCl or HI.

## Mechanism of Anti Markownikoff addition:

<u>Anti Markownikoff</u>addition reaction is found to follow a free radical mechanism. The peroxide compound involved helps in the generation of free radicals. A general mechanism of anti-Markovnikov addition reaction is discussed below:

- Generation of free radical through homolytic cleavage of peroxide compound.
- Attack of generated free radical on hydrogen halide to form halide radical through hemolysis
- Attack of generated halide radical on alkene molecule to form alkyl radical through hemolysis.
- Attack of a generated alkyl radical on hydrogen halide to form alkyl halide through homolytic cleavage of hydrogen halide bond.



**A.** <u>Finkelstein Reaction</u>: R-Cl and R-Br on heating with NaI in acetone or methanol solution forms R-I. It is exclusively used for the preparation of alkyl iodides.



**B.** <u>Swarts Reaction</u>: Alkyl fluorides ca be prepared from corresponding chlorides by the action of  $Hg_2F_2$ , AsF<sub>3</sub>, SbF<sub>3</sub> etc.

 $H_3C - Br + AgF \rightarrow H_3C - F + AgBr$ 

## 3. Borodine-Hunsdiecker Reaction:

Hunsdiecker Reaction is a chemical reaction that involves the silver salts of carboxylic acid reacting with halogens to form an unstable intermediate which further undergoes decarboxylation thermally leading to the formation of a final product known as alkyl halides.

$$CH_3COOAg + Br_2 \xrightarrow{CCl_4} CH_3Br + AgBr + CO_2$$

## Mechanism of The Reaction:

Hunsdiecker Reaction mechanism mainly involves organic radical intermediates where;

- > Formation of the reactive intermediate.
- > The occurrence of decarboxylation to form a diradical pair.
- Recombination of reactant to form the desired product.



## Points to be noted:

**1.** The reaction is used to directly convert one carboxylic acid into an alkyl halide.

**2.** The reaction is useful for decreasing the number of carbon atoms within the carbon chain i.e. to descend down the carbon chain length.

# **Physical Properties of Haloalkanes**

The physical properties of organohalogen compounds (alkyl halides and aryl halides) are influenced by factors like: i) polar nature of C-X bond, ii) molecular size (or indirectly the molecular weight), iii) type of halogen, iv) branching in the carbon chain etc.

- Nature of C-X bond
- Bond length and bond strength
- Dipole moment
- Boiling and Melting points
- > Density
- Solubility

## A. Nature of C-X bond

The bond between carbon and halogen atom (C-X) is polar. Since halogen atoms (except iodine) are more electronegative than carbon, there is partial accumulation of negative charge on halogen atom and positive charge on carbon. This is referred to as polarity and makes the molecule permanently dipolar.



The polar nature of C-X bond is expected to increase with increase in the electronegativity difference between carbon and halogen atom.

#### **B. Bond length and bond strength**

The bond length of C-X bond depends on the nature of halogen as well as the hybridization of carbon atom.

A) The bond length increases with increase in the size of halogen atom. The C-X bond weakens with increase in the bond length and decrease in the overlap of atomic orbitals.

Order of bond length: C-F < C-Cl < C-Br < C-I

## Order of bond strength (bond energy): C-F > C-Cl > C-Br > C-I

B) The sp<sup>3</sup> C-X bonds of alkyl halides are longer than sp<sup>2</sup> C-X bonds of vinyl and aryl halides. In the latter case, the C-X bond has partial double bond character that arises due to delocalization of  $\pi$  electrons. Hence the bond strength also increases with increase in double bond character.

#### C. Dipole moment

Dipole moment,  $\mu$  is defined as the product of magnitude of charge accumulated on either of pole on a polar bond and the distance between the two poles. Thus dipole moments of organohalogen compounds depend on not only the polarity of the bond and also on the bond length.

It is expected that organofluorides possess highest dipole moment values since the C-F bond is more polar. However, usually organochlorides possess greater dipole moment values. It is due to cumulative result of polarity and longer bond length of C-Cl compared to C-F.

e.g. The dipole moments of methyl halides vary as follows.

 $CH_{3}CI > CH_{3}F > CH_{3}Br > CH_{3}I$ 

## **D. Boiling and Melting points PREPAREDBY: MR. ARNAB PAUL CHOWDHURY**

The boiling and melting points are affected by intermolecular forces of attractions like van der Waals dispersion forces and van der Waals dipole-dipole attractions.

The van der Waals dispersion forces, also known as London dispersion forces, arise due to temporary dipoles induced in the molecules. The strength of these forces depends on the size of molecule. Greater the size and number of electrons, greater is the polarization and hence greater is the attraction.

However, the dipole-dipole attractions are permanent. The magnitude of dipole-dipole interactions depend on the polarity of C-X bond.

Since organohalogen compounds are comparatively more polar (due to presence of polar C-X bond), the permanent dipole-dipole inter-molecular attractions also exist along with temporary dispersion forces. However, there are only London dispersion forces operating in their parent hydrocarbons. Therefore, the melting and boiling points (MPs & BPs) of these compounds are greater than the hydrocarbons of comparable molecular weights.

The MPs and BPs of alkyl and aryl halides increase with increase in the molecular size or molecular weight. The main reason is strengthening of dispersion forces rather than permanent dipole-dipole interactions.

It is clearly evident from the melting and boiling points of methyl halides. Even though the polarity of the C-X bond decreases from methyl fluoride to methyl iodide, the MP and BP trend upwards. This is due to increase in the size of molecule with increase in the size of halogen atom that results in strengthening of dispersion forces of attractions. i.e. The London forces outweigh dipole-dipole forces.

#### POINTS TO BE NOTED:

1. The melting & boiling points of alkyl halides are also affected by the size of and branching in alkyl chain. In a given homologous series, the MP and BP are increased from lower member to higher member.

2. The boiling points decrease with increase in the branching of carbon chain. With branching, the surface area of contact between molecules decreases and hence strength of attractions between them also decreases. BPs are more affected by branching than MPs.

3. The melting points are also affected by symmetry of the molecule. The symmetrical molecules fit better into the crystal lattice and hence possess higher melting points. This is evident from the higher melting point of tert-butyl chloride. It is more spherical and hence fits better than other butyl chlorides into the lattice.

4. The para isomer of dihalo substituted benzenes is more symmetrical than corresponding ortho and meta isomers and hence possess higher melting point.

e.g. Para dichlorobenzene has higher melting point than ortho and meta dichlorobenzenes.

#### E. Density

The densities of organohalogen compounds are related to mass as well as intermolecular attractive forces and tend to parallel boiling points. The density increases from fluorides toiodides. In general, the density of monofluoro and monochloro alkanes are usually less than that of water, whereas monobromo and monoiodo alkanes are denser than water.

However poly halo compounds are denser than water.

## **F.Solubility**

Organohalogen compounds are sparingly soluble in water since they are comparatively less polar than water. They cannot mix with water molecules since breaking of stronger hydrogen bonds in water requires more energy and cannot be compensated by the attractions formed between water and organohalogen molecules. Less energy is released when new attractions are set up between the organo-halides and the water molecules as these are not as strong as the H- bonds in water.

However these compounds are miscible with non-polar organic solvents because the new intermolecular attractions formed between molecules of organohalogens and solvent have much the same strength as the ones being broken.

# **Chemical Reactions of Haloalkanes**

1. <u>Nucleophilic Substitution Reactions (S<sub>N</sub> reactions)</u>

<u>A. S<sub>N</sub>1 AND S<sub>N</sub>2:</u>

Aryl halides are relatively unreactive toward nucleophilic substitution reactions. This lack of reactivity is due to several factors. Steric hindrance caused by the benzene ring of the aryl halide prevents S<sub>N</sub>2 reactions. Likewise, phenyl cations are unstable, thus making S<sub>N</sub>1 reactions impossible. In addition, the carbon-halogen bond is shorter and therefore stronger in aryl halides than in alkyl halides. The carbon-halogen bond is shortened in aryl halides for two reasons.

First, the carbon atom in aryl halides is sp  $^{2}$  hybridized instead of sp  $^{3}$  hybridized as in alkyl halides.

Second, the carbon-halogen bond has partial double bond characteristics because of resonance. B. S<sub>N</sub>Ar reactions

Nucleophilic substitution reactions can occur with aryl halides, provided that strong electron-withdrawing groups (deactivators) are located ortho and/or para to the carbon atom that's attached to the halogen. (This arrangement makes the carbon susceptible to nucleophilic attack.)



**NOTE:**KCN is predominantly ionic and provides cyanide ions in solution, which is ambident nucleophile and bind with carbon side to form as the major product, while AgCN is covalent and form isocyanide as the major product.

Like KCN, KNO<sub>2</sub> form R-ONO while AgNO<sub>2</sub> produces R-NO<sub>2</sub> as product. Vinyl chloride is less reactive towards nucleophilic substitution reactions due to resonance. Nucleophilic substitution reactions are of two types

(a) <u>S<sub>N</sub>1 type (Unimolecular nucleophilic reactions</u>) proceed in two steps:



- **Rate, r = k [RX).** It is a first order reaction.
- ➢ Reactivity order of alkyl halide towards S<sub>N</sub>1 mechanism

3° > 2° > 1°

- ➢ Polar solvents, low concentration of nucleophiles and weak nucleophiles favour S<sub>N</sub>1 mechanism.
- In S<sub>N</sub>1 reactions, partial racemisation occurs due to the possibility of frontal as well as backside attack on planar carbocation.



## (b) <u>S<sub>N</sub>2 type (Bimolecular nucleophilic substitution):</u>

These reactions proceed in one step and is a second order reaction with r = k[RX] [Nu]. During S<sub>N</sub>2 reaction, inversion of configuration occurs (Walden inversion) i.e., starting with dextrorotatory halide a laevo product is obtained and vice-versa, e.g.,



- > Reactivity of halides towards  $S_N 2$  mechanism is:  $1^\circ > 2^\circ > 3^\circ$
- $\blacktriangleright$  Rate of reaction in S<sub>N</sub>2 mechanism depends on the strength of the attacking nucleophile.

NOTE: Strength of some common nucleophiles is

 $CN^{-} > I^{-} > OR^{-} > OH^{-} > CH_{3}COO^{-} > H_{2}O > F^{-}$ 

Non-polar solvents, strong nucleophiles and high concentration of nucleophiles favour S<sub>N</sub>2 mechanism.

## POINT TO BE NOTED:

Relative rates of some alkyl halides in S<sub>N</sub>1 and S<sub>N</sub>2 reactions are in the order **PREPAREDBY: MR. ARNAB PAUL CHOWDHURY** 

$$\begin{split} \mathbf{S_N1:} &(\mathbf{CH_3})_3 \mathbf{CX} > \mathbf{C_6H_5} - \mathbf{CH_2} - \mathbf{X} > \mathbf{CH_2} = \mathbf{CH} - \mathbf{CH_2X} \\ &> (\mathbf{CH_3})_2 \mathbf{CHX} > \mathbf{CH_3CH_2X} > \mathbf{CH_3X} \\ \mathbf{S_N2:} & \mathbf{C_6H_5CH_2X} > \mathbf{CH_2} = \mathbf{CH} - \mathbf{CH_2X} > \mathbf{CH_3X} \\ & \mathbf{resonance stabilised} \\ &> \mathbf{CH_3CH_2X} > (\mathbf{CH_3})_2 \mathbf{CHX} > (\mathbf{CH_3})_3 \mathbf{CX} \end{split}$$

Resonating structure of benzyl carbocations are-



Relative reactivity of alkyl halides for same alkyl group is

RI > RBr > RCI > RF

## 2. Elimination Reactions

Dehydrohalogenation is a  $\beta$  – elimination reaction in which halogen is from  $\alpha$ -carbon atom and the hydrogen from the  $\alpha$ -carbon according to Saytzeff rule, e.g.,



Ease of dehydrohalogenation among halides: 3° > 2° > 1°
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$$(CH_3)_3 CCl > (CH_3)_2 CHCl > CH_3 CH_2 Cl$$

3. Reduction

$$\begin{array}{ccc} C_2H_5 & \longrightarrow & C_2H_6 + HBr \\ C_2H_5I + HI & \xrightarrow{\text{Red P, 420 K}} & C_2H_6 + I_2 \end{array}$$

## 4. Reaction with Metals



Grignard reagent is never isolated in the solid state as it explodes in dry state. So it is used as ethereal solution.

5. Isomerisation

$$\begin{array}{c} CH_3 CH_2 CH_2 \\ \xrightarrow{1-chloropropane} \\ \hline \end{array} \xrightarrow{or anhy. AlCl_3} \\ CH_3 \\ \xrightarrow{Cl} \\ CH_3 \\ \xrightarrow{Cl} \\ CH_3 \\ \xrightarrow{CH} \\ CH_3 \\ \xrightarrow{CH} \\ CH_3 \\ \xrightarrow{CH} \\ \xrightarrow{CH}$$

**General Methods of Preparation of Aryl Halides** 

1. <u>By Halogenation of Aromatic Hydrocarbons</u> **PREPAREDBY:** MR. ARNAB PAUL CHOWDHURY

i.e.,



It is an electrophilic substitution reaction.

## 2. By Side Chain Halogenation



**NOTE:**It involves free radical mechanism.

# 3. From Benzene Diazonium Salt



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4. From Phenol



# **Physical Properties of Aryl Halides**

1. Aryl halides are colourless liquids or colourless solids with characteristic odour.

2. Boiling point generally increases with increase in the size of aryl group or halogen atom. Boiling point order

Ar - I > Ar - Br > Ar - CI > Ar - F

3. The melting point of p -isomer is more than 0- and m-isomer.

This is because of more symmetrical nature of p-isomer.

4. Due to resonance in chlorobenzene, C-CI bond is shorter and hence, its dipole moment is less than that of cyclohexylchloride.

# **Chemical Properties of Aryl Halides**

# 1. Nucleophilic Substitution Reaction

Aryl halides are less reactive towards nucleophilic substitution reaction. Their low reactivity is attributed due to the following reasons:

- 1. Due to resonance, C-X bond has partial double bond character.
- 2. Stabilisation of the molecule by delocalisation of electrons.
- 3. Instability of phenyl carbocation.

However, aryl halides having electron withdrawing groups (like  $- NO_2$ ,  $-SO_3H$ , etc.) at ortho and para positions undergo nucleophilic substitution reaction easily.



Presence of electron withdrawing group (-NO<sub>2</sub>) increases the reactivity.



# 2. Electrophilic Substitution Reactions

Halogens are deactivating but O, p-directing. Thus, chlorination, nitration, sulphonation and Friedel Craft's reaction give a mixture of o- and P- chloro substituted derivatives.

## (i) Halogenation



(ii) Nitration



(iii) Sulphonation







3. Reaction with Metals

(i) Wurtz- Fittigreaction :



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(ii) Fittigreaction :



(iii) Ullmann reaction :



Dichloromethane  $(CH_2Cl_2)$  is widely used as a solvent, as a propellant in aerosols. Direct contact of dichloromethane in humans causes intense burning and milk redness of the skin.

## Trihalogen Derivatives

1. Chloroform [Trichloromethane, CHCl<sub>3</sub>] PREPAREDBY: MR. ARNAB PAUL CHOWDHURY

# Methods of preparation



# **Properties**

1. Oxidation of CHCl<sub>3</sub> gives poisonous gas phosgene (carbonyl chloride).

$$2\text{CHCl}_3 + \text{O}_2 \xrightarrow{\text{Light}} 2\text{COCl}_2 + 2\text{HCl}$$
phosgene

## POINTS TO BE NOTED:

1. To avoid this oxidation CHCl<sub>3</sub> is stored in dark brown bottles and filled to the brim.

1% ethanol is added to chloroform which converts harmful phosgene gas into diethyl carbonate.

2. CHCl<sub>3</sub> is widely used in the production of Freon refrigerant R-22.

3. On nitration, it gives tear producing insecticide substance chloropicrin.

$$\begin{array}{c} \mathrm{CHCl}_8 + \mathrm{HONO}_2 \ (\mathrm{conc.}) &\longrightarrow \mathrm{NO}_2 \cdot \mathrm{CCl}_8 + \mathrm{H}_2\mathrm{O} \\ & \mathrm{chloropicrin} \end{array}$$
4. On dehalogenation, it gives  $\mathrm{C}_2\mathrm{H}_2 \ (\mathrm{acetylene}).$ 

$$\mathrm{CHCl}_8 + 6\mathrm{Ag} + \mathrm{CHCl}_8 \xrightarrow{} \mathrm{CH} \Longrightarrow \mathrm{CH} \Longrightarrow \mathrm{CH} + 6\mathrm{Ag}\mathrm{Cl} \end{array}$$
5. When subjected to hydrolysis, it gives formate.
$$\begin{array}{c} \mathrm{OH} \\ \mathrm{CHCl}_8 + 3\mathrm{NaOH} \longrightarrow \mathrm{CH} & \xrightarrow{\mathrm{OH}} \mathrm{HCOONa} \\ \mathrm{OH} & \xrightarrow{\mathrm{OH}} \mathrm{HCOONa} \end{array}$$

# 2. Iodoform (tri-iodornethane, CHI<sub>3</sub>)

lodoform is prepared by iodoform reaction.

$$\begin{array}{rl} \mathrm{CH}_{3}\mathrm{COCH}_{3}+3\mathrm{I}_{2}+4\mathrm{NaOH} & \longrightarrow \\ & & \mathrm{CHI}_{3}+3\mathrm{NaI}+\mathrm{CH}_{3}\mathrm{COONa}+3\mathrm{H}_{2}\mathrm{O} \end{array}$$

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<u>CRITERIA</u>: Compounds containing either CH<sub>3</sub>CO- or CH<sub>3</sub>CH(OH) group form yellow colouriodoform with I<sub>2</sub> and NaOH.

<u>Note</u>: lodoform when comes in contact with organic matter, decomposes easily to free iodine, an antiseptic. Due to its objectionable smell, it has been replaced by other formulations containing iodine.

## **POLYHALOGEN DERIVATIVES**

## 1.<u>Tetrachloromethane (Carbon Tetrachloride, CCl.</u>) <u>Preparation</u>



CCl₄ is a colourless, non-inflammable, poisonous liquid, soluble in alcohol and ether.

## <u>Uses</u>

1. Carbon tetrachloride is used as a solvent for oils, fats, resins

2. Carbon tetrachloride is used in dry cleaning

3. Carbon tetrachloride is used as fire extinguisher under the name 'pyrene'.

## 2. FREONS

The chlorofluorocarbon compounds of methane and ethane are collectively known as freons. These are usually produced for aerosol propellants, refrigeration and air conditioning purposes. Carbon tetra chloride when reacts with antimony trifluoride in the presence of SbCl<sub>5</sub> as catalyst, dichlorofluromethane (freon) is obtained.

**3. <u>DDT</u> (p, p'-Dichlorodiphenyltrichloroethane)** 



DDT is the first chlorinated organic insecticide. Its stability and fat solubility is a great problem.

It is prepared from chloral and chlorobenzene in the presence of conc. H₂SO₄·

## 4. PERCHLOROETHANE (C<sub>2</sub>Cl<sub>6</sub>)

It is used as moth repellant and is also known as artificial camphor.

5. **WESTRON** (CHCl<sub>2</sub>CHCl<sub>2</sub>) OR Acetylene tetrachloride is non-inflammable and highly toxic in nature.

6. WESTROSOL (CHCl<sub>2</sub>=CCl<sub>2</sub>) OR Trichloroethene.