

Solutions

CMR
INSTITUTE OF
TECHNOLOGY



Sub:	Engineering Chemistry				Code:	18CHE12			
Date:	10/12/2019	Duration:	90 mins	Marks:	50	Sem:	I	Branch:	All

Internal Assessment Test III

1. (a) Define COD. In a COD test 26.5 cm³ and 18.2 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: COD (Chemical Oxygen Demand): It is defined as the amount of oxygen required by microorganisms to oxidize the organic and inorganic wastes present in one litre of waste water using a strong oxidizing agent such as acidified K₂Cr₂O₇.

Given, V = 25 mL, b = 27.5cm³, a = 13.2 cm³, N_{FAS} = 0.05N

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

$$= 0.05 \times (26.5-18.2) \times 8000 / 25 = 132.8 \text{ mg of O}_2 / \text{dm}^3$$

(b) Describe the softening of water by ion exchange process. (05 Marks) (CO4, L4)

Solution:

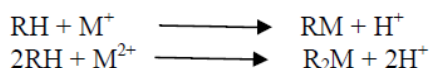
Water softening is the process of reducing the dissolved salts of Ca, Mg and Fe in water, thus reducing the hardness of water and making it soft.

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.

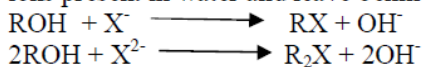
1. **Cation exchange resin or cation exchanger:** These resins have acidic group as the ionisable group such as -SO₃H, -COOH, -H₂PO₃ group. These resins contains replaceable hydrogen (H⁺) ion and they exchange cationic portion of salts with H⁺.
2. **Anion exchange resin or anion exchanger:** These resins have basic group which are capable of exchanging their OH⁻ group with the anion present in water. They have group like -NH₂, -NHCH₃, -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 Ca²⁺, Mg²⁺ are removed from hard water by exchanging H⁺ ions as follows.



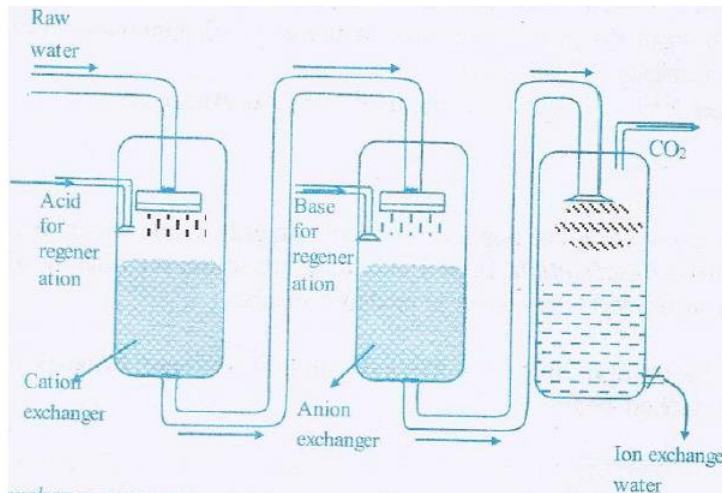
Where R is part of resin, M⁺ is monovalent ion like Na⁺ and M²⁺ is divalent ion like Ca²⁺, Mg²⁺.

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.



Where X⁻ and X²⁻ represent the anion such as Cl⁻, NO₃⁻, SO₄²⁻

Thus the cation and anion impurities in water are replaced by an equal number of H⁺ and OH⁻ ions respectively.

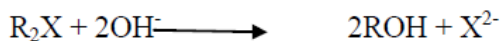


Regeneration of spent catalyst: After some time when the resins are exhausted and lose their capacity to exchange ions, they need to be regenerated again. Regeneration is the reversal of the reaction taking place for ion exchange.

The cation exchange resin is regenerated by flushing it with hydrochloric acid



The anion exchange resin is regenerated by reacting it with sodium hydroxide.



2. (a) Explain the scale and sludge formation in boiler. Mention their ill effects and prevention. (06 Marks) (CO1, L3)

Solution:

1. **Scale and Sludge formation:** 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.

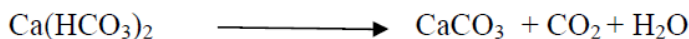
- If precipitate formed is hard, dense and adherent coating on the boiler surface, it is called as scale.
- On the other hand if the ppt formed within the boiler are soft, loose, greasy silky ppt, it is known as sludge.

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.



- Calcium bicarbonate decomposed on heating produces calcium carbonate which has low solubility in water and hence forms scales



- 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 choked 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. **Expense of cleaning:** Cleaning process of scale is very much expensive.

Removal of scales:

1. With the help of scapper or piece of wood, loosely adhering scale can be removed.
2. Brittle scale can be removed by thermal shock i.e. heating the boiler and suddenly cooling it with cold water.
3. By dissolving them by adding chemicals. For eg HCl is used for removal of CaCO_3 scale and EDTA is used for removal of CaSO_4 scales.

(b) Describe the sources, effects and control of mercury pollution? (04 Marks) (CO4, L4)

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

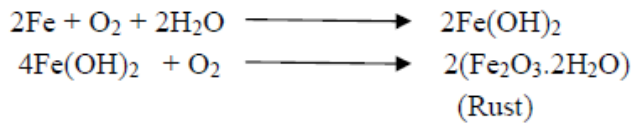
3. (a) Discuss the reactions involved in boiler corrosion and its prevention. (06 Marks)
(CO4, L2)

Solution:

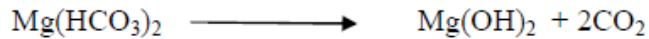
Boiler Corrosion: It is the most serious problem created by the use of unsuitable water in boiler. It is largely due to presence of

- Dissolved Oxygen
- Dissolved CO₂
- Acid from the dissolved salts

1. **Corrosion due to Dissolved Oxygen:** When water containing O₂ 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.



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



It dissolves in water to produce carbonic acid which is slightly acidic in nature and cause corrosion.



3. **Acids from the dissolved salts:** Minerals acids are produced by the hydrolysis of salts like MgCl₂, FeCl₂ present in boiler feed water.



This acid reacts with iron to form rust.



Control of boiler corrosion: It can be controlled by removing O₂, CO₂, or any impurities from the feed water.

1. Removal of O₂:

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 as O₂ scavengers 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.



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



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

2. Removal of CO₂:

1. Mechanical removal can be done by deaeration.
2. Chemical removal can be done by treating with lime or NH₄OH



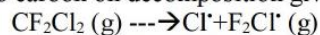
3. Removal of acidic impurities: Finally acidic impurities can be removed by treatment of water with alkaline NH₄OH.

(b) Discuss the mechanism of ozone depletion. Mention its ill effects and control. (04 Marks) (CO4, L2)

Solution:

Destruction or depletion of Ozone Layer:

A Chloro Fluoro carbon on decomposition gives Chlorine free radical



- i) The chlorine radical then react with stratospheric ozone to form chlorine monoxide radicals and molecular oxygen. $\text{Cl} \cdot (\text{g}) + \text{O}_3 (\text{g}) \rightarrow \text{ClO} \cdot (\text{g}) + \text{O}_2 (\text{g})$
- ii) Reaction of chlorine monoxide radical with atomic oxygen produces more chlorine radicals. $\text{ClO} \cdot (\text{g}) + \text{O} (\text{g}) \rightarrow \text{Cl} \cdot (\text{g}) + \text{O}_2 (\text{g})$

(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:

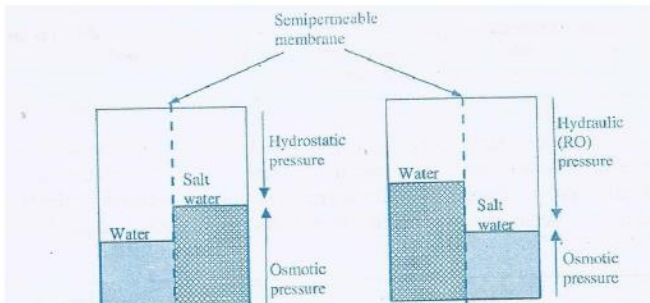
Ozone depletion can be controlled by using hydro chloro fluoro carbons and hydro fluoro alkanes in place of CFCs. These contain more hydrogen in their molecule and undergo oxidation readily.

4. (a) What is potable water? Describe the reverse osmosis process of water. Mention its advantages. (05 Marks) (CO4, L2)

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).



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.

A series of tubes made up of porous material is lined on the inside with extremely thin film of cellulose acetate semi-permeable membrane. These tubes are arranged in parallel array in fresh water.

Brackish water is pumped continuously at high pressure through these tubes. Water flows from brackish water into fresh water. The flow of water is proportional to applied pressure which in turn depends on the characteristics of the film. Greater the number of tubes, larger is the surface area and hence more production of fresh water. Concentrated brine and fresh water are withdrawn through their respective outlets.

Advantages:

1. The energy requirements are low.
2. Process is simple and continuous.
3. It involves no phase changes
4. Provides odorless, crystal clear water.
5. Easy to maintain

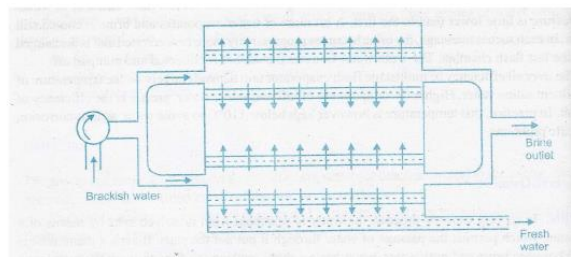


Fig: Reverse osmosis method of desalination

(b) 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 penetrate 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 is coated on circuit boards, cables, and PVC
- Copper cables and plastic coated computers release toxic dioxins and furan when burnt
- Flat screens contain mercury
- Old capacitors contain PCB

HEALTH HAZARDS OF E-WASTE

Solder Solder contains lead that damages the nervous system, blood system, kidney and also affects 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

When burnt 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

5. (a) Explain the determination of sulfate in water using gravimetric method. (05 Marks) (CO4, L3).

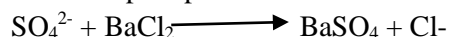
Solution:

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.



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 desiccator to room temperature and determine the mass of the residue. (as BaSO₄).
5. Water soluble sulphates content = $(W_2 - W_1) \times \frac{96}{233.3} \times 10^3$ ppm

(b) What are nano-materials? Explain the synthesis of nano-materials by precipitation method. (05 marks) (CO5, L4)

Solution: Nanomaterials: are nano-sized materials having atleast one physical dimension in the size range of 1-100 nm.

Precipitation method:

The method employs mixing of reagents to get an insoluble material as a precipitate. For preparation of nanosized particles by this method, the reagents to be mixed are introduced at critical supersaturation limit. For example, when AgNO_3 is mixed with NaCl , a precipitate of AgCl is formed. White BaSO_4 precipitate is formed when BaCl_2 is mixed with H_2SO_4 .

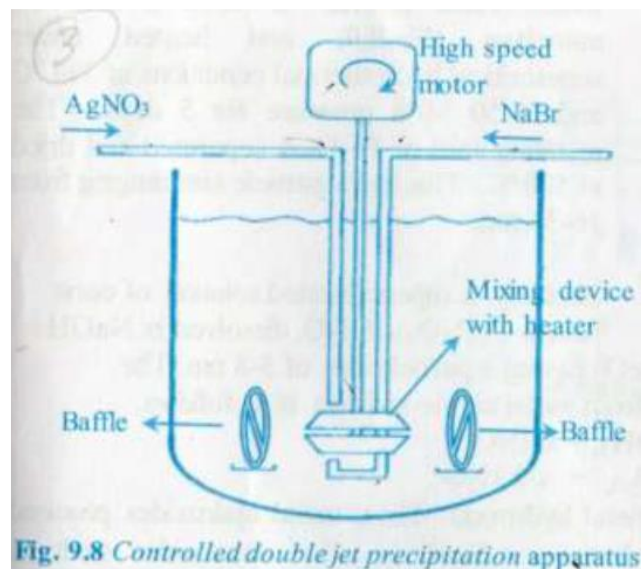
The process involves (i) nucleation and (ii) growth of nuclei to form a particle. During nucleation few molecules come together and aggregate to form several nuclei. In the growth phase, smaller precipitates dissolve and get deposited on the bigger ones. This is Ostwald's ripening.

Bulk precipitates of the size of μm to mm are generally formed when saturation concentration is reached and in absence of a controlled reaction. For nano-sized particles, the reagents are mixed at critical supersaturation limit, beyond which nucleation begins.

Preparation of nano-sized AgBr from AgNO_3 and NaBr solutions: A double jet precipitation apparatus is used to prepare nanoparticles of AgBr by solution precipitation using equimolar AgNO_3 and NaBr solutions. The apparatus allows to regulate particle concentration, temperature, rate of reagent addition and mode of mixing for the reaction.

The reagents are introduced through fine tubes into the apparatus in regulated pulses and a mixing device is used that is attached to a high speed motor shaft and rotates at controlled speed of 2000 rpm. The rate of reagent addition through fine tubes is controlled using a remote pump. One of the reagents (0.01 M AgNO_3) is introduced above the inlet zone of the mixing device, while NaBr (0.01 M) is added below. The solution concentration is kept high (> 0.5 M) and the temperature of the system maintained at 70°C . Baffles are present around the mixing device that inhibits the vertical rotation of the contents in the vessel.

At high rates of reagent addition, supersaturation is obtained at the introduction point leading to high nucleation rate for the particle formation. Supersaturation is relieved by stirring at regulated speed and the resulting emulsion will have particles of 7-60 nm AgBr . The use of capping agents and re-dispersion will stabilize the prepared nanoparticles.



6. (a) (Describe the activated sludge treatment of waste water with suitable diagram. (05 Marks) (CO4, L2)

Solution:

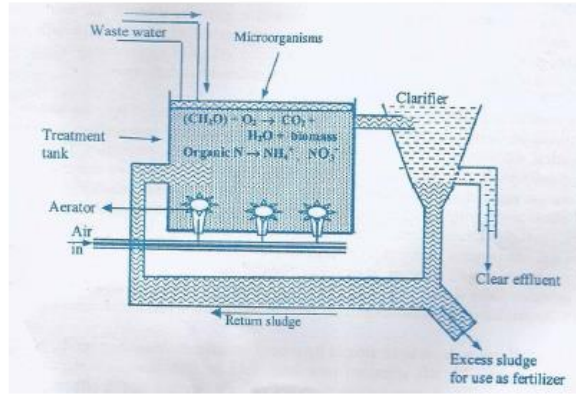


Fig. Activated sludge process

(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.

(b) Explain the synthesis of nanomaterials by Sol-gel technique. (05 Marks) (CO5, L4).

Solution:

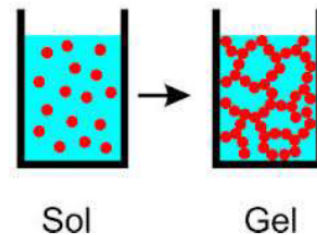
Sol-Gel:

This is a colloidal process in which dispersions have two phases, a dispersed phase with particles having colloidal dimensions ($< \mu\text{m}$) and a dispersion medium. The process can be used to obtain metal and metal oxide nanocrystals with controlled particle sizes.

Sols are solid particles formed by hydrolysis of metal precursors and are dispersed in the solution medium. The commonly used metal precursors are their (i) alkoxides $[M(\text{OR})_n]$ and (ii) salts (MX), and should have the tendency to form gels. Examples of $M(\text{OR})_n$, where $-\text{OR}$ is an alkoxide group, may be methoxides, ethoxides, propoxides of Al, Fe, Ti, Zn, and salts like FeCl_3 , MnCl_2 , AlCl_3 , $\text{Zn}(\text{NO}_3)_2$ etc.

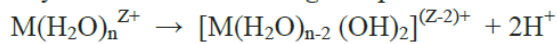
For nanomaterial synthesis, the process involves:

- Hydrolysis of precursors
- Condensation and polycondensation to form particles
- Allowing gelation to occur (ageing)
- Drying of gel to obtain solid material, followed by its sintering to form nanoparticles

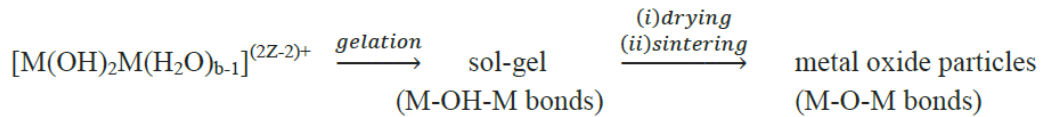
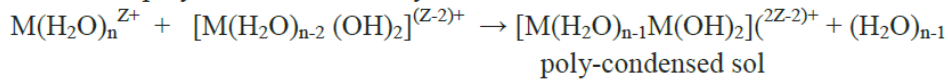


The important reactions in the process:

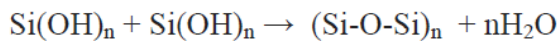
(i) Hydrolysis of metal salt through de-protonation



(ii) Condensation-polymerisation of the hydroxide intermediate



When an alkoxide is used, the important reactions are:



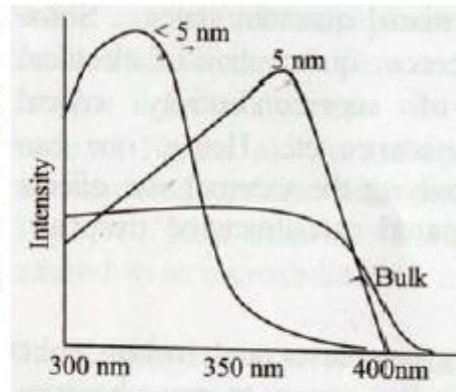
The material can be used to prepare nanocrystals, films and fibres.

7. (a) Discuss any three size dependent properties of nanomaterials. (06 marks) (CO5, L2)

Solution:

Catalytic activity: Nanomaterials have high surface to volume ratio and so exhibit good catalytic activity. For example, nano-structured metal clusters (Pd clusters) show improved catalytic properties for hydrogenation. Such clusters are integral part of cortex catalysts (heterogeneous type), where the active catalytic material is supported on solid oxide surface. These catalysts have improved life time and better catalytic activity.

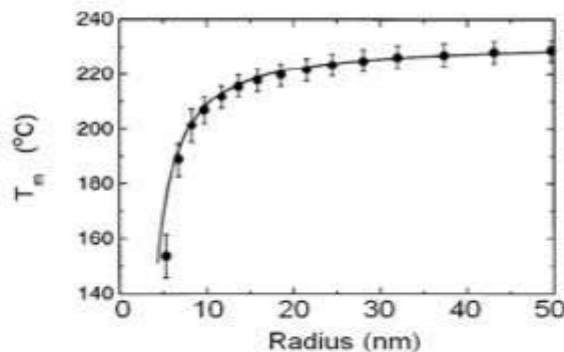
Optical properties: Optical properties are connected with the electronic structure. A change in crystal size brings about changes in electronic structure and bandgap (electrons are more restricted in movement in nano-sized particles) leading to changes in absorption or luminescence behaviour of the material. Example: Bulk gold appears yellow in colour, whereas nanosized Au appears red. In ZnO, the luminescence spectra shows blue-shift as particle size reduces. i.e. The wavelength of the emitted light shifts towards lower wavelengths.



(b)

Luminescence spectra of ZnO with change in

Thermal properties: As size decreases, the surface energy of the crystals increases and their melting point decreases. This occurs because, the surface atoms in nano-sized crystals are in contact with fewer atoms of the substance and so require less energy to diffuse. For example, 3 nm CdSe nanocrystals (NCs) melts at 700 K compared to bulk CdSe, whose melting point is 1678 K.



Variation in melting points with particle size for Sn particles

(b) Describe Sources, harmful effects and prevention of oxides of sulphur (SO_x). (04 Marks) (CO4, L2)

Solution:

Sources:

- ❖ Volcanic eruptions (natural activity) & also through combustion of sulphur bearing fuels such as coal & oil (human activity).
- ❖ This pollutant is also produced during roasting & smelting of sulphide ores (human activity)
- ❖ A part of SO₂ undergoes photolytic & catalytic oxidation to form SO₃. The SO₃, so formed gets converted to H₂SO₄ in the presence of moisture.

Ill effects of SO₂:

- ❖ It causes cough, shortness of breath & spasm of larynx, acute irritation to the membrane of gas resulting tears & reduces hearing ability.
- ❖ SO₂ irritates the respiratory system of animals & human, produces leaf injuries (called necrotic blotching) to broad leaved plants & gases. It also causes deterioration of fabric (cotton, rayon) paper & leather.
- ❖ The oxidation of Sulphur dioxide to Sulphur trioxide occurs which reacts with water to form Sulphuric acid
- ❖ Sulphuric acid causes stone leprosy.
- ❖ SO₂ pollution is responsible for smog formation.

Control:

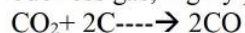
- ❖ The SO₂ emissions are controlled using a spray dryer absorber (SDA) flue gas desulfurization system.
- ❖ The calcium hydroxide in the atomized slurry reacts with the SO₂ in the flue gas to produce calcium sulfate and calcium sulfite.
- ❖ Use of alternative source of energy such as nuclear, hydro power, low Sulphur CNG, Natural gas
- ❖ Use of desulfurized coal
- ❖ Build tall smoke stacks.

8. (a) Explain the sources, harmful effects and prevention of following air pollutants

(i) Carbon monoxide (ii) Hydrocarbon (06 Marks) (CO4, L4)

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.



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 O₂, 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.

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.

- ❖ They harm plants by causing ageing, breakdown of tissues and shedding of leaves and flowers
- ❖ Contribute to smog

Control:

- ❖ Smokestacks with electrostatic precipitator
- ❖ Incineration, adsorption and absorption process

(b) Write a note on fullerene. Mention their properties and applications. (04 Marks) (CO5, L2)

Solution: Fullerenes are clusters made of carbon and are zero dimensional solids. They are allotropes of carbon with the formula C-60 and have 60 C atoms arranged spherically. They are also called Bucky balls and have truncated icosahedrons structure with 20 hexagonal and 12 pentagonal rings forming the symmetry.

Fullerenes have particle size of 2 nm, density of 1.65g/cm³ and sublimes at 800K. The carbon atoms are sp² hybridised, each carbon being bonded to three others in this material. Accordingly, there are two C-C bond lengths in fullerenes, the hexagonal bonds are shorter than pentagonal bonds.

They behave as soft electrophile and readily accept electrons during reactions. C60 structure can be easily hydrogenated, methylated and fluorinated. They form exohedral complexes in which an atom or group is attached to the outside of the cage, as well as endohedral complexes in which an atom is trapped inside the cage structure.

Synthesis: Fullerenes are prepared by creating an electric arc between two carbon or graphite electrodes in an inert gas atmosphere, when a black powder in the form of soot is produced. 10% of the soot is made up of C-60. They can be extracted from the soot by solvation in small amounts of toluene. After extraction, solvent is removed using a rotary evaporator, leaving behind a solid mixture of mostly C-60 with small amounts of larger fullerenes.

Bucky balls having more number of C atoms such as, 70, 76, 78, 84 etc arranged spherically have been isolated.

More properties:

- Superconductivity is discovered in alkali doped fullerites at moderately high temperatures.
- Superconducting critical temperature (T_c) of doped fullerites increases with curvature of fullerenes cages, i.e. as cluster size is reduced from C60 to C36, C28 and C20, their T_c increases.
- The index of refraction for fullerenes is 2.2 at 600 nm and they have a resistivity of 10¹⁴ Ω/m.
- They function as catalysts in organic reactions.



Buckminster Fullerene - C60