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ENGINEERING CHEMISTRY & ENVIRONMENTAL SCIENCES (AS-203)

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Q1. Write explanatory notes on solar cells, wind energy, geothermal energy and ocean energy.

SOLAR CELLS

A solar cell or photovoltaic cell is an electrical device that converts energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. Individual solar cell devices can be combined to form modules, also called solar panels. A common single silicon solar cell can produce a maximum open circuit voltage of 0.5 to 0.6 volts. The operation of photovoltaic cell requires three basic Attributes:

(i) The absorption of light, generating either electron hole pairs or excitons.

(ii) The separation of charge carriers of opposite types.

(iii) The separate extraction of those carriers to an external ckt.

Solar cell modules can be connected in series or parallel configurations to obtain desired voltage or current levels, additionally a battery buffer is installed with panels to discharge energy whenever required in absence of sun or insufficient output. Solar energy is renewable and ecofriendly, Global installed photovoltaic capacity reached more than 300 Gigawatts in 2016 and grew to supply 1.3% of global power by 2016.

WIND ENERGY

It is the use of wind to provide the mechanical power through wind turbines to turn electric generators wind power is a sustainable and renewable energy, and has much smaller impact on environment compared to burning fossil fuels wind farms consist of many individual wind turbines which are connected to the electric power transmission network. wind is an intermittent energy source which cannot make electricity nor be dispatched on demand. It also gives variable power which is consistent from year to year but varies greatly over shorter time scales. Therefore it must be used together with other power sources to make a reliable supply. In 2018, global wind power capacity grew 9.6% to 591 GW and yearly wind energy reached 4.8% of world wide electric power cons.

GEOTHERMAL ENERGY

It is the thermal energy generated and stored in the Earth. Earth's internal heat is thermal energy generated from radioactive decay and heat loss from Earth's formation. Temperatures at the core-mantle boundary may reach over 4000°C. The high T & P in earth's interior cause some rock to and solid mantle to behave plastically, resulting part of mantle connecting upward since it is lighter than surrounding rock. Rock and water is heated in the crust, sometimes upto 400°c.

with water from hot springs, geothermal energy is used for electricity generation. Geothermal power is cost-effective, reliable, sustainable and environmentally friendly but is limited to regions near tectonic plate boundaries.

The thermal efficiency of geothermal plants is low, around 10-20%, because geothermal fluids do not reach to high temperatures of steam from boilers.

OCEAN ENERGY

It refers to the energy carried by ocean waves, tides, salinity and ocean temperature differences. The movement of water in world's oceans create a vast store of kinetic energy. Some of this energy can be harnessed to generate electricity to power homes, transport and industries.

The term ocean energy, encompasses both wave power ie power from surface waves and tidal power ie obtained from kinetic energy of large bodies of moving water.

ocean energy has a potential of providing a substantial amount of new renewable energy around the world.

Q2. What is biotechnology? Discuss its applications.

- Biotechnology is the use of living organisms or their components in manufacturing pharmaceuticals and other products to promote industrial or commercial products, which can be aided by the technique of genetic engineering in developing novel plants for agriculture and industry. The word "biotechnology" is a combination of two terms, biology & technology.

- Applications of Biotechnology.
  (i) Microbial Biotechnology
  Synthesis of chemicals by microbes.
  Ethanol : Beverage and fuel industry
  Oxalic Acid : printing & dyeing
  Propenoic Acid :
  Acrylic Acid : production of plastics
  Acetic Acid : food industry

  Many industrially important chemicals are produced in large amounts feasibly using microbes eg fermentation of sugar by yeast (Saccharomyces cerevisiae) to yield ethanol etc.

  Enzymes
  Microbes also make many different enzymes whose applications range from removal of stains (by enzymes incorporated in detergent that attack fats and proteins) to conversion of cornflour to high fructose syrup (used to sweeten edibles) etc.

  Pharamaceutical chemicals
  - Pencillin by penicillin moulds
  Streptomycin by streptomyces griseus etc.
  Many antibiotics are obtained by microbes
  - Moreover, in preventive medicine and vaccines use weakened or dead microbes for acquiring active immunity against potential diseases eg for rabies and hepatitis-B.
  - Using genetic engineering, bacteria are now programmed to produce hormones like insulin, growth hormones etc which were rare or not available previously

  (ii) Environmental Applications.
  Bioremediation : use of microbes to break down pollutants, harnessing their detoxifying capabilities.

  Metallurgy : Bacteria are also used to leach metals such as iron, zinc and uranium out of inaccessible and low grade ores.

  Microbial Mining : To obtain minerals not easily accessible or depleted reserves.

(iii) Plant biotechnology

- Traditional plant breeding replaced by genetic engineering to develop crops with advantages like
  - resistance to pests : Maize resistent to european cornborer achieved by incorporating a gene of Bacillus thuringiensis into plant that instructs it to produce toxic chemicals effective on pests
  - resistance to drought
  - improved palatability & nutrient content
    : Oilseed rape has been genetically altered to produce industrially important chemicals.
    : rice with higher amount of iron
    : increase level of specific protein in wheat to get desired breads etc.

(iv) Animal Biotechnology

- New genes may be introduced in fertilised embryos or inherited diseases can be deleted from genetic material. eg haemophilia or lactose intolerance etc.
- New genes encorporated in animals can make them more productive like sheeps producing more wools or cows producing more milk etc. (Transgenic Cow rosie etc)
- Cloning can be achieved. eg Dolly the sheep was the first mammal cloned from adult somatic cell.

Q3. What is fermentation? Discuss production of Alcohol & vitamins.

FERMENTATION

Decomposition of complex organic compounds into simpler substances taking place in presence of living microorganisms is called fermentation

The process of fermentation is the slow decomposition of complex organic compounds into simpler substances through the agency of complex nitrogenous compounds called enzymes, generally produced by living microorganisms. Fermentation is generally accompanied by evolution of gases like carbon dioxide, methane and is exothermic in nature.

(The word fermentation is derived from latin word 'fervor', meaning to boil as during fermentation, there is lot of frothing ~~during~~ due to evolution of gases giving a boily look)

In daily life, fermentation is observed in

- souring of milk or curd
- souring of kneaded flour
- Rottening of fruits or vegetables
- Putrefaction of meat
- conversion of fruit, sugars into wine etc.

PRODUCTION OF ETHANOL BY FERMENTATION

The conversion of sugar into ethanol by yeast is called alcoholic fermentation. The starting raw materials are
(i) starchy materials (like potato maize, barley etc)
(ii) Molasses a by-product in sugar industry.

Two methods for manufacturing ethanol are.

(i) From molasses.

Molasses is a syrup left after the separation of cane sugar (or beet-sugar) crystals from the concentrated juice. It contains ~30% uncrystallizable sucrose & ~30% invert sugar (Mix. of glucose & fructose)

STEP-1 : Dilution
- Molasses diluted with water until 8-10% sugar concn
- Small amt. of dil. H_2SO_4 is added to adjust pH ~ 4-4.5. (favourable for yeast, unfavourable for bacteria)
- Small amt of $(NH_4)_2SO_4$ Added as food for yeast cells

STEP-2 : Alcoholic fermentation
- soln shifted into large fermentation tanks.
- yeast is added (5% by vol. of liq.)
- Mixure is allowed to stand
- Temperature maintained at 30°C

following reactions take place.

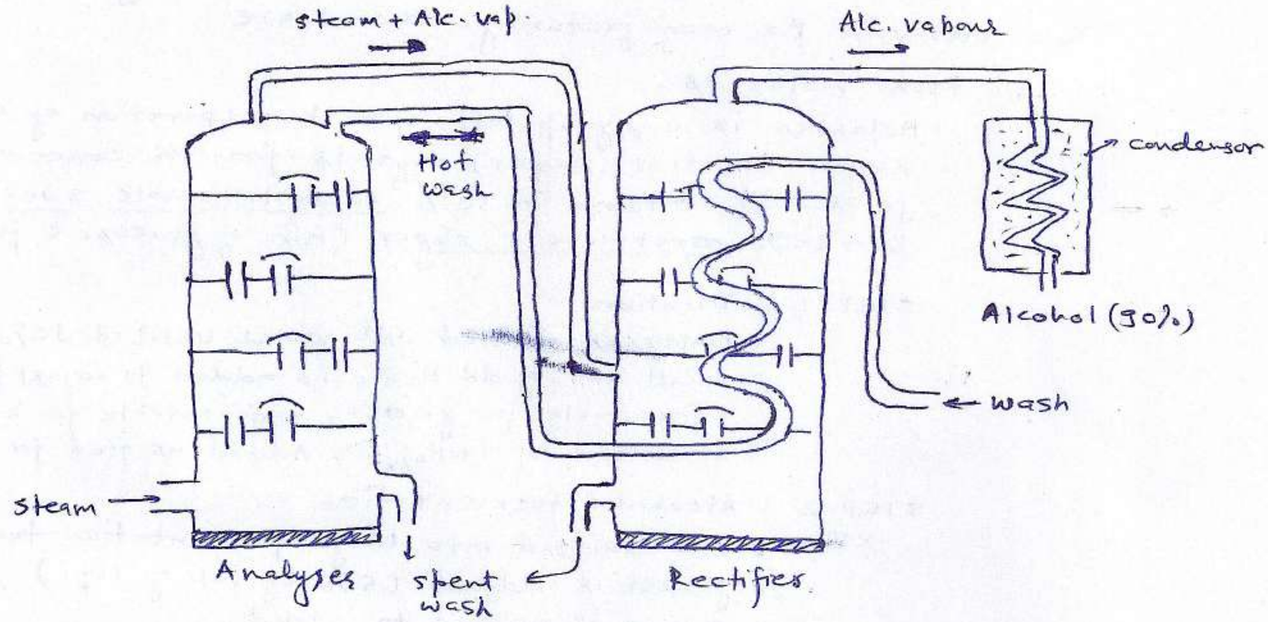
$$\underset{\text{cane sugar}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{invertase}]{\text{enzyme}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{gluc./fruc.}}{C_6H_{12}O_6} \xrightarrow[\text{zymase}]{\text{enzyme}} \underset{\text{(Ethanol)}}{2C_2H_5OH} + 2CO_2$$

STEP-3 : Fractional Distillation
- composition of fermeted liquor (wash)
  6-10% ethanol
  3-5% glycerol
  higher Alcohols, acetyl Aldehydes etc.
- wash is subjected to fractional distillation in a coffey still, which consist of two fractionating columns known as analyser and rectifier, which are provided with perforated plates. It works on counter-current principle, since steam and alcohol travel in opposite direction through the still.

- Mechanism.
The wash is preheated by circulating it through the coil round the rectifier and then introduced into the analyser. A current of steam is passed from bottom of Analyser, whereby the alcohol (and other volatile constituents) present in the wash rise up along steam and enter rectifier. During the upward passage.

steam goes on condensing ; while vapour of Alcohols leaving from the top of rectifier are condensed and collected. This is known as <u>raw spirit</u>, which contains about 90% Alcohol. The liquid collected at bottom of Analyser is called <u>spent wash</u>.



STEP-4 : RECTIFICATION

ethanol obtained after fractional distillation contains water and other impurities, which are removed by further careful distillation (fractional).

First fraction : contain low boiling liqs like acetaldehyde

second frac^n : containing 93-95% ethanol called rectified spirit.

last frac^n : containing water & fusel oil (Mix of other alcohols)

(ii) from starch.

STEP-1 : Saccharification

starch is first converted into maltose.

STEP 1.1 Malting

Geminated barley (malt) is crushed and extracted with water & filtered. The filterate containing <u>diastase</u> enzyme is known as <u>malt extract</u>

STEP 1.2 : Mashing

Process of liberating starch from starchy materials. The starchy material is treated with superheated steam to break cell walls and form pastelike mass called mash.

STEP 1.3 : Hydrolyses

Malt extract added to mash at 50-60°c, when hydrolyses of starch into maltose takes place.

$$2(C_6H_{12}O_5)_n + nH_2O \xrightarrow[50-60°C]{Diastase} nC_{12}H_{22}O_{11}$$

(starch) Maltose

STEP - 2 : Alcoholic fermentation

The hydrolysed starch soln (containing maltose) is then fermented by yeast for 2-4 days at 30°c. The enzyme maltase (present in yeast) hydrolyses maltose into glucose; while the other enzyme, zymase (present in yeast) converts glucose to ethanol

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{Maltase}} 2C_6H_{12}O_6$$

Maltose → Glucose

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2C_2H_5OH + 2CO_2$$

STEP - 3 : Distillation & rectification of fermented liqor

Done in a similar way as molasses.

MANUFACTURE OF VITAMINS BY FERMENTATION

Three vitamins namely, riboflavin (vitamin B), cyanocobalamin (vitamin B12) and ascorbic acid (vitamin C) have been prepared by fermentation process.

(i) Vitamin B_2

Prepared from residue of butanol - acetone fermentation. A suitable carbohydrate mash is prepared and sterlised and pH adjusted 6-7. The mass is buffered with calcium carbonate, inoculated with <u>clostridium butyricum</u> at 37 - 40°c for 2-3 days. The yield is ~ 70 mg riboflavin / litre.

(ii) Vitamin B12

is made in nature by microbial synthesis - produced by bacteria in the intestinal tracts of animals and stored in tissues, Some B_{12} is made during fermentation as well. Technically, it ~~[illegible]~~ is prepared by fermentation process using <u>Propionibacterium freudenreichii</u> at an optimum pH of 7.0 - 7.5 at 30°C for 5 - 7 days. The culture medium for vitamin B_{12} prepn consists of.

(i) yeast	20 parts
(ii) Glucose	25 parts
(iii) Glycine	0.2 parts
(iv) $CoCl_2 \cdot 2H_2O$	0.08 part
(v) Water	1000 parts.

The yield of B_{12} is ~ 25 - 40 mg/L.

Q4. write short notes on:
(i) Biological indicators
(ii) Biosensors.
(iii) Bioremediation
(iv) Biopesticides.
(v) Biofertilisers
(vi) Bioreactors

(i) Biological indicators.
A bioindicator is any species (An indicator species) or a group of species whose function, population, or status can reveal the qualitative status of the environment. Bio indicators can tell about cumulative effects of different pollutants in the ecosystem and about how long a problem may be present, which PHYSICAL & CHEMICAL TESTING CANNOT.

Eg. Plant indicators
The dissappearence of lichens in a forest may indicate environmental stresses, such as high levels of SO_2, sulfhur based pollutants or Nitrogen oxides

Animal indicators
Changes in animal populations, whether increase or decrease can indicate poll^n^. For instance if poll^n^ depletes a plant species, animal species depending on that plant will show <u>popul^n^ decline</u>. Conversely <u>overpopulation</u> may be opportunistic growth of a species in response to loss of other species in an ecosystem.

Microbial indicators
- Chemical pollutants
  Microorganisms produce stress proteins when exposed to contaminants like cadmium or benzene etc.
- Oil & Gas exploration
  oil & gases seep towards surface from their reservoirs due to buoyancy forces of sealing pressures below. These hydrocarbons can alter the chemical & microbial occurences found in near surface soils and can be picked directly.

(ii) Biosensor

It is an analytical device, used for detection of a chemical substance that combines a biological component with a physicochemical detector. The sensitive biological element eg- tissue, microorganisms, organelles, cell receptors, ~~enzymes~~, antibodies, nucleic acids etc is a biologically derived material or biomimetic component that interacts with, binds with, or recognises the analyte under study

The biologically sensitive elements can also be created by biological engineering. It has various applicns ex. glucose monitoring in diabetes patients, detection of pesticides or river water contaminants etc.

(iii) Bioremediation

It is a process used to treat contaminated media, including water, soil, subsurface material, by altering environmental conditions to stimulate growth of microorganism and degrade the target pollutants. In many cases, bioremediation is less expensive and more sustainable than other remediation alternatives.

Most bioremediation processes involve oxidn-redn reactions where either an electron acceptor (commonly oxygen) is added to stimulate the oxidn of a reduced pollutant (eg hydrocarbon) or an electron donor (commonly an organic substrate) is added to reduce oxidised pollutants (eg nitrate, perchlorate, oxidised metals, chlorinated solvents etc). In both these approaches, additional nutrients, vitamins, minerals and pH buffers may be added to optimise conditions for microorganisms.

Eg. Bioremediation related technologies are:

(i) Bioleaching
(ii) landfarming
(iii) Bioreactor
(iv) Composting
(v) Bioaugmentation etc.

(iv) Biopesticides.

~~Biopestides include several types of pest management intervention: through predatory, parasitic or chemical relationships.~~ These are naturally occuring substances that are used for pest control (biochemical pesticides) or microorganisms that control pests (microbial pesticides) or pesticidal substances produced by plants themselves containing plant incorporated protectants.

Biopesticides can be classified into three classes.

(i) Microbial pesticides.
consist of bacteria, entomopathogenic fungi (or metabolites that bacteria or fungi produce), entomopathogenic nematodes. (insect killing insects)

(ii) Bioderived chemicals.
Naturally occuring substances that control pests or microbial diseases.
eg. essential oils.
pheromones

(iii) Plant incorporated protectants

which have genetic material from other species encorporated into their genetic material (ie Genetically modified - GM crops)

eg. genes derived from Bacillus thuringiensis incorporated into cotton plants yield BT-cotton which secrete toxins to kill specific insects when the consume cotton plant parts.

- RNA interference pesticides are also emerging as potent pesticides.

(v) Biofertilisers.

A biofertilizer is a substance which contains living microorganisms which, when applied to seeds, plants surfaces, or soil, colonise the rhizosphere (or interior) of the plant and promotes growth by increasing supply or availability of primary nutrients to the host plant. Biofertilisers add nutrients through natural processes of nitrogen fixation, solubilising phosphorus, and stimulating plant growth through the synthesis of growth promoting substances. Biofertilisers are expected to to reduce the use of synthetic fertilisers & pesticides. Biofertilisers restore the soil's natural natural nutrient cycle and build organic soil matter. Through the use of biofertilisers healthy plants can be grown, while enhancing sustainability and health of the soil.

eg plant growth promoting rhizobacteria (PGPR)
Rhizobium : used with leguminous crops
Azotobacter : used with crops like wheat, maize, mustard
Blue green Algae : fix atmospheric nitrogen etc.

(vi) Bioreactors

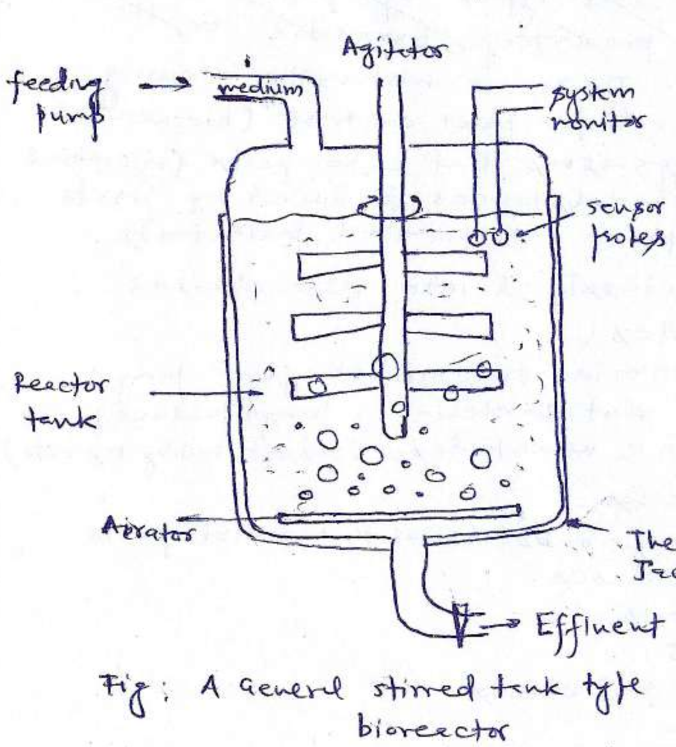


Fig: A General stirred tank type bioreactor

A bioreactor refers to any manufactured device or system that supports a biologically active environment. In one case, a bioreactor is a vessel in which a chemical process is carried out which involves organisms or biochemically active substances derived from such organisms. This process can either be aerobic or anaerobic. These bio reactors are commonly cylindrical, ranging in size from litres to cubic meters

Q5. What is sewage? Explain aerobic and anaerobic oxidation. Discuss sewage treatment in detail.

SEWAGE

Sewage is a type of wastewater that is produced by a community of people. It consists mostly of greywater (from sinks, bathtubs, laundry etc), black water (water used to flush toilets combined with human waste), soaps, detergents etc. It is characterised by.

(i) volume or rate of flow
(ii) Physical condition
(iii) chemical & toxic constituents
(iv) Bacteriologic status (which organisms it contains and in what quantities.)

AEROBIC OXIDATION

In presence of good amount of dissolved/ free oxygen above 8 mL / Litre, organic compounds in sewage underga a process of oxidation brought about by aerobic bacterias and the oxidation products are inoffensive smelling, non-putrefying nitriles, nitrates, sulfhates, phosphates etc. This kind of oxid" of sewage is called aerobic oxid".

ANAEROBIC OXIDATION

When dissolved / free oxygen supply is below a certain value, the sewage is called stale and anaerobic bacteria bring about petrification causing production of methane, hydrogen sulfhide, ammonium sulfhide and phosphates which give offensive order. Such oxid" of sewage is called anaerobic oxid". Anaerobic bacteria extract combined oxygen contained in organic matter. Such sewage is also called septic sewage.

SEWAGE TREATMENT.

Sewage water cannot be discharged into natural water bodies like rivers or streams directly because it contains large amount of organic matter, microbes and other pollutents. Before disposal, hence, sewage water is treated in sewage treatment plants (STPs) to make it less polluting. Treatment of wastewater is done by the heterotrophic microbes naturally present in the sewage. The treament is carried out in two stages.

(i) PRIMARY TREATMENT

sequential filtration	: To remove floating debris.
sedimentation	: To remove grit (soil & pebbles)
primary sludge	: formed by all solids that settle
effluent	: supernatant after sludge formation.

(ii) SECONDARY TREATMENT / BIOLOGICAL TREATMENT

The primary effluent is passed into large aeration tanks where it is constantly agitated mechanically and air is pumped into it. This allows vigourous growth of useful aerobic microbes into flocs (masses of bacteria associated with fungal filaments to form mesh like structures) while growing these microbes consume a major part of of the organic matter in the effluent. This significantly reduces the BOD (Biochemical oxygen demand). The sewage water is treated until BOD is reduced. The greater the BOD of waste water, more is its polluting potential.

Once BOD of sewage is reduced significantly, the effluent is then passed into a settling tank where the bacterial flocs are allowed to sediment. This sediment is called activated sludge. A small part of activated sludge is pumped back into aeration tank as inoculum. The remaining ~~part~~ major part of the sludge is pumped into large ~~aeration~~ tanks called anaerobic sludge digesters. Here other kind of bacteria, which grow anaerobically, digest the bacteria and fungi in the sludge. During this digestion, bacteria produce a mixture of gases such as methane, hydrogen sulfide and carbon dioxide. These gases form biogas and can be used as source of energy as it is inflammable.

Effluent from secondary treatment is generally released into natural water bodies like rivers & streams.

Q6. Define the terms BOD and COD. Discuss the determination of BOD and COD.

BOD (Biochemical Oxygen demand)

It is the amount of dissolved oxygen needed by aerobic biological organisms to breakdown organic material present in a given water sample at certain temperature over a specific time period. The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20°c ~~it~~ is often used as a surrogate of the degree of organic pollution of water. BOD reduction is used as a guage of effectiveness of water treatment plants.

COD (Chemical oxygen demand)

It is an indicative measure of the amount of oxygen that can be consumed by reactions ~~measured~~ in a measured solution. It is commonly expressed in mass of oxygen consumed over volume of soln which in SI units is milligrams/Litre. A COD test can be used to easily quantify the amount of organics in water.

Method for determination of BOD.

After carefully incubated period. The dissolved oxygen can be determined by many methods, one of the popular is

WINKLER'S METHOD

It determines the dissolved oxygen based on a redox titration. A manganese salt (II) and with an iodide and a hydroxide salt are first added to the water sample. The initially formed Manganese hydroxide is oxidised by dissolved oxygen.

$$2Mn(OH)_2\ (s) + O_2\ (aq) \rightarrow 2MnO(OH)_2\ (s)$$

sulphuric acid dissolves the $MnO(OH)_2$ (s)

$$MnO(OH)_2\ (s) + 2H_2SO_4 \longrightarrow Mn(SO_4)\ (aq) + 4H_2O$$

The Mn (IV) oxides the iodide to iodine

$$Mn(SO_4)_2 + 2I^-\ (aq) \longrightarrow Mn^{2+}\ (aq) + I_2\ (aq) + 2SO_4^{2-}\ (aq)$$

The concn of iodine is determined by a titration with thiosulphate using starch as an indicator.

$$2S_2O_3^{2-}\ (aq) + I_2 \longrightarrow S_4O_6^{2-}\ (aq) + 2I^-\ (aq).$$

Method of determination of COD

The organic matter, present in the water sample is oxidised by potassium dichromate in the presence of sulphuric acid, silver sulphate and mercury sulphate to produce carbon dioxide and water. The quantity of potassium dichromate used is calculated by the difference in volumes of ferrous ammonium sulphate consumed in blank and sample titrations. The quantity of Pot. dichromate used is equivalent to the oxygen (O_2) used to oxide the organic matter of waste water. Indicator used is Ferroin indicator.

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