CMR
INSTITUTE OF
TECHNOLOGY

CMRIT

Sub:	**Engineering Chemistry**	Code:	18CHE12

Date:	07/01/2019	Duration:	90 mins	Max Marks:	50	Sem:	I	Branch:	All

Internal Assessment Test III

1. (a) Explain the mechanism of photochemical smog formation with relevant reactions. Mention its ill effects. (05 Marks) (CO4, L2)

Solution:

Photochemical smog

Photochemical smog is a mixture of pollutants that are formed when nitrogen oxides and volatile organic compounds (VOCs) react to sunlight, creating a brown haze above cities.

It tends to occur more often in summer, because that is when we have the most sunlight.

Causes for Photochemical smog:

➤ **Primary pollutants:**
 The two major primary pollutants, nitrogen oxides and VOCs, combine to change in sunlight in a series of chemical reactions, outlined below, to create the secondary pollutants.

➤ **Secondary pollutants**: The secondary pollutant that causes the most concern is the ozone that forms at ground level. While ozone is produced naturally in the upper atmosphere, it is a dangerous substance when found at ground level. Many other hazardous substances are also formed, such as peroxyacetyl nitrate (PAN).

Below is a simplified explanation of the chemistry of smog formation. Nitrogen dioxide (NO_2) can be broken down by sunlight to form nitric oxide (NO) and an oxygen radical (O):

Atmospheric oxidant production:

1. $NO + VOC \longrightarrow NO_2$ (nitrogen dioxide)

2. $NO_2 + UV \longrightarrow NO + O$ (nitric oxide + atomic oxygen)

3. $O + O_2 \longrightarrow O_3$ (ozone)

4. $NO_2 + VOC \longrightarrow PAN$, etc. (peroxyacetyl nitrate)

Net results:

$NO + VOC + O_2 + UV \longrightarrow O_3$, PAN, and other oxidants

Harmful effects of photochemical smog:
- Their' high concentration causes headache, chest pain and dryness of the throat.
- Ozone and PAN act as powerful eye irritants.
- Photochemical smog leads to cracking or rubber and extensive damage to plant life.
- It causes corrosion of metals, stones, building materials, and painted surface etc.

Control:
- Use of catalytic converter in automobiles prevents the release of nitrogen dioxide and hydrocarbons to the atmosphere.
- Pinus, juniparus, quercus, pyrus etc. can metabolise nitrogen dioxide thus their plantation could help to some extent.

(b) Define BOD. In a COD test 31.2 cm3 and 15.5 cm3 of 0.05 N FAS solution are required for blank and sample titration respectively. The volume of the test sample used was 25 cm3. Calculate the COD of the sample solution. (05 Marks) (CO4, L3)

Solution: **BOD (Biological Oxygen Demand):** It is defined as the amount of oxygen required by microorganisms to oxidize the organic wastes present in one litre of waste water over a five-day period at 20C.

Given, $V = 25$ mL, $b = 31.2 cm^3$, $a = 15.5 cm^3$, $N_{FAS} = 0.05N$

$$\text{COD of the sample} = \frac{N_{FAS} \times (b\text{-}a) \times 8 \text{ g dm}^{-3}}{V}$$

$$= 0.05 \text{ X } (31.2\text{-}15.5) \text{ X } 8000/ 25 = 251.2 \text{ mg of } O_2 /dm^3$$

2. (a) What are the sources, effects and control of lead pollution?   (05 Marks) (CO4, L2)
Solution:

Sources:
- The exhaust from automobiles which use lead tetraethyl as antiknocking agent-
- When TEL is used as antiknocking agent, lead is converted to halide and released into the atmosphere. This leads to increase in the concentration of lead in the atmosphere.
- Paint pigments : Litharge and red lead (oxides of lead) and lead chromate are used as pigments. These cause lead pollution
- Plumbing systems- lead pipes are used for plumbing and these may cause lead pollution.

Ill effects:
- Lead competes with calcium and enters the blood and bone marrow.
- The lead interferes in the manufacture of red blood corpuscles and abnormal multiplication of blood cells and thus leads to anemia and blood cancer in human beings.
- Lead enters the blood and various organs of the body including the brain and the   Kidneys leading to dysfunction of the kidney and damage to the brain.

Control: Use of unleaded petrol.
Lead contamination in drinking water is minimized by RO process.
Maintain soil pH 6.5 to avoid absorption of lead by plants, can be achieved by using composted leaves and manure.

(b) What is potable water? Describe the reverse osmosis process of water. (05 Marks) (CO1, L3)

Solution: **Potable Water: The water which is free of any impurities and is fit for human consumption is called potable water.**

Reverse Osmosis:

Osmosis is the physical movement of a solvent through a semi permeable membrane from lower concentration to higher concentration. When two aq. Solution of different concentration are separated by a semi-permeable membrane, water passes through the semipermeable membrane in the direction of more conc. solution as a result of osmotic pressure. (i.e. pressure exerted by this mass transfer is known as osmotic pressure).

(a) Osmosis (b) Reverse osmosis
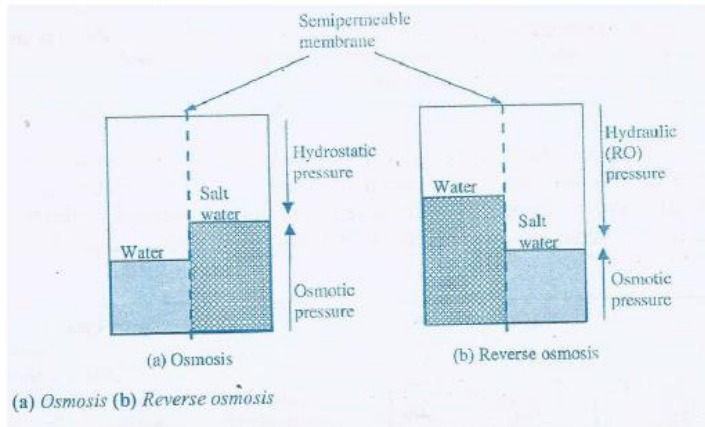
This natural process may be reversed by applying a pressure on the brine side higher than that of the osmotic pressure, and then fresh water tends to flow from brine into fresh water. Thus the process, which reverses the natural spontaneous osmosis, is called reverse osmosis. The greater the pressure applied the more rapid is the diffusion.

Sea water exerts an O.P. of about 240 psi. Reverse osmosis can be effected by the use of pressure in the range of 410-510 psi.

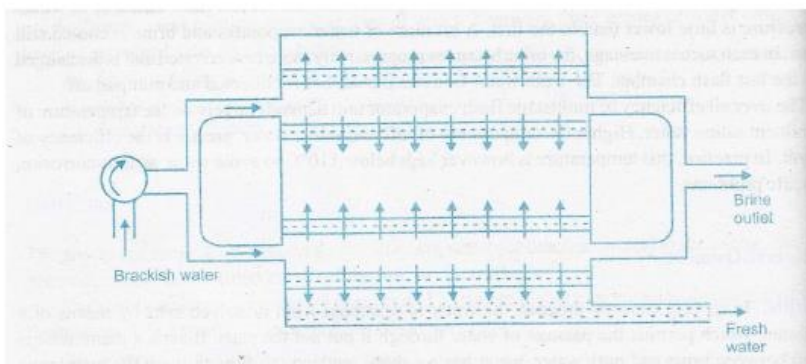**Process:** An R.O. unit is simple as shown in fig. given below.

Fig: Reverse osmosis method of desalination

3. (a) What are the causes, effects and disposal methods of e-waste? (05 Marks) (CO4, L2)
Solution:

E Waste:
"E-waste" is a popular, informal name for electronic products attaining the end of their "useful life.
"E-wastes are considered dangerous, as certain components of some electronic products contain materials that are hazardous, depending on their condition and density. The hazardous content of these materials poses a threat to human health and environment. The discarded computers, televisions, VCRs. stereos, copiers, fax machines, electric lamps, cell phones, audio equipment and batteries if improperly disposed can penetrates into soil and groundwater.

Constituents of e-Waste:
- Circuit Boards- these include heavy metals like lead and cadmium
- Batteries- these include cadmium
- Cathode ray tubes- they contain lead and barium oxide
- Brominated flame retardant in coated on circuit boards, cables, and PVC
- Copper cables and plastic coated computers release toxic dioxins and furan when burnt

When burn these produce dioxin, which causes problems of reproduction, destruction of the immune system, and regulatory hormones are damaged too.

e-Waste disposal:
   a) Reuse b) recycle c) land fill d) incineration

Characteristics of e-waste:
   a) Partly hazardous: e-waste contains different substances, some of which can pose serious risk due to wrong handling.
   b) Partly valuable: Mother boards can be recycled.
   c) E-waste is increasing at alarming rates
 HEALTH HAZARDS OF E-WASTE
Solder Solder contain lead that damage the nervous system, blood system, kidney and also affect the development of brain in children.
Relays, Switches and Printed Circuit Boards
Mercury present in these elements leads to brain damage, disorders in the respiratory system and skin diseases.
Corrosion Protectors
Asthmatic bronchitis and DNA damage are caused due to the Hexavalent Chromium present.
Cabling and Computer Housing

(b) Explain the activated sludge treatment of sewage water.   (05 Marks) (CO4, L2)
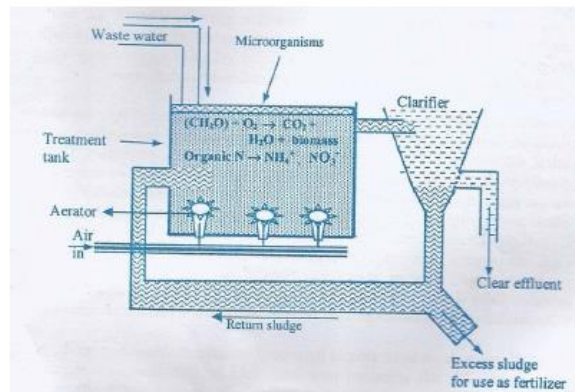**Solution:**

Fig. *Activated sludge process*

(b) Secondary(Biological) treatment (Activated sludge process).

- The waste water after the primary treatment is allowed to flow into large tanks where biological treatment is carried out.
- *Activated sludge* containing microorganisms (from a previous operation) is sprayed over the water. The microorganisms present in the sludge form a thin layer and thrive on the organic wastes in the sewage.
- Air is passed vigorously from the centre of the tank in order to bring good contact between the organic wastes and bacteria in presence of air and sunlight. Under these conditions, aerobic oxidation of organic matter occurs.
- The sludge formed is removed by settling or filtration. A part of the sludge is reused and the rest is used as fertilizer.
- The residual water is chlorinated to remove bacteria and finally discharged into running water or used for watering plants. The activated sludge process operates at 90-95 % efficiency of BOD treatment.

4. (a) What are the sources, effects and control of mercury pollution? (04 Marks) (CO4, L2)
Solution:

Mercury: Sources: Thermometers, Mercury Vapour Lamp, Batteries
Ill effects:
- ❖ Effects of mercury can result in complex neurological problems, especially in young children and babies.
- ❖ Affect the brain and nervous system, potentially leading to cerebral palsy, delayed onset of walking or talking, learning disabilities.

Control:
- ❖ Promote the use of clean energy sources.
- ❖ Eliminate mercury mining and recycle mercury,
- ❖ Alternative gold extraction method

(b) Describe ion exchange method for softening of water? How do you regenerate the resin in this method? (06 Marks) (CO4, L3)
**Solution:**

Water softening is the process of reducing the dissolved salts of Ca, Mg and Fe in water, thus reducing the hardness of water and making it soft.
In this method, softening of water is done by exchanging the ions causing hardness of water with desired ions from an ion exchange resin.
Ion exchange resin is a cross-linked organic polymer having some ionisable group. It may be of two types depending upon the nature of the ionisable group.

1. **Cation exchange resin or cation exchanger:** These resins have acidic group as the ionisable group such as $-SO_3H$, $-COOH$, $-H_2PO_3$ group. These resins contains replaceable hydrogen (H+) ion and they exchange cationic portion of salts with H+.
2. **Anion exchange resin or anion exchanger:** These resins have basic group which are capable of exchanging their OH- group with the anion present in water. They have group like $-NH_2$, $-NHCH_3$, $-OH$ groups.

Process: In this process cations and anions are packed in separate column. Hard water is first passed through cation exchange resin where cations like Ca^{2+}, Mg^{2+} are removed from hard water by exchanging H+ ions as follows.

$$RH + M^+ \longrightarrow RM + H^+$$
$$2RH + M^{2+} \longrightarrow R_2M + 2H^+$$
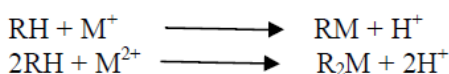
Where R is part of resin, M+ is monovalent ion like Na+ and M2+ is divalent ion like Ca2+, Mg2+.

The cation free water is passed through another tank having anion exchanger, which absorbs all the ions present in water and leave behind the water molecules.

$$ROH + X^- \longrightarrow RX + OH^-$$
$$2ROH + X^{2-} \longrightarrow R_2X + 2OH^-$$
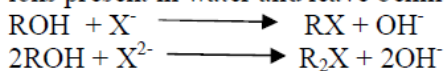
Where X- and X2- represent the anion such as Cl^-, NO_3^-, SO_4^{2-}
Thus the cation and anion impurities in water are replaced by an equal number of H^+ and OH^- ions respectively.
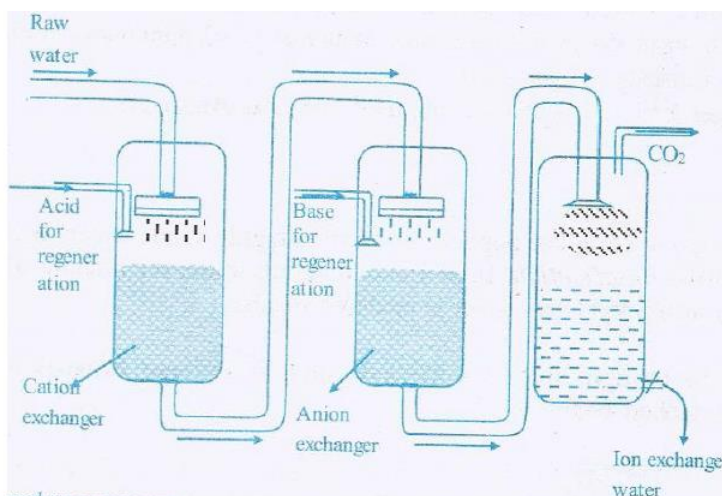

Regeneration of spent catalyst: After some time when the resins are exhausted and loose their capacity to exchange ions, they need to be regenerated again. Regeneration is the reversal of the reaction taking place for ion exchange.
The cation exchange resin is regenerated by flushing it with hydrochloric acid

$$RM + H^+ \longrightarrow RH + M^+$$

$$R_2M + 2H^+ \longrightarrow 2RH + M^{2+}$$
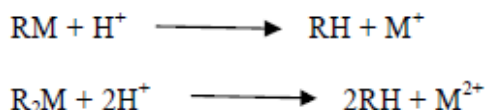
The anion exchange resin is regenerated by reacting it with sodium hydroxide.

$$RX + OH^- \longrightarrow ROH + X^-$$

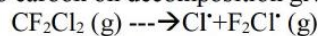$$R_2X + 2OH^- \longrightarrow 2ROH + X^{2-}$$
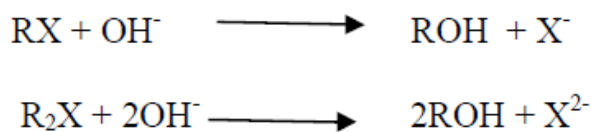
5. (a) Write a note on ozone depletion.   (04 Marks) (CO4, L2)
Solution:

Destruction or depletion of Ozone Layer:
A Chloro Flouro carbon on decomposition gives Chlorine free radical

$$CF_2Cl_2 \text{ (g)} \dashrightarrow Cl^{\bullet} + F_2Cl^{\bullet} \text{ (g)}$$

i) The chlorine radical then react with stratospheric ozone to form chlorine monoxide radicals and molecular oxygen. $Cl^{\bullet} \text{ (g)} + O_3 \text{ (g)} \rightarrow ClO \bullet \text{ (g)} + O_2 \text{ (g)}$

ii) Reaction of chlorine monoxide radical with atomic oxygen produces more chlorine radicals. $ClO^{\bullet} \text{ (g)} + O \text{ (g)} \rightarrow Cl\bullet \text{ (g)} + O_2 \text{ (g)}$

(iii) The chlorine radicals are continuously regenerated and cause the breakdown of ozone. Thus, CFCs are transporting agents for continuously generating chlorine radicals into the stratosphere and damaging the ozone layer

Coolants, Aerosols, and Refrigerators are main source for ChloroFluro carbons

Effects of depletion of ozone layer:
- With the depletion of ozone layer, more uv radiation filters into the troposphere. uv radiations lead to ageing of skin, cataract, sunburn, skin cancer, killing of many phytoplankton's, damage to fish productivity etc.
- The plant protein gets easily affected which leads to the harmful mutation of cells, increase in uv radiations damage paints and fibers, causing them to fade faster.

Control of ozone depletion:
Ozone depletion can be controlled by using hydro chloro fluoro carbons and hydro fluoro alkanes in place of CFCs. These contain more hydrogen in their molecule and undergo oxidation readily.
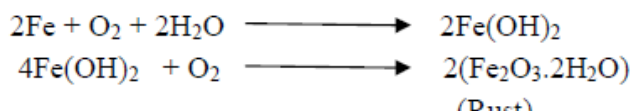
(b) Discuss the boiler corrosion and its control. (06 Marks) (CO4, L2)
**Solution:**

Boiler Corrosion: It is the most serious problem created by the use of unsuitable water in boiler. It is largely due to presence of

- Dissolved Oxygen
- Dissolved CO_2
- Acid from the dissolved salts

1. **Corrosion due to Dissolved Oxygen:** When water containing O_2 is heated (350-450 °C)in the boiler, the free gas is evolved under high pressure of the boiler and attacks the boiler material and forms rust.

$$2Fe + O_2 + 2H_2O \longrightarrow 2Fe(OH)_2$$
$$4Fe(OH)_2 + O_2 \longrightarrow 2(Fe_2O_3.2H_2O)$$
$$(Rust)$$

$$Fe(OH)_2 + O_2 \longrightarrow 2(Fe_2O_3. 2H_2O)$$

2. **Corrosion due to CO_2:** CO2 is present in the water either from the airor due to the presence of temporary hardness.

$$Mg(HCO_3)_2 \longrightarrow Mg(OH)_2 + 2CO_2$$
$$Ca(HCO_3)_2 \longrightarrow CaCO_3 + CO_2 + H_2O$$
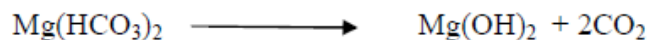
It dissolves in water to produce carbonic acid which is slightly acidic in nature and cause corrosion.

$$H_2O + CO_2 \longrightarrow H_2CO_3$$

Control of boiler corrosion: It can be controlled by removing O_2, CO_2, or any impurities from the feed water.

1. Removal of O_2:

1. First it is removed by deaeration. Removal of dissolved gases from boiler feed water is called deaeration. Several types of deaerator are available for this purpose.
2. Deoxygenation can also be carried by using chemicals such O_2 scavangers to the boiling water.

   - In low pressure boilers, the removal of oxygen is effected by adding a 3-5% solution of sodium sulphite to boiling water.

     $$2 Na_2SO_3 + O_2 \longrightarrow 2Na_2SO_4$$

   - In High pressure boilers the removal of oxygen is done by treatment with a very small amount of hydrazine.

     $$N_2H_4 + O_2 \longrightarrow N_2 + 2H_2O$$

     The reaction is complete in a few seconds and no trace of hydrazine remains as it is completely converted into nitrogen.

2. Removal of CO_2:

1. Mechanical removal can be done by deaeration.
2. Chemical removal can be done by treating with lime or NH_4OH

   $$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$
   $$2NH_4OH + CO_2 \longrightarrow (NH_4)_2CO_3 + H_2O$$

3. Removal of acidic impurities: Finally acidic impurities can be removed by treatment of water with alkaline NH_4OH.

$$MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2 + 2HCl$$

This acid reacts with iron to form rust.

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2$$
$$FeCl_2 + 2H_2O \longrightarrow Fe(OH)_2 + 2HCl$$

6. (a) What are the causes, effects and disposal methods of solid waste? (05 Marks) (CO4, L2).
Solution:

PROBLEMS OF SOLID WASTE: Groundwater Contamination, Production of Landfill Gas , Landfill fires, Offensive odours, Pests (Vermin, seagulls, flies)
DISPOSAL OF WASTE TO LANDFILL
- Waste is placed in layers approximately 3 m thick and compacted.

- At the end of each working day approximately 0.3 m of clay or sand material is placed on top of the waste to minimize the infiltration of rainwater and isolate the waste from birds and vermin, reduce odours.

Control:
- Minimizing solid waste
- Minimizing packaging
- Recyclable: Paper, plastics, metals, glass, wood
- Reusable: Textiles, leather, rubber, metals, wood
- Compostable: Yard trimmings, food scraps (vegetable)

Composting: Composting is a natural biological process, carried out under controlled aerobic conditions (requires oxygen). In this process, various microorganisms, including bacteria and fungi, break down organic matter into simpler substances. The effectiveness of the composting process is dependent upon the environmental conditions present within the composting system i.e. oxygen, temperature, moisture, material disturbance, organic matter and the size and activity of microbial populations

The three R's – **reduce**, **reuse** and **recycle** – all help to cut down on the amount of waste we throw away. They conserve natural resources, landfill space and energy. Plus, the three R's save land and money communities must use to dispose of waste in landfills.

(b) Explain the determination of sulfate by gravimetric method. (05 Marks) (CO4, L3).

Solution:

Gravimetric method: Sulphate is a substance that occurs naturally in drinking water. High levels of sulphate in drinking water can be detrimental to human health.

Reagents: BaCl2 solution, Conc. HCl, saturated bromine solution.

Procedure:

1. Pipette out 200 ml of the filtered water in a 400ml beaker. Add 3 ml bromine solution and 1 ml of HCl mix, and boil until all the bromine has been driven off. Make up the volume to 200ml by adding boiling water.

2. Add 10 ml of BaCl2 drop by drop while stirring the contents of the beaker continuously. Boil the contents for 2 min, then place the beaker on a water bath for 2 hours and stir the contents occasionally, allow the precipitate to settle.

$SO_4^{2-} + BaCl_2 \longrightarrow BaSO_4 + Cl^-$

3. Filter off the precipitate using Whatmans No. 42 and transfer the ppt quantitatively on to the filter paper with a jet of warm water from a wash bottle. Wash the filter paper and ppt with small volumes of warm water until the filtrate is free from chlorides.

4. Place the filter paper and ppt in an ignited platinum crucible, incinerate the paper slowly , then increase the temperature and maintain around 600 degree Celsius until all carbon has burnt off. Cool the crucible in a dessicator to room temperature and determine the mass of the residue. (as BaSO4).

5. Water soluble sulphates content = (A*34.5*B)/5*2

7. (a) Describe Sources, effects and control of primary air pollutant hydrocarbons. (05 Marks) (CO4, L2)
Solution:

Hydrocarbons: Hydrocarbons are composed of hydrogen and carbon.
Sources
- From incomplete burning of fuel or evaporated from fuel supplies.
- Major source is automobiles, but some from industry

Ill effects:
- ❖ Hydrocarbons are carcinogenic, i.e., they cause cancer.

(b) What is boiler feed water? Explain the scale and sludge formation in boiler. Mention their ill effects.   (05 Marks) (CO4, L3)

Water is used in boiler for the generation of steam for industries and power houses. Water absorbs large amount of heat for a given rise in temperature and expands extensively as it evaporates to form steam. This steam carries huge amount of heat with it. These unique properties of water make it an ideal raw material for heating and power generating processes.

"A boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat. The water used in boiler is called the boiler feed water."

The steam generated should be pure and uncontaminated and may be used for diverse purpose such as power generation, space heating, process heating, drying etc.
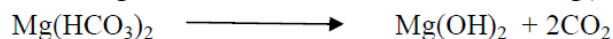
1. <u>**Scale and Sludge formation:**</u> water is heated under high temperature and high pressure inside the boiler. It gets evaporated to get steam and thus the impurities present in water get progressively concentrated, when impurities reach a saturation point it precipitates out.
    * If precipitate formed is hard, dense and adherent coating on the boiler surface, it is called as scale.
    * On the other hand if the ppt formed with in the boiler are soft, loose, greasy silky ppt, it is known as sludge.

<u>**Scales:**</u> These are hard deposits which stick to inner wall/surface of the boiler and are difficult to remove. The composition of boiler scales varies over a wide range. However they may be broadly classified into 3 types.

1. **Scales containing salts of Ca and Mg** such as $CaCO_3$, $CaSO_4$ etc. These scales are characterized by their names such as carbonate scale, sulphate scales etc.
    * Salt of Mg form scale due to the formation of $Mg(OH)_2$, which has low solubility.
      $$Mg(HCO_3)_2 \longrightarrow Mg(OH)_2 + 2CO_2$$
    * Calcium bicarbonate decomposed on heating produces calcium carbonate which has low solubility in water and hence forms scales

❖ They harm plants by causing ageing, breakdown of tissues and shedding of leaves and flowers
❖ Contribute to smog
$$Ca(HCO_3)_2 \longrightarrow CaCO_3 + CO_2 + H_2O$$
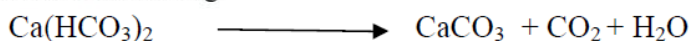
* Solubility of $CaSO_4$ decreases with increase in temperature. In boiler the temperature at the walls will be higher than in the interior. The $CaSO_4$ gets saturated in the water which is in contact with surface and it gets precipitated out in the form of scales.

2. **Scales containing ferrous and ferric compounds** such as oxides, carbonates and phosphates.
3. **Silicate Scales:** Silica react with Ca and Mg present in water to form silicates of calcium and magnesium. These silicates form hard and glassy scale on the inner surface of boiler.

Harmful effects of boiler scales:

1. **Wastage of fuel:** scales is a bad conductor of heat. It is like coating of insulating layer on metal surface. This leads to reduced rate of heat transfer and thus loss or wastage of fuel.
2. **Lowering of boiler efficiency:** Excessive scaling results clogging of boiler tubes or boiler parts may get chocked by deposition of scales. This may reduce the water circulation and thus efficiency of boiler.
3. **Boiler explosion:** Scales forms a coating on inner surface of boiler. On heating metal gets heated faster than scales as metal is a very good conductor of heat. This results in expansion of metal but scales do not expand much. Due to this, scales crack and water from inside the boiler comes in contact with hot metal and immediately forms steam. This steam exerts a pressure on the boiler wall which may crack under pressure and burst.
4. **Loss of strength of boiler:** Because of overheating boiler material gets softer and weaker and thus make boiler unsafe to use.
5. **Expanse of cleaning:** Cleaning process of scale is very much expensive.

8. (a) **Describe Sources, effects and control of primary air pollutant carbon monoxide. (05 Marks) (CO4, L2)**

Solution:

Carbon monoxide: carbon monoxide is one of the most serious air pollutants. It is a colorless and odorless gas, highly poisonous to living beings.

$CO_2 + 2C \longrightarrow 2CO$
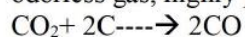
Sources:
- ❖ Incomplete combustion of carbonaceous matter, automobile engines & also in defective furnaces, incomplete combustion of fossil fuels, agricultural, slash matter and other carbon
- ❖ Dissociation of carbon dioxide.

Ill effects:
- ❖ Carbon monoxide is poisonous as it combines with hemoglobin of red blood cells about 300 times faster than O_2, thus forming carboxyl hemoglobin.
- ❖ This decreases the transport of oxygen to the body organs & cells.

Control:
- ❖ Implementing national fuel quality standards,
- ❖ Promoting alternative fuels, use of catalytic converter,
- ❖ Supporting the implementation of tighter vehicle emission standards.

(b) **Define COD. Explain the experimental determination of COD of industrial waste water. (05 Marks) (CO4, L3)**

Solution: Defination of COD:

The principle of the method is the oxidation of organic matter using chemical oxidizing agents such as acidified potassium dichromate in the presence of a catalyst such as silver sulphate (which catalyzes the oxidation of organic matter) and mercuric sulphate (which combines with chloride ions present in water thus preventing its interference).

A typical reaction representing the oxidation of organic matter is given below.

$$3CH_2O + 16H^+ + 2Cr_2O_7^{2-} \xrightarrow[\text{HgSO}_4]{\text{Ag}_2\text{SO}_4} 4Cr^{3+} + 3CO_2 + 11 H_2O$$
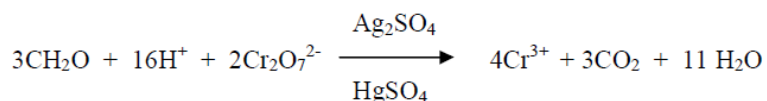
The method consists in adding excess of a standard solution of potassium dichromate acidified with sulphuric acid to a known volume of effluent sample and back titrating the excess of potassium dichromate against a standard solution of ferrous ammonium sulphate using ferroin indicator. COD values are also expressed in mg dm^{-3}

It is defined as the amount of O_2 consumed in the complete chemical oxidation of organic and inorganic wastes present in 1 litre of waste water by using strong oxidizing agent, such as acidified $K_2Cr_2O_7$.

Determination of COD:

Method: To a measured volume of waste water sample taken in a flask, add 10 cm^3 of std. $K_2Cr_2O_7$ solution followed by 30 cm^3 of 6N H_2SO_4. Add 1 g of Ag_2SO_4 followed by 1 g of Hg_2SO_4. Attach a reflux condenser and reflux the contents for 2 hours. Cool and titrate the excess unreacted $K_2Cr_2O_7$ against ferrous ammonium sulphate solution using ferroin as indicator till the bluish green colour turns sharply to reddish brown. Let the volume of FAS required be 'a' cm^3. Perform a blank titration without taking water sample. Let the volume of FAS required for blank titration be 'b' cm^3.

Calculations:

Volume of FAS required for the (reacted $K_2Cr_2O_7$) sample = b-a cm^3

Normality of FAS solution = N_{FAS}

Volume of waste water sample = V cm^3

Normality of water x vol. of water = Normality of FAS x vol. of FAS

$$\text{Normality of water sample} = \frac{\text{Normality of FAS x vol. of FAS}}{\text{Vol of water}}$$

$$= \frac{N \times (b\text{-}a)}{V}$$

$$\text{COD of the sample} = \frac{N \times (b\text{-}a) \times 8 \text{ g dm}^{-3}}{V}$$

$$= \frac{N \times (b\text{-}a) \times 8000 \text{ mg dm}^{-3}}{V}$$