

Ques 1: What are the methods for the determination of alkalinity of water.

Ans 1: Alkalinity of water is a measure of its acid neutralizing ability or it is the tendency of water to accept  $H^+$  ions in order to neutralize it with the supply of  $OH^-$  ions.

Alkalinity may be determined by potentiometric method or using pH meter or titrimetry using different acid base indicators.

The most commonly used method for determining alkalinity is acid-base titration using a strong acid (e.g.,  $HCl$  or  $H_2SO_4$ ) and a pH indicator. It is based on the neutralization of the alkaline compounds in the water sample.

**Procedure:**

- A known volume of the water sample is titrated with a standard solution of a strong acid.
- Two indicators are typically used: **phenolphthalein** (for detecting carbonate alkalinity) and **methyl orange or bromocresol green** (for detecting total alkalinity).
  - Phenolphthalein alkalinity:** Titration is done until the pH reaches around 8.3 (pink to colorless endpoint).
  - Total alkalinity:** Continue titration until the pH drops to around 4.5 (methyl orange endpoint), which indicates the neutralization of bicarbonates and other alkaline species.
- The amount of acid used to reach these endpoints is used to calculate alkalinity in terms of mg/L of  $CaCO_3$ .

**Types of Alkalinity Measured:**

- Phenolphthalein Alkalinity:** Measures hydroxides ( $OH^-$ ) and half of the carbonates ( $CO_3^{2-}$ ).
- Total Alkalinity:** Measures the combined effect of bicarbonates ( $HCO_3^-$ ), carbonates ( $CO_3^{2-}$ ), and hydroxides ( $OH^-$ ).

**Table 4.6: Computing the alkalinity due to different ions**

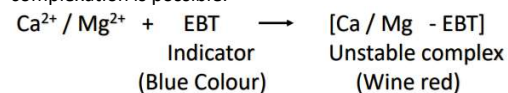
Alkalinity	$OH^-$ (ppm)	$CO_3^{2-}$ (ppm)	$HCO_3^-$ (ppm)
$P=0$	NIL	NIL	M
$P = \frac{1}{2}M$	NIL	2P	NIL
$P < \frac{1}{2}M$	NIL	2P	(M-2P)
$P > \frac{1}{2}M$	(2P-M)*	2 (M-P)	NIL
$P=M$	P=M	NIL	NIL

Ques 2 : Explain briefly the principle of EDTA method for determination of hardness of water.

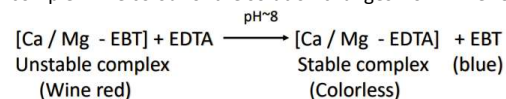
Ans 2: It is a complexometric titration of water sample with EDTA using EBT indicator. This is a reliable method because of its greater accuracy. EDTA (Ethylene diamine tetra acetic acid) forms a colourless stable complex with  $Ca^{2+}$  and  $Mg^{2+}$  ions in water at pH 8-10. Ammonia buffer is used to maintain the pH. In this method EBT (Eriochrome Black-T) is used as an indicator. Initially EBT forms an unstable complex with  $Ca^{2+}$  and  $Mg^{2+}$  ions, giving wine red colour to the solution. During the titration EDTA reacts with this complex (Ca-EBT or Mg-EBT complex), forms a stable complex (Ca-EDTA or Mg-EDTA) and releases the blue EBT into the solution. Hence the end point is wine red to blue colour.

**Principle of EDTA Method**

- Disodium salt of EDTA forms complex with calcium and magnesium ions present in water.
- The indicator used in this titration is Eriochrome Black-T (EBT)\* which also form unstable complex with calcium and magnesium ions present in water, at pH value about 8-10.
- In order to maintain the pH, buffer solution [ $NH_4Cl-NH_4OH$ ] mixture is added. Only at this pH such a complexation is possible.



- This wine red colour solution is titrated against EDTA, EDTA replaces EBT indicator from  $[Ca / Mg - EBT]$  complex. The colour of the solution changes from wine red to blue at the end point.



Ques 3: Explain the secondary treatment process of wastewater for the removal of organic matter.

Ans 3: In waste water much of the organic material is dissolved or in colloidal form which is not removed by primary treatment. Thus removed by secondary treatment. Secondary treatment is achieved through biological processes:

- Coagulation of the finely divided or colloidal matter.
- Oxidation of organic matter to  $CO_2$
- Conversion of nitrogenous organic matter to ammonia, which is eventually converted into nitrite and nitrate.
- Anaerobic digestion of the sludge so obtained.

Three commonly used approaches are:

- Trickling filters
- Activated Sludge Process
- Oxidation Ponds (Lagoons)

**(i) Trickling Filters (Aerobic filtration)**

A trickling filter consists of a rotating distribution arm that sprays the liquid over a circular bed of rocks or other coarse material. Individual rocks get coated with layer of biological slime (aerobic microorganisms, zooglea-bacteria, algae, protozoa etc.) that absorbs and consumes wastes through the bed. Biological towers made with plastic media are prevalent.

Advantages

1. Simple to operate and can produce BOD removal to the extent of 65 to 85%.
2. Constant monitoring is not required.
3. Effluents so produced are of better quality.

Limitations

1. Microbial film formed is sensitive to temperature changes.
2. Efficiency of the filter is dependent upon the composition of waste, pH, size uniformity of the filtering medium & supply of air.
3. Cost of construction is high.
4. Trickling filters are used for treating industrial waste water from dairy, brewery, food processing, pulp and paper mills, pharmaceuticals, petrochemicals etc.

#### (ii) Activated Sludge Process

Most versatile biological oxidation method, employed for the treatment of waste water containing organic matter. Mixture of waste water and activated sludge is agitated and aerated.

The activated sludge is the sludge obtained by settling the sewage in presence of excess of oxygen. The activated sludge is biologically active because it is heavily laden with microorganisms which are in active state of growth.

Advantages

1. The primary advantage is good effluent quality. The effluent after going through activated sludge has little BOD (< 20mg/L)
2. It takes less area as compared to trickling water filters.
3. The activated sludge process equipment is less expensive.

Limitations

1. For the process to be efficient, at least 0.5ppm oxygen must be present.
2. The optimum pH 6.5 to 9.0 has to be maintained throughout.
3. The presence of detergents (which are not biodegradable) lead to the formation of foam, making the process difficult.
4. The disadvantage of this process is production of a huge amount of sludge, which should be digested and disposed off

#### (iii) Oxidation Ponds

- Shallow ponds, typically 1-2 m deep
- Organic matter is oxidized by microorganisms present in the pond
- Waste water enter the pond at one end and treated waste water is collected at the other end
- Decomposition of the organic matter near the surface is aerobic (algal photosynthesis), anaerobic near the bottom, hence, called facultative ponds
- deeper ponds (lagoons) are mechanically aerated.

Advantages

1. The process is simple and cheap.
2. Can be used for all types of waste waters
3. Due to the high pH of waste water in the pond, the heavy metal ions present in waste water are precipitated as hydroxides which settle as sludge.

Limitations

1. The oxidation ponds require larger space.
2. Anaerobic conditions may lead to release of bad odours.
3. The main drawback of the above secondary treatment processes is the formation of sludge.
4. The collection, processing and disposal of sludge can be the most costly and complex aspect of waste water treatment.

Ques 4: Differentiate between chemical flocculation and chemical coagulation.

Mechanical Flocculation	Chemical Coagulation
Waste water is passed through a sedimentation tank which is <b>fitted with rotating paddles</b> moving slowly at a speed of 0.4-0.5 m/s.	The coagulants react with colloidal matter in the sewage to form Floc. The floc entraps the smaller particles and eventually <b>settles down as sludge</b> .
This slow mechanical stirring allows the <b>finely divided solid particles to coalesce into larger particles</b> and settle out.	Common coagulants used in sewage treatment are: <b>alum, copperas, hydrated lime, ferric chloride, and chlorinated copperas.</b>

Ques 5: Explain the types of tertiary treatment for waste water treatment process.

Ans 5: Type of tertiary treatment depends upon the specific goal which include removal of:

**(i) Removal of suspended solids (Micro-straining):**

- This can be achieved by micro-straining.
- The filter media consists of finely woven stainless steel fabric.
- The treated waste is allowed to pass through it.
- The solids retained on the fabric are washed into a trough, which recycles the solids to the sedimentation tank.

**(ii) Removal of dissolved solids**

- a) Adsorption: Dissolved solids can be organics or inorganics which are removed by adsorption on activated carbon. Special adsorbents are commercially available for the removal of toxic heavy metals from industrial waste water.
- b) Solvent Extraction: Used to recover phenolic materials from waste waters of refineries and coke plants. Waste water is intimately brought in contact with a solvent having high affinity for the solute.
- c) Ion Exchange: Used to remove hardness and iron and manganese salts from drinking water. This technique has been extended to waste water treatment for the removal and recovery of waste during water treatment.
- d) Reverse Osmosis: When waste water containing dissolved solids is allowed to pass through a semi-permeable membrane at a pressure, which is more than osmotic pressure, the water from the waste passes through the membrane. Hence a highly concentrated solution containing dissolved salts is left behind.
- e) Chemical precipitation: The precipitating agents like lime etc. remove heavy metal ions by precipitating these as hydroxides. Precipitating agents include  $\text{FeSO}_4$ , alum and ferric chloride.

**(iii) Removal of Nutrients**

- (a) Nitrogen Removal: All forms of nitrogen in wastewater are harmful because plants can utilize the inorganic forms as nutrients,  $\text{NH}_3$  can be utilized by bacteria resulting in reduced oxygen in water.
- Ammonia stripping: Ammonia is present in natural water as ammonium ion. This  $\text{NH}_4$  is changed to ammonia gas by raising the pH (the  $\text{OH}^-$  concentration) of the waste water by adding quick lime. The ammonia gas is liberated.  
 $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$
  - Another approach of nitrogen removal is nitrification i.e. to convert  $\text{NH}_4^+$  to  $\text{NO}_3^-$ , followed by anaerobic stage in which microorganisms convert nitrates to nitrogen gas ( $\text{N}_2$ ).  
 $\text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^- + 2\text{H}^+ + \text{H}_2\text{O}$   
 $2\text{NO}_3^- + \text{organic matter} \rightarrow \text{N}_2 + \text{CO}_2 + \text{H}_2\text{O}$

- (b) Phosphorus Removal (Chemical precipitation): Phosphorus is present in the form of orthophosphates ( $\text{H}_2\text{PO}_4^-$ ,  $\text{HPO}_4^{2-}$  and  $\text{PO}_4^{3-}$ ). Phosphates are removed by adding coagulants usually alum [ $\text{Al}_2(\text{SO}_4)_3$ ] or lime [ $\text{Ca}(\text{OH})_2$ ].  
 $\text{Al}_2(\text{SO}_4)_3 + 2\text{PO}_4^{3-} \rightarrow 2\text{AlPO}_4 + 3\text{SO}_4^{2-}$   
 $3\text{Ca}(\text{OH})_2 + 2\text{PO}_4^{3-} \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 3\text{H}_2\text{O} + \text{O}_2$

**(iv) Removal of bacteria**

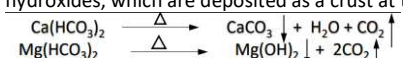
- Chlorination
- Bacteria are removed by retaining the effluents in maturation ponds or lagoons for specified period of times.

Ques 6: Differentiate between temporary and permanent hardness with suitable examples.

Ans 6: Hardness of water can be classified into two categories.

**1. Temporary hardness (or) Carbonate hardness**

This hardness is caused by two dissolved bicarbonate salts  $\text{Ca}(\text{HCO}_3)_2$  and  $\text{Mg}(\text{HCO}_3)_2$ . The hardness is called temporary because, it can be removed easily by boiling. During boiling, bicarbonates are decomposed to yield insoluble carbonates or hydroxides, which are deposited as a crust at the bottom of vessel.



**2. Permanent hardness (or) Non-Carbonate hardness**

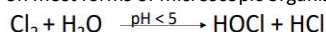
This hardness is due to the dissolved chlorides, sulphates and nitrates of calcium and magnesium. These salts are  $\text{CaCl}_2$ ,  $\text{MgCl}_2$ ,  $\text{CaSO}_4$ ,  $\text{MgSO}_4$ ,  $\text{Ca}(\text{NO}_3)_2$ ,  $\text{Mg}(\text{NO}_3)_2$ . It cannot be removed easily by boiling. Hence, it is called permanent hardness. Only chemical treatment can remove this hardness.

The **EDTA method** is used to measure the **total hardness**, which includes both **calcium hardness** and **magnesium hardness**.  
Total Hardness = Temporary hardness + Permanent hardness

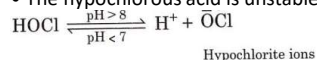
Ques 6: Elaborate 'Disinfection of water by chlorination' and discuss the relationship between the amount of chlorine added to water and the free residual chlorine.

Ans 6: • It means the chlorination of water to such an extent that living organisms as well as other organic impurities in water are destroyed.

- Chlorine is cheap, reliable and easy to handle. Moreover it is capable of providing residual disinfecting effects for long periods and thus prevent future recontamination of water.
- It involves addition of sufficient amount of chlorine to oxidise organic matter, reducing substances, and free ammonia in raw water, leaving behind mainly free chlorine, which possesses disinfecting properties against pathogenic bacteria.
- It is also known as free residual chlorine.
- When chlorine is added to water, it forms hypochlorous acid or hypochlorite ions which have immediate disastrous effect on most forms of microscopic organisms.



- The hypochlorous acid is unstable and dissociates as



- All the three forms HOCl, -OCl, Cl<sub>2</sub> existing in a sample of water are termed as free chlorine. HOCl is found to be most destructive according to enzymatic hypothesis given by Gleen and Stumpt. For this reason the pH value of water during chlorination is generally maintained slightly less than 7 so as to prevent the dissociation of HOCl.

#### Break point chlorination

- The amount of chlorine required for disinfecting water depends upon the inorganic and organic impurities present in water.
- When chlorine is added to water and its amount is estimated after a few minutes, it is found that the available chlorine is not equal to the amount of chlorine added.
- A relation ship between the amount of chlorine added to water and the free residual chlorine is shown in figure. The curve shown in figure can be divided into four stages

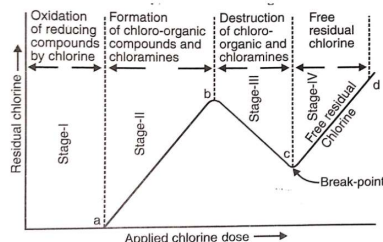


Fig. 4.20 Break-point chlorination curve

### Stages of Chlorination and Relationship to Free Residual Chlorine:

#### 1. Initial Stage: Chlorine Demand Zone:

- When chlorine is first added to water, it reacts with various impurities such as organic matter, ammonia, and metal ions.
- During this stage, **all the added chlorine is consumed** in chemical reactions, and there is **no free residual chlorine** yet.
- The chlorine added is called **chlorine demand**, and it continues until the reactive substances in the water are fully oxidized.

#### 2. Breakpoint Chlorination:

- As more chlorine is added, a point is reached where the demand has been satisfied, and additional chlorine begins to react with ammonia, forming **chloramines** (combined chlorine).
- Chloramines provide some disinfecting properties, but they are much weaker than free chlorine. At this point, the water may have an unpleasant odor and taste.
- As chlorine continues to be added, the chloramines are further oxidized and destroyed.
- The point at which chloramines are fully oxidized and **free chlorine** begins to accumulate in the water is known as the **breakpoint**. This is called **breakpoint chlorination**.

#### 3. Post-Breakpoint: Free Residual Chlorine:

- Beyond the breakpoint, additional chlorine no longer reacts with impurities or forms chloramines. Instead, it remains in the water as **free residual chlorine**, which is the active form responsible for disinfection.
- The amount of **free residual chlorine** increases proportionally with the chlorine dose after the breakpoint is reached.
- In this stage, the free chlorine (HOCl and OCl<sup>-</sup>) serves as a disinfectant to inactivate pathogens and protect the water from future contamination.

Ques 7: Discuss the sources and effects of NO gaseous pollutant.

Ans 7: Number of oxides of Nitrogen are introduced in atmosphere: NO, N<sub>2</sub>O, NO<sub>2</sub>, N<sub>2</sub>O<sub>3</sub>, out of these NO & NO<sub>2</sub> are responsible for pollution, represented as NO<sub>x</sub>. NO is colourless and odourless gas

#### SOURCES:

Natural: During lightening discharge, N<sub>2</sub> and O<sub>2</sub> in air combine to form NO

Man-made sources: Combustion of fossil fuels N<sub>2</sub> + O<sub>2</sub> → 2NO, Temperature 1200 – 17500C

Though reaction is reversible but rapid cooling of combustion product prevents the dissociation of NO.

#### EFFECTS

- Almost all NO<sub>x</sub> emissions are in form of NO, which has no known adverse health effects at concentrations found in atmosphere
- NO can oxidise to NO<sub>2</sub>, which may react with hydrocarbons in presence of sunlight to form photochemical smog, which is injurious to health.

Ques 8: Describe the two methods to control emissions of particulate matter in the air.

Ans 8: • Gravity Settling Chamber: Removes large particulates (> 50 μm) from the gaseous effluents. Velocity of the horizontal carrier gas is reduced adequately so that particles settle by gravitational force.

- Cyclonic Separators: Gas containing particulates is allowed to flow into a tight circular spiral-fitted chamber. Now particulates possess greater inertia than the gas molecules and experience greater centrifugal force. This drive these particulates towards the wall of chamber. From there they settle down due to force of gravity. Efficient for removal of large particles (5-20 μm). More efficient because centrifugal force is much greater than force of gravity.
- Fabric Filters: Exhaust gases are forced through bags of very fine cloth-like mesh, capable of retaining small particles. Used in industries dealing with rock products, pigments etc

Ques 9: Discuss the formation of PAN in photochemical smog with chemical reactions involved.

Discuss the mechanism for formation of peroxyacynitrate (PAN) during formation of photochemical smog with chemical reactions involved.

Ans 9: The atmospheric pollutants or gases that form smog are released in the air when fuels are burnt. When sunlight and its heat (~180C) react with nitrogen oxides and hydrocarbons in the atmosphere, smog is formed.

### Chemistry of Photochemical Smog

Photochemical smog formation proceeds through a sequence of reactions, all involve a free radical mechanism. The main steps can be outlined as

- The hydrocarbons combine with the oxygen atom produced by the photolysis of NO<sub>2</sub>, to form highly reactive intermediates (free radicals)
- $$\text{O} + \text{RCH}_3 \longrightarrow \text{RCH}_2^\bullet + \text{other products}$$

## Chemistry of Photochemical Smog

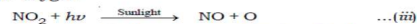
Photochemical smog formation proceeds through a sequence of reactions, all involving a free radical mechanism. The main steps can be outlined as follows:

- Nitrogen dioxide is formed as a result of one of the following reactions. At high temperature of the combustion chamber of the vehicle  $N_2$  and  $O_2$  combine to form NO



The (i) reaction is endothermic so the formation of NO is favoured at high temperatures.

- $NO_2$  so formed is an efficient absorber of ultra-violet (UV) radiations. Thus UV rays in the sunlight cause the photodissociation of  $NO_2$  to form NO and atomic oxygen



- The atomic oxygen formed in (iii) then reacts with abundant oxygen molecules producing ozone

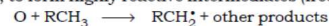


Ozone can convert NO back to  $NO_2$

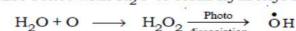


Note that nitric oxide (NO) acts to remove ozone ( $O_3$ ) from the atmosphere.

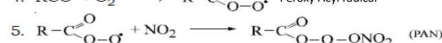
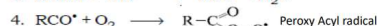
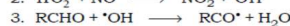
- The hydrocarbons combine with the oxygen atom produced by the photolysis of  $NO_2$ , to form highly reactive intermediates (free radicals)



Oxygen atom can also react with  $H_2O$  to form hydroxyl radicals.

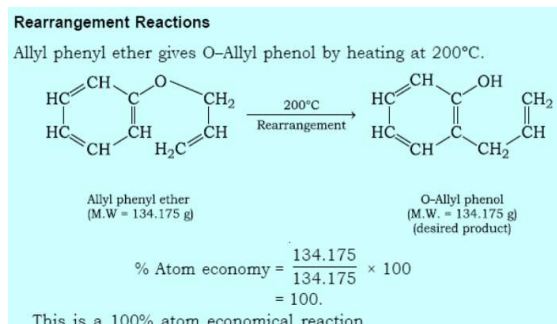


- The free radicals then react with  $O_2$  or NO to produce a number of by products which are highly reactive organic oxidants i.e. secondary pollutants such as acrolein, formaldehyde, peroxyacetyl nitrate (PAN). These secondary pollutants collectively form photochemical smog.



Ques 10: Calculate the atom efficiency for 'Claisen rearrangement reaction'

Ans 10:



Ques 11: Explain the complete process of the formation of power alcohol with reactions

Ans 11: **Power alcohol** is a fuel that consists of a mixture of ethanol (ethyl alcohol,  $C_2H_5OH$ ) and gasoline, used as an alternative to conventional fossil fuels in internal combustion engines.

1. Raw Material Preparation and Hydrolysis (If Using Starch-Based Biomass)

**Hydrolysis of Starch:**

- Starch is a polysaccharide, and it must first be broken down into glucose (a monosaccharide) using enzymes or acids.
- The hydrolysis reaction is as follows:



Starch ( $C_6H_{10}O_5$ )<sub>n</sub> is broken down into glucose ( $C_6H_{12}O_6$ ).

If the feedstock is already sugar-rich, like sugarcane or sugar beet, this hydrolysis step is not needed.

## 2. Fermentation Process to Produce Ethanol

In fermentation, microorganisms like yeast (*Saccharomyces cerevisiae*) convert the glucose (or other fermentable sugars) into ethanol and carbon dioxide under anaerobic (oxygen-free) conditions.

**Fermentation Reaction:**



- Glucose ( $C_6H_{12}O_6$ )** is converted into **ethanol ( $C_2H_5OH$ )** and **carbon dioxide ( $CO_2$ )**.
- This process occurs under anaerobic conditions, where the yeast metabolizes sugar, releasing ethanol as the main product and carbon dioxide as a byproduct.

## 3. Distillation to Purify Ethanol

After fermentation, the ethanol concentration in the solution is typically between 8-12% by volume. The next step is to purify the ethanol through **distillation**, which removes water and other impurities.

**Distillation Process:**

- Ethanol boils at a lower temperature (78.37°C) than water (100°C), allowing it to be separated by heating the fermented mixture.
- The ethanol-water mixture can be distilled up to 95% purity (azeotropic mixture)

Ethanol + water ----distillation----> Ethanol(95%)

**Dehydration (to obtain absolute ethanol):**

To achieve **100% ethanol**, the remaining water must be removed. This can be done using methods like **azeotropic distillation** or using **molecular sieves**.

Ethanol(95%) -----dehydration-----> Ethanol(100%)

## 4. Blending Ethanol with Gasoline

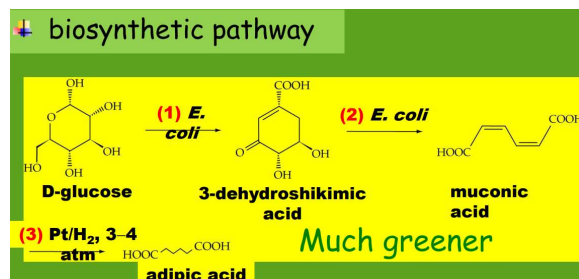
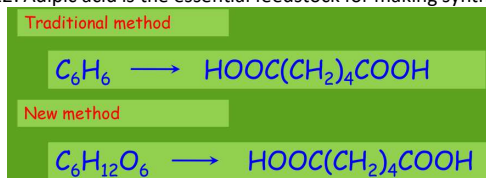
Once pure ethanol is obtained, it is mixed with gasoline to form **power alcohol**. The ethanol typically ranges from 5% to 20% in the mixture. One of the common mixtures is **E10**, which contains 10% ethanol and 90% gasoline.





Ques 12: Discuss the merits of the green method over the traditional method for the synthesis of adipic acid.

Ans 12: Adipic acid is the essential feedstock for making synthetic fibres such as nylon.



ADVANTAGES:

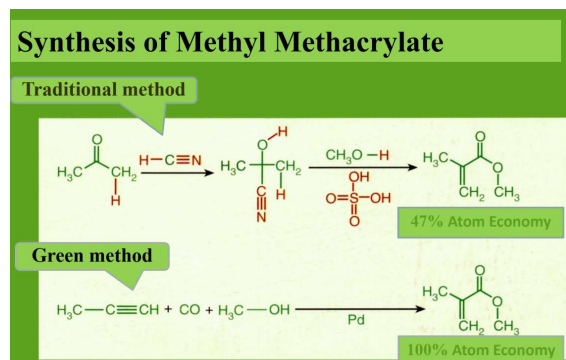
1. The starting material, glucose, is harmless
2. E. coli is used to catalyse two steps of the reaction. This reduces the use of certain chemical reagents with significant toxicity
3. there are no by-products generated during the synthesis

Ques 13: Discuss the “Green reaction” tool of green chemistry in detail with suitable example

Ans 13: Green reactions is based on the “Concept of Atom Economy”.

Few examples of green reactions are given below:

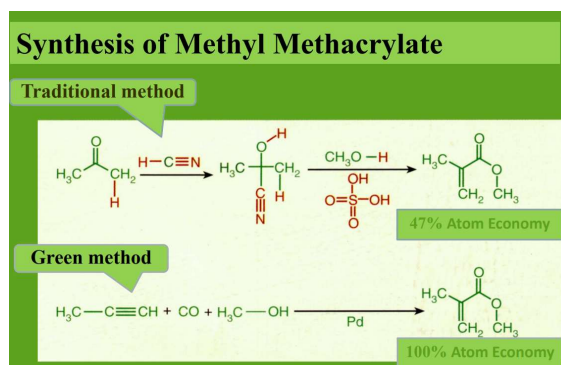
- Synthesis of Methyl Methacrylate (used for manufacture of polymers)
- Synthesis of ibuprofen



Ques 14: Differentiate between conventional and green synthesis of methyl methacrylate

Ans 14:

Aspect	Conventional Synthesis (ACH Process)	Green Synthesis
Raw Materials	Petrochemicals (acetone, HCN)	Renewable resources (biomass, bioethanol, CO <sub>2</sub> )
Process	Multi-step, high-temperature, use of toxic chemicals	Catalytic or enzymatic processes, mild conditions
Energy Requirements	High energy consumption (multiple steps, high temperature)	Low energy (mild conditions, bio-based processes)
Environmental Impact	Toxic by-products (ammonium sulfate, acidic waste), high carbon footprint	Minimal waste, reduced carbon emissions, eco-friendly
Sustainability	Non-renewable feedstocks, hazardous waste	Renewable feedstocks, waste minimization, sustainable
Economic Consideration	Established infrastructure, high waste management costs	Higher initial investment, long-term cost reduction



Ques 15: Explain the process ‘sanitary landfill’ involved in solid waste treatment.

Ans 15: Sanitary landfills are sites where waste is isolated from the environment until it is safe.

**Waste treatment in a sanitary landfill**

Phase I- Aerobic bacteria deplete the available oxygen due to aerobic decomposition.

Phase II- Anaerobic conditions prevail and H<sub>2</sub>O and CO<sub>2</sub> are evolved.

Phase III & IV- Methane forming bacteria decompose the organic matter to CH<sub>4</sub> and CO<sub>2</sub>. The escape vents for gases are provided in landfills.

Phase V- Methanogenic activity decreases, representing the depletion of organic matter and ultimately the system returns to aerobic conditions within the landfill

Ques 16: Describe the chemical processes involved in the treatment of hazardous waste

Ans 16: 1. Neutralization

- Converts to less hazardous substances by changing their pH.

- Acidic wastes are neutralised with Ca(OH)<sub>2</sub> with continuous stirring in a chemical reactor. The pH is regularly monitored.

- Alkaline wastes are neutralized by adding acid directly or by bubbling CO<sub>2</sub>.

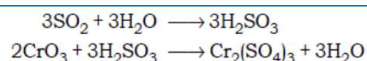
- Simultaneous alkaline and acidic neutralization can also be accomplished in same vessel.

2. Chemical Precipitation: The pH of waste water is so adjusted that the solubility of toxic metals is decreased, leading to the formation of a precipitate that can be removed by settling and filtration.

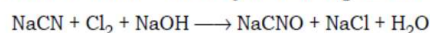
## 2. Oxidation-Reduction Process

- Certain hazardous substances have variable oxidation states. All the states do not have the same toxicity.
- Substances can be converted to oxidation state which is less toxic by redox reactions.
- One of the most important redox treatment process is reduction of Cr<sup>6+</sup> to Cr<sup>3+</sup>. The trivalent Cr<sup>3+</sup>, which is non-toxic can be easily precipitated. In this process SO<sub>2</sub> is often used as reducing agent.

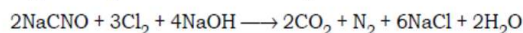
[\*Cr<sup>3+</sup> is an essential nutrient that uses sugar, protein and fat and promotes action of insulin in the body]



Similarly cyanide wastes are treated using redox process. These hazardous substances which are common in effluents from metal finishing industry, are converted to less toxic cyanate using alkaline chlorination.



If chlorination is continued further, the cyanate ion oxidizes to CO<sub>2</sub> and N<sub>2</sub> resulting in complete destruction of cyanide



The wastes that can be treated using redox *oxidation* include the waters which contain benzene, toluene, phenols, cyanide, arsenic ions, iron, and manganese. The wastes which can be treated using redox *reduction* include the ones containing chromium (VI), mercury, lead, silver, and chlorinated organics.