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I B.Tech. I Semester - Regular Examinations, December / January – 2025

Green Chemistry

SCHEME OF VALUATION

<table>
<tr><th>Q.No</th><th>Question</th></tr>
<tr><td>1.a)</td><td>

Ion exchange resin compartment diagram

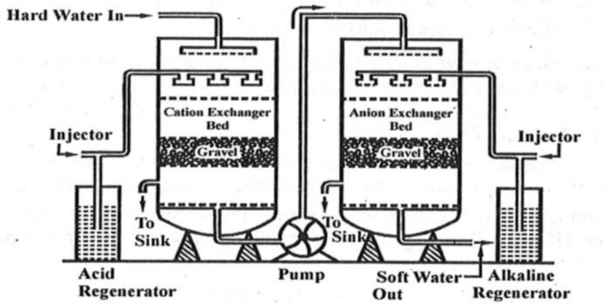

Fig. Demineralization of Water --->1M

- **Process:** The hard water is passed first through cation exchange column, which removes all the cations like (Ca^{2+}, Mg^{2+}, etc) and equivalent amount of H^+ ions are released from this column to water. Thus: -->3M

$$2RH^+ + Ca^{2+} \longrightarrow R_2Ca^{2+} + 2H^+$$

$$2RH^+ + Mg^{2+} \longrightarrow R_2Mg^{2+} + 2H^+$$

After cation exchange column, the hard water is passed through anion exchange column, which removes all the anions (like SO_4^{2-}, Cl^-, etc) and equivalent amount of OH^- ions are released from this column to water. Thus:

$$R'OH^- + Cl^- \longrightarrow R'Cl^- + OH^-$$

$$2R'OH^- + SO_4^{2-} \longrightarrow R'_2SO_4^{2-} + 2OH^-$$

$$2R'OH^- + CO_3^{2-} \longrightarrow R'_2CO_3^{2-} + 2OH^-$$

--------------------------------------->3M

H^+ and OH^- ions (released from cations exchange and anion exchange columns respectively) get combined to produce water molecule.

$$H^+ + OH^- \longrightarrow H_2O$$

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<tr><td>1.b)</td><td>

<u>**Chlorination**</u>: It is the process of adding chlorine to drinking water to kill bacteria and parasites. Itcan be done in three ways .------------------------------------->2M

By adding bleaching powder: 1kg of bleaching powder is added to 1000 kilolitres of water and water is kept undisturbed for several hours.

$$CaOCl_2 + H_2O \rightarrow Ca(OH)_2 + HCl$$

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

Breakpoint of chlorination definition .--->1M

When sufficient amount of chlorine is added then it gives residual chlorine.The point where residual chlorine is obtained called as break-point chlorination

Mechanism involved during additin of chlorine along with graph --------------------4M

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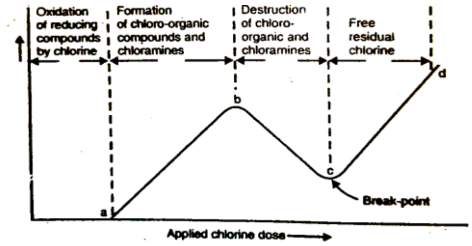
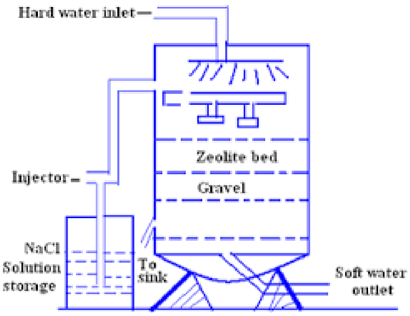
When we add chlorine to the water came from filtration it oxidises the impurities and increases the



percentage of derivatives of chlorine and ammonia.
Then we add some more amount of chlorine to water which decreases derivative percentage and pathogenic bacteria. When sufficient amount of chlorine is added then it gives residual chlorine.The point where residual chlorine is obtained called as break-point chlorination.

2.a) **Zeolite process diagram --->1M**



Process involved in Zeolite process --->2M
Process: For softening of water by zeolite process ,hard water is percolated at a specified rate through a bed of zeolite, kept in the cylinder.The hardness causing ions (Ca^{+2},Mg^{+2},etc..)are retained by zeolites as CaZe and MgZe ;while the outgoing water contains sodium salts
Reactions associated with Zeolite process -->2M

Mg(HCO3)2 + Na2X ------> MgX + 2NaHCO3

Na2Ze +CaCl2 (or CaSO4) ------> CaZe + 2NaCl (or Na2SO4)

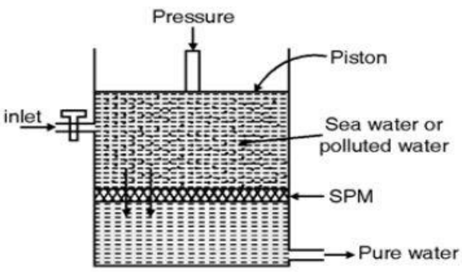
Na2Ze +MgCl2(or MgSO4) -----→ MgZe +2NaCl (or Mg2SO4)

Advantages -->1M

a)Removes hardenss and results water having hardness around 10 ppm
b) Doesn't produce any precipitate(therefore disposal of sludge won't be a problem)

Disadvantages:-->1M
a) Replaces cations only and leaves less acidic ions
b) Treated water contains more amount of sodium ions

2.b) **Reverse osmosis compartment diagram --->1M**



Mechanism involved in the Reverse osmosis process -------------------------------->4M
Reverse Osmosis:- Osmosis can be defined as flow of solvent from low concentration to high concentration solution through semi permeable membrane.

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- When we apply an excess and opposite hydro-static pressure to over come the osmotic pressure, then flow of solvent from high concentration to low concentration of solution. This is known as Reverse Osmosis.
- During the reverse osmosis , only the water flows across the membrane and it prevents the salt migration.

Advantages:-. -->1M

- Simple operational procedure.
- Low capital cost.

Disadvantages: -->1M

- It requires routine filter changes and maintenance..
- The process does not help in disinfecting the water. You will require a separate process to disinfect the water.

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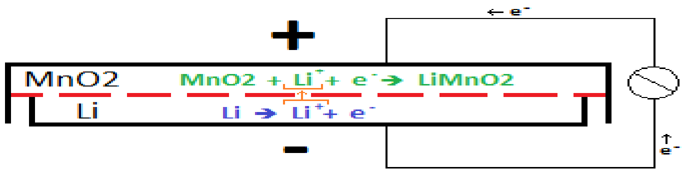
<tr><td>3. a)</td><td>

Construction of Li- MnO_2 --->2M
Lithium-Manganese Dioxide cells comprises of a metallic lithium anode and a hard solid manganese delivers the voltage of 3.0V and are cylindrical in shape.
Lithium is used as an ideal negative electrode as it offers lowest potential amongst other chemical elements therefore it is offering the highest cell voltage.
Diagram --->1M



Working mechanism of battery --->**3M**
Energy density is similar to that of the Li/SO_2 cells when discharged slowly and their slow self-discharge characteristic make them suitable for memory backup, watches, calculators, cameras, mines and munitions, etc.During the discharge process , the anode (Li) undergoes oxidation to release electrons and Lithium ions,While at cathode (MnO_2), Reduction reaction taking place and it gains electrons from anode through external circuit

It can be represented as follows-->**1M**

Reaction at anode : Li $\rightarrow Li^{+} + e^{-}$

Reaction at Cathode : $MnO_2 + e^{-} \rightarrow MnO^{-}_2$

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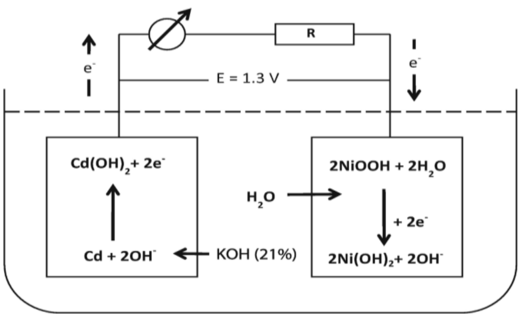
Nickel – Cadmium battery construction along with diagram----------------------->**2M**



Working mechanism of battery along with reactions -->**4M**
At anode : Oxidation reaction is taking place and it involves release of electrons from Cd and it can be represented as follows

$Cd + 2OH^{-} \rightarrow Cd(OH)_2 + 2e^{-}$

At cathode, Reduction reaction taking place and it involves gaining of electrons from anode through

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external circuit , and it can be represented as follows

$2NiO(OH) + 2\,H_2O + 2\,e^- \rightarrow 2\,Ni(OH)_2 + 2\,OH^-$

Net reaction,

$2NiO(OH) + Cd + 2\,H_2O \rightarrow 2\,Ni(OH)_2 + Cd(OH)_2$

Advantages and disadvantages of battery-->1M

- Compared to other secondary batteries these batteries having good life cycle and performance at low temperatures
- Cadmium metal is toxic to living organism

4.a)

Working principle of Zinc carbon battery-->4M
Reaction associated with the battery --->2M

In Leclanche battery cell, zinc is used as anode, manganese dioxide is used as cathode and ammonium chloride is used as main electrolyte but there is some percentage of zinc chloride in the electrolyte. During discharge, zinc anode involves in oxidation+ reaction and each zinc atom involved in this reaction releases two electrons.

$$Zn \rightarrow Zn^{2+} + 2e$$

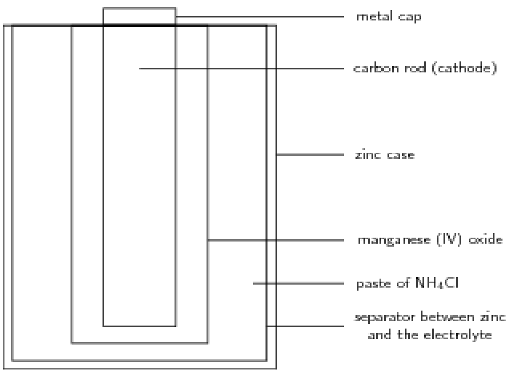
These electrons come to the cathode through external load circuit.
In Leclanche battery cell ammonium chloride (NH_4Cl) exists in electrolyte mixture as NH_4^+ and Cl^-.
In cathode MnO^2 will be reduced to Mn_2O_3 in reaction with ammonium ion (NH_4^+). In addition to Mn_2O_3 this reaction also produces ammonia (NH_3) and water (H_20).

$$2NH_4^+ + 2MnO_2 + 2e \rightarrow 2e + Mn_2O_3 + H_2O + 2NH_3$$

But during this chemical process some of ammonium ions (NH_4^+) are directly reduced by electrons and form gaseous ammonia (NH_3) and hydrogen(H_2).

$$2NH_4^+ + 2e \rightarrow 2NH_3 + H_2$$

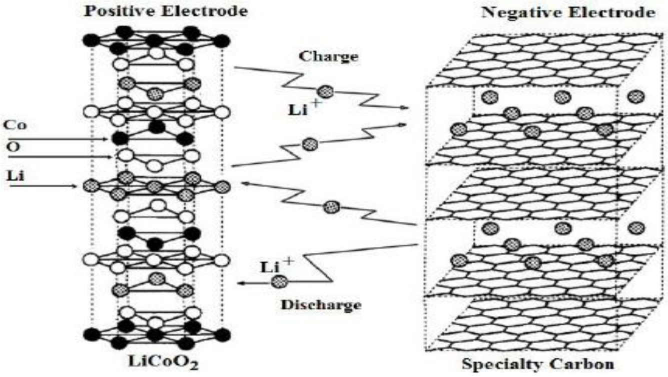
Diagram -->1M

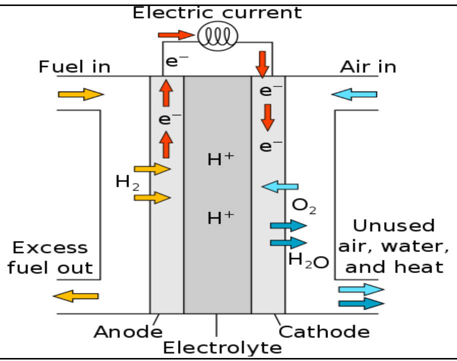


4.b)

Construction of Li- ion battery --->2M

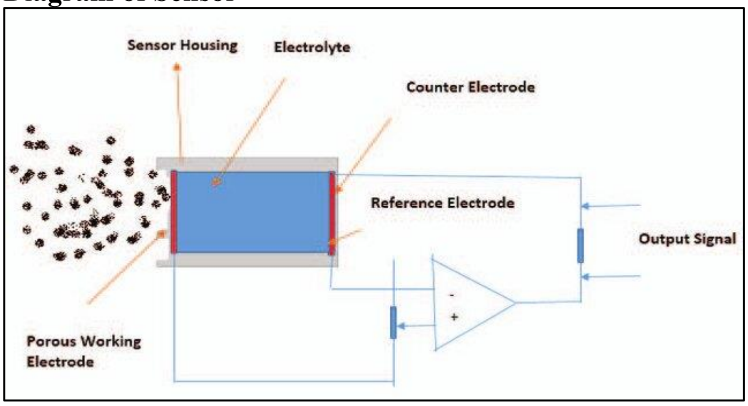
Construction: Li-ion uses liquid, gel or dry polymer electrolyte. The reactants in the electrochemical reactions in a lithium-ion cell are materials of anode and cathode, both of which are compounds containing lithium atoms. During discharge, an oxidation half-reaction at the anode produces positively charged lithium ions and negatively charged electrons.

	 **Working of the battery --->2M** **Reactions associated with the battery --->2M** During charging these reactions and transports go in the opposite direction: electrons move from the positive electrode to the negative electrode through the external circuit. Both electrodes allow lithium ions to move in and out of their structures with a process called *insertion* (*intercalation*) or *extraction* (*deintercalation*), respectively. The positive electrode (cathode) half-reaction in the lithium-doped cobalt oxide substrate is $CoO_2 + Li^+ + e^- \rightleftharpoons LiCoO_2$ The negative electrode (anode) half-reaction for the graphite is $LiC_6 \rightleftharpoons C_6 + Li^+ + e^-$ The full reaction (left to right: discharging, right to left: charging) being $LiC_6 + CoO_2 \rightleftharpoons C_6 + LiCoO_2$ **<u>Advantages</u> -->1M** • It has high rate of discharge • Light weight
5.a)	**Working mechanism of Proton Exchange membrane fuel cell------------------------->3M** **Cell reactions reactions associated with PEMFC-->2M** The protons formed at anode permeate through the polymer electrolyte membrane to the cathode side. The electrons travel along an external load circuit to the cathode side of the MEA, thus creating the current output of the fuel cell. Oxidation reaction at anode is as follows $2\ H_2 \rightarrow 4\ H^+ + 4e^-$ At the cathode: At the cathode side oxygen molecules react with the protons permeating through the polymer electrolyte membrane and the electrons arriving through the external circuit to form water molecules. This reduction half-cell reaction $O_2 + 4H^+ + 4\ e^- \rightarrow 2\ H_2O$ Unfortunately however, splitting the oxygen molecule is more difficult, and this causes significant electric losses. An appropriate catalyst material for this process is platinum/C or pt- alloy/C Overall reaction: $2H_2 + O_2 \rightarrow 2\ H_2O$ EMFCs are built out of membrane electrode assembly(MEA) which include the electrodes, electrolyte, catalyst, and gas diffusion layers. An ink of catalyst, carbon, and electrode are sprayed or painted onto the solid electrolyte and carbon paper is hot pressed on either side to protect the inside of the cell and also act as electrodes. Operating temperatures above 100 °C are desired.Therefore, electricity ,water along with heat was obtained **Diagram of PEMFC-->2 M**



5.b) **Working mechanism of Electrochemical sensor-->3M**
Reactions associated with it --->2M

When a chemically reactive gas, passes through the diffusion barrier or sensing electrode, it is either oxidized (accepts oxygen and/or gives up electrons) or reduced (gives up oxygen and/or accepts electrons) depending upon the gas.
This results in a potential difference between the two electrodes, this causes a current to flow.
For example if CO, a reducing gas diffuses to the sensing electrode, it is oxidized, thereby causing the potential of the sensing electrode to shift in a negative cathodic direction.
The cells chemical process is:
Sensing- electrode: $2CO + 2H_2O \longrightarrow 2CO_2 + 4H^+ + 4e^-$
Counter- electrode: $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$
Cell Reaction : $2CO + O_2 \longrightarrow 2CO_2$
Diagram of Sensor --->2M



6.a) **Advantages of fuel cell --->2M**

1.The product is drinking water, which can be used as drinking water.Therefore, it can be used in submarine and space vehicles

2.It doesn't causes environmental pollution

3.High current density

Disadvantages of fuel cell -->2M

1. Requires proper water management

2. Based on the requirements to work the fuel cell , the efficiency may low

3. It may causes catalytic poisoning

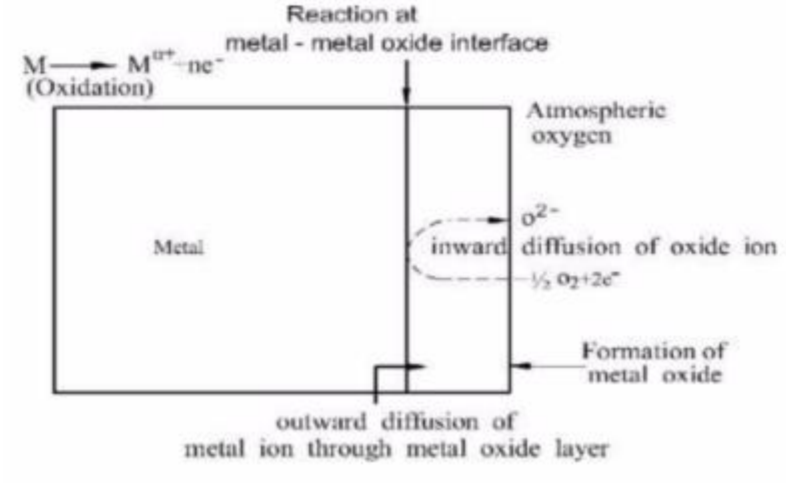
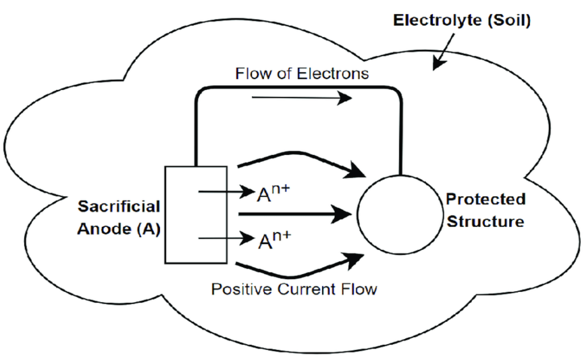
Environmental aspects of fuel cell -->2M

- Fuel cells have sparked considerable debate within the renewable energy community. While some argue that they offer a better alternative to batteries and solar power, others believe they may not be as sustainable as they appear. Let's take a closer look at the environmental advantages and disadvantages of fuel cell technology.

Fuel Cell Pros

- Fuel cells offer significant environmental benefits, primarily due to their lack of emissions—only water vapor and heat are produced when hydrogen and oxygen react. This contrasts with battery

	power, which often relies on fossil fuels. • Hydrogen and oxygen are abundant, ensuring that fuel cells won't deplete natural resources. **Fuel Cell Cons** • Extracting hydrogen from chemical bonds also requires energy, and if this energy comes from fossil fuels, hydrogen power isn't fully emissions-free. • Combining fuel cells with renewable energy sources like solar or wind for hydrogen production could eliminate emissions.
6.b)	**Construction of DMFC --->2M** It consists of anode ,cathode and electrolyte, while the electrolyte is placed in between anode and cathode . Left hand side electrode acts as anode , Right hand side electrode acts as cathode. The electrode consists Polymer electrode assembly, where the electrode consists of different types of layer to promote either reduction or oxidation reaction at electrode **Working of DMFC--->2M** **Reactions involving in DMFC-->1M** The DMFC relies upon the oxidation of methanol on a Platinum/Ruthenium catalyst layer to form carbon dioxide. Water is consumed at the anode and is produced at the cathode. Protons (H^+) are transported across the proton exchange membrane—often made from polymer—to the cathode where they react with oxygen to produce water. Electrons flow through the external circuit from anode to cathode , providing power to connected devices. Reaction at anode: $CH_3OH + H_2O \longrightarrow 6H^+ + 6e^- + CO_2$ Oxidation Reaction at cathode: $3/2O_2 + 6H^+ + 6e^- \longrightarrow 3H_2O$ Reduction Overall reaction: $CH_3OH + 3/2\ O_2 \longrightarrow 2H_2O + CO_2$ **Advantages and disadvantages of DMFC--->2M** • Methanol has low carbon content • The OH group is easily oxidisable • The need for water limits the energy density of the fuel • Cell efficiency is quite low
7.a)	**Effect of metal on corrosion -->3M**)Nature of metal and corroded product Position in galvanic series: ii)Relative areas of anodic and cathodic parts iii)Purity of metal:iv)Nature of surface film:v)Physical state of metal: vi)Passive character of metal vi)volatility of corrosion product: **Effect of environment on corrosion -->4M** **i**)**Temperature** ii) **Humidity of air** iii)**presence of impurities in atmosphere** iv)**P^H value of mediumv) Amount of oxygen in atmosphere**:
7.b)	**Definiton of dry corrosion -->1M** Oxidation Corrosion is brought about by the direct attack of oxygen at low or high temperature on metal surfaces in the absence of moisture **Diagram associated with it --->1M**

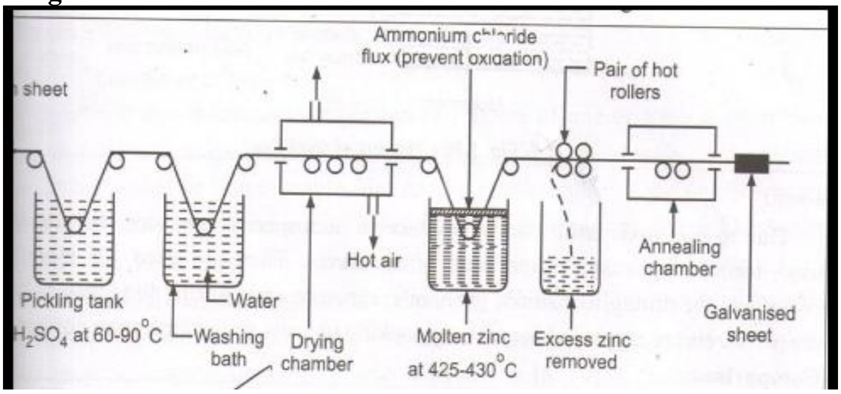
	 **Effect of nature of different metal oxides on corrosion -->5M** Oxidation Corrosion is brought about by the direct attack of oxygen at low or high temperature on metal surfaces in the absence of moisture. Alkali metals (Li, Na, K etc.,) and alkaline earth metals (Mg, Ca, Sn, etc.,) are rapidly oxidized at low temperature. At high temperature, almost all metals (except Ag, Au and Pt) are oxidized. The reactions of oxidation corrosion are as follows: Mechanism: 1)Oxidation takes place at the surface of the metal forming metal ions M^{+2} $M \rightarrow M^{+2} + 2e-$ 2)Oxygen is converted to oxide ion (O^{2-}) due to the transfer of electrons from metal. $1/2\ O2+ 2\ e- \rightarrow O^{2-}$ 3) The overall reaction is of oxide ion reacts with the metal ions to form metal oxide film. $M + 1/2\ O2 \rightarrow MO$ The Nature of the Oxide formed plays an important part in oxidation corrosion process. Metal + Oxygen→Metal oxide (corrosion product) When oxidation starts, a thin layer of oxide is formed on the metal surface and the nature of this film decides the further action. If the film is stable, unstable ,volatile and porous then the rate of corrosion will be effected
8.a)	**Cathodic protection -->2M** The technique of providing cathodic protection to steel preserves the metal by providing a highly active metal that can act as an anode and provide free electrons. By introducing these free electrons, the active metal sacrifices its ions and keeps the less active steel from corroding. **Principle of sacrificial anodic protection method with example -------------------------------->4M** In this method of protection ,the metallic structure to be protected called base metal, which is connected to more anodic metal (having high oxidation potential) through a wire. The anodic metal undergoes corrosion slowly , while the base metal is protected. The corroded sacrificial anode block is replaced by a fresh one. Commonly used anodic metal are Mg and Zn Diagram associated with sacrificial anodic protection method --------------------------------->1M 

8.b)

Hot dipping in galvanizing process --->3M

The base metal iron or steel sheet Is cleaned by acid pickling method with dilute sulphuric acid for 15-20 minutes at 60-90 ^{0} C .The sheet is then washed well and dried.It is dipped in a bath of molten zinc maintained at 425-450^{0} C .The surface of the bath is kept covered with ammonium chloride flux to prevent oxide formation.The sheet is taken out and excess zinc is removed by passing in between a pair of hot rollers.Then the sheet is subjected to annealing process at 650 ^{0} C and cooled slowly.An alloy of iron and zinc were formed at the junction of the base metal and coating meta

Diagram involved -->1M



Tinnig process --->3M

Coating of tin over iron is called tinning. In this process the surface of the base metal (iron sheet) is cleaned by acid pickling with dil. Sulphric acid and passed through a bath of zinc chloride flux. The flux helps the molten metal to adhere to the second metal surface .Then the sheet is passed through molten tin bath and pressed between the rollers .The rollers remove excess of tin and produce a thin film of uniform concentration

9.a)

12 principles of green chemistry --->7M

Reactants should have low toxicity, easily renewable, while the reaction should have low accidental potentiality,product easily degradable and should have low toxicity.Reaction should completed in an aqueous solvent, at room temperature in presence of catalyst with high atom economy with improving analytical technology

9.b)

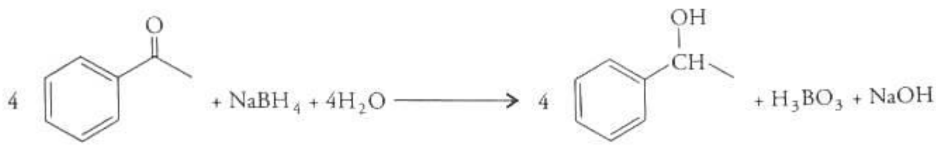
Atom economy definition --->1M

It states that “the need to incorporate maximum number of reactant molecules in product formation. Atom economy is a measure of the percentage of reactant leading to product formation. Most reactions have a yield of about 70-90 % remaining considered to be the wast

Formula --->1M

$$\text{Atom economy \%} = \frac{\text{Formula weight of the desired product}}{\text{Formula weight of all reactants}} \times 100$$

Example--->2M



Calculation for the reaction -->3M

Reagent formula	Reagent formula weight	Utilized atoms
C_8H_8O	120X4=480	C_8H_8O
$NaBH_4$	38	
H_2O	18	
TOTAL	590	122X4=488

10.a)

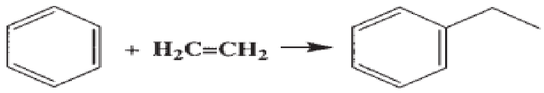
Zeolite significance structure with applications--->3M

Zeolite" is the broad term used to describe a family of minerals called tectosilicates. Zeolites are constructed of tetrahedral AlO4-5 and SiO4-4 molecules bound by oxygen atoms. Currently, there are 40 known natural zeolites and in excess of 140 synthetic zeolites. Zeolites can be custom made by manipulating the structure, silica-alumina ratio, pore size, and density. Other metals can also be incorporated into zeolites to obtain specific catalytic properties.

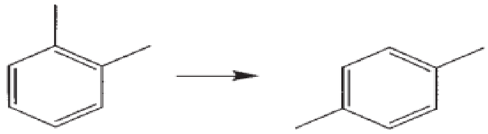
Other examples from zeolite are ZSM-5 and ZSM-11. The motivations for using zeolite catalysts are primarily profit and environmental regulation compliance with low operating cost.

A major application of the zeolites in catalysis is in acid catalyzed reactions such as alkylation,acylation, electrophilic aromatic substitution, cyclization, isomerization and condensation.

Industrial Process	Catalyst
(1) *Alkylation*	H-ZSM-5



(2) o-Xylene *isomerisation* to paraxylene	H-ZSM-5



Ion exchange resin significance ,structure along with applications ------------------------------->4M

IERs are insoluble, organic materials consisting of a polymeric, amorphous backbone with a hydrophobic character with evenly distributed hydrophilic functional groups. .These were prepared by free-radical cross-linking copolymerization of, for instance, styrene (ST) and divinylbenzene (DVB) monomers through suspension polymerization.Apart from water purification they are also useful in alkylation, acylation, hydration, condensation, oxidation or hydrogenation reactions

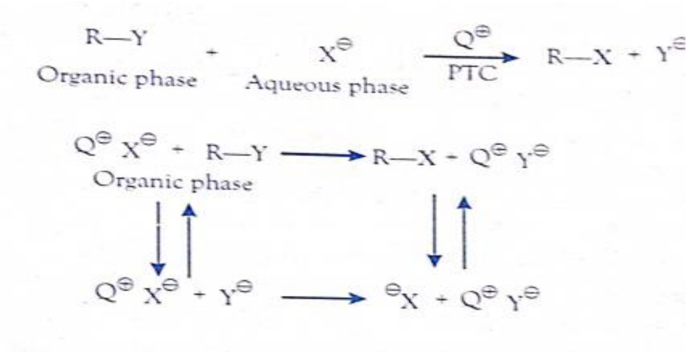
Ion-Exchange Resins Application to Hydrogenation Reactions

1.Hydrogenation of alkene, alkyne and aromatic arene using palladium supported ion exchange resin is as follows

10.b) **Phase transfer catalyst(PTC) definition -->2M**

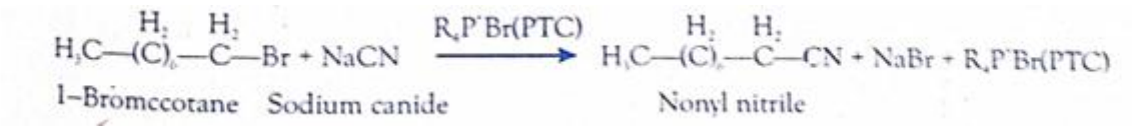
PTC significance -->2M

Aqueous and organic phase were not able to miscible with each other, i.e they were not participating in any reaction. In order to complete the reaction it requires a compound which was soluble in both organic and aqueous phase there by it produces a homegeneous solution while that compound is called "Phase transfer catalyst".



Explanation of PTC with the example --->3M

The nucleophilic aliphatic substitution reaction of an aqueous sodium cyanide(NaCN) solution with ethereal solution of 1 – bromo octane does not readily occur due to 1- bromo octane which is poorly soluble in the aqueous phase containing cyanide solution and the sodium cyanide does not dissolve well in the ether. Upon the addition of small amount of hexadecyltributylphosphonium bromide(PTC) a rapid reaction ensure to give nonyl nitrile.



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