Model Question Paper-2 with effect from 2021 (CBCS Scheme)

First Semester Engineering Degree Examination

Subject Title 21CHE12/22

TIME: 03 Hours **Max. Marks: 100**

Note: Answer any **FIVE** full questions, choosing at least **ONE** question from each **MODULE**.

		MODULE 1	Marks
Q.1	a	Define Single Electrode Potential. Obtain the expression for single electrode potential.	7
	b	What are ions Selective Electrodes? Explain construction and working of glass electrode	7
	c	Write briefly the recycling of Li-ion battery by direct recycling method	6
		OR	
Q.2	a	Explain the construction, working and applications of Li-ion batteries.	6
	b	Explain the experimental determination of P^H using glass	7
	c	Calculate the single electrode potential of Cu electrode at 27^oC when the standard potential of Cu is 0.34V and [Cu^{2+}] 0.1M	7
Q.3	a	Explain the following factors which affecting the rate of corrosion i) Ratio of anodic and cathodic areas ii) nature of corrosion product	7
	b	What is anodizing? Explain the process of anodizing of Al	6
	c	What is electroless plating? Distinguish between electro and electroless plating.	7
		OR	
Q.4	a	What is meant by metal finishing? Mention (any five) technological importance of metal finishing.	6
	b	A thick steel sheet of area 400 cm^2 is exposed to air near the ocean. After a one year period it was found to experience a weight loss 375 g due to corrosion. If the density of the brass is 7.9g/cm^2 calculate the corrosion penetrating rate in mpy and mm/y (given K= 534 in mpy and 87.6 in mm/y)	7
	c	What is cathodic protection? Explain sacrificial anode and impressed voltage methods of cahtodic protection	7
		MODULE 3	
Q.5	a	What are polymer composites? Explain the synthesis and application of Kevlar fibre	7
	b	What are conducting polymers? Explain the various factors influencing the conduction in organic polymers.	7
	c	Briefly explain the carbon nanotubes with properties and applications.	6

OR			
Q.6	a	Explain optical and electrical properties of nanomaterials.	7
	b	What are nanomaterials? Explain the synthesis of nanomaterials by precipitation method	6
	c	What are Biodegradable polymers? Explain the properties and applications of Polylactic acid.	7
MODULE 4			
Q.7	a	Briefly explain any six basic principles of green chemistry.	6
	b	Explain the following i) Phase transfer catalyst ii) Solvent free reaction	7
	c	With a neat diagram explain the production of Hydrogen by Photocatalytic method	7
OR			
Q.8	a	Describe the hydrogen production by photo electrocatalytic method.	7
	b	Explain the synthesis of Paracetamol by conventional and green route from phenol.	7
	c	Explain the construction and working of photovoltaic cells.	6
MODULE 5			
Q.9	a	Explain the theory, instrumentation and applications of flame photometry.	7
	b	Write the principles and requirement of titrimetric analysis.	7
	c	In a COD test, 30.5 cm^3 and 15.5 cm^3 of 0.05 N FAS solutions were consumed for blank & sample titration respectively. The volume of test sample used was 25 cm^3. Calculate the COD of the sample solution.	6
OR			
Q.10	a	Explain the determination of hardness by EDTA method.	7
	b	Define the following units of standard solution. i) Molarity ii) Normality iii) ppm	6
	c	Explain the theory and instrumentation of potentiometry.	7

Table showing the Bloom's Taxonomy Level, Course Outcome and Program Outcome

Question		Bloom's Taxonomy Level attached	Course Outcome	Program Outcome
Q.1	(a)	L1, L2	CO.1	PO-1,2,12
	(b)	L2	CO.1	PO-1.2,12
	(c)	L2	CO.1	PO-1,2,12
Q.2	(a)	L1	CO.1	PO-1,2,12
	(b)	L2	CO.1	PO1,2.12
	(c)	L3	CO.I	PO-1
Q.3	(a)	L2	CO.2	PO-1,2,12
	(b)	L2	CO.2	PO-1,2,12
	(c)	L2	CO.2	PO-1,2,12
Q.4	(a)	L1	CO.2	PO-1,2,12
	(b)	L2	CO.2	PO1
	(c)	L2	CO.2	PO-1,2,12
Q.5	(a)	L2	CO.3	PO-1,2,12
	(b)	L2	CO.3	PO-1,2,12
	(c)	L2	CO.3	PO-1,2,12
Q.6	(a)	L2	CO.3	PO1,2,12
	(b)	L2	CO.3	PO-1,2,12
	(c)	L2	CO.3	PO-1,2,12
Q.7	(a)	L2	CO.4	PO-1,2,12
	(b)	L2	CO.4	PO-1,2,12
	(c)	L2	CO.4	PO-1,2,12
Q.8	(a)	L2	CO.4	PO-1,2,12
	(b)	L2	CO.4	PO-1,2,12
	(c)	L2	CO.4	PO-1,2,12
Q.9	(a)	L2	CO.5	PO-1,2,12
	(b)	L2	CO.5	PO-1,2,12
	(c)	L3	CO.5	PO-1
Q.10	(a)	L2	CO.5	PO-1,2,12
	(b)	L2	CO.5	PO-1,2,12
	(c)	L2	CO.5	PO-1,2,12

Bloom's Taxonomy Levels	**Lower order thinking skills**		
	Remembering(knowledge):L_1	Understanding Comprehension): L_2	Applying (Application): L_3
	Higher order thinking skills		
	Analyzing (Analysis): L_4	Valuating (Evaluation): L_5	Creating (Synthesis): L_6

21CHE12 Prof. Sneha.S.K

AY: 2021-22

Department: Chemistry Model Qp Set : 2
Subject with Sub. Code: Engineering Chemistry (21CHE12/22) Semester / Division: ½ common to all
Name of Faculty: Prof. Sneha S Kulkarni

Q.No.	Solution and Scheme	Marks
	Module-1	
1a.	Define single electrode potential. Obtain the expression for single electrode potential	7M
→	Single electrode potential It is the potential developed at the interface of substance and its solution at unit activity of ionic species, at 298 K and at 1 atmospheric gas pressure it is a gas electrode.	1M
→	Expression for single electrode potential is derived by Nernst in 1889. It depends on 3 quantities — → a) System temperature → b) Electrode potential → c) Molar concentration of ionic species. Let the reversible reduction electrode reaction be; $M^{n+} + ne^- \rightleftharpoons M$ If this reaction is spontaneous, there is decrease in free energy of the system and is equal to maximum energy obtainable from the system.	1M

Q.No.	Solution and Scheme	Marks

$$-\Delta G = W_{max}$$

$$-\Delta G = nFE \quad \text{——— (1)}$$

where, 'n' is number of moles of electrons transferred during reaction.
'F' is one Faraday of electricity
'E' is electrode potential
ΔG is change in free energy
'nF' is number of columbs of charge that is transferred during the reaction.

For the reactants and products at unit activity, ΔG° (standard) is given as

$$-\Delta G^\circ = nFE^\circ \quad \text{——— (2)}$$ —1M

where, ΔG° = Standard change in free energy. E° = standard electrode potential

Change in free energy is related to equilibrium constant of the reaction, K_{eq} by Van't Hoff reaction isotherm

$$\Delta G = -RT\ln K_{eq} + RT\ln Q \quad \text{——— (3)}$$ —1M

where, Q is the reaction quotient, R is molar gas constant, T is the system temperature in Kelvin.

Also, standard change in free energy

$$\Delta G^\circ = -RT\ln K_{eq}$$

$$\therefore \Delta G = \Delta G^\circ + RT\ln\frac{[M]}{[M^{n+}]} \quad \text{——— (4)}$$

By definition, $[M] = 1$

Substitute ΔG and ΔG° in equation (4) gives

$$-nFE = -nFE^\circ + RT\ln\frac{1}{[M^{n+}]} \quad \text{——— (5)}$$ —1M

Q.No.	Solution and Scheme	Marks

Divide whole equation by $-nF$ (on both sides)

$$E = E^\circ - \frac{RT}{nF} \ln \frac{1}{[M^{n+}]} \quad \text{——(6)}$$

$$E = E^\circ + \frac{2.303RT}{nF} \log [M^{n+}] \quad \text{——(7)} \quad \text{——1M}$$

$$E = E^\circ + \frac{0.0591}{n} \log [M^{n+}] \quad \text{——(8)}$$

$R = 8.314\ J mol^{-1} K^{-1}$, $T = 298\ K$, $F = 96500$ columb mol^{-1}

Eqn 7 and 8 is the expression for single electrode potential.

1b. What are ion selective electrodes? Explain construction and working of glass electrode. —7M

→ Ion selective electrode

Electrode, which responds selectively to the presence of specific ions ignoring all other ions, is called ionselective electrode 1M

→ Construction

→ Coupled with external reference electrode through potentiometer and both electrodes together are immersed in test solution

→ HCl solution

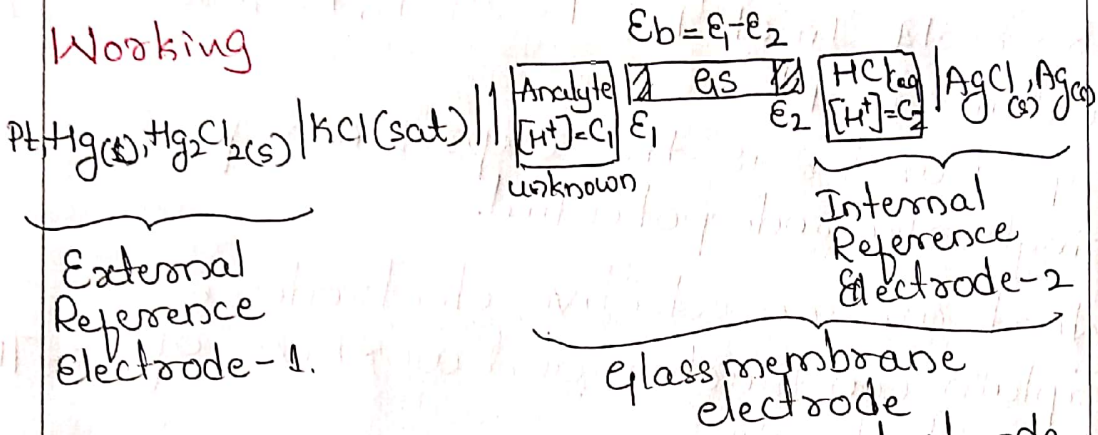
→ Ag-AgCl internal reference electrode

Q.No.	Solution and Scheme	Marks

A glass membrane electrode consists of a specially made glass membrane extending out as a bulb at the end of a plane glass tube containing Ag-AgCl electrode immersed in a solution of HCl. 1M

Composition of glass membrane is 6% CaO, 22% Na_2O and 72% SiO_2.

Working



1M

Very soon after immersion of electrode into analyte, an equilibrium is reached,

$$Na^+Gl^- + H^+ \rightleftharpoons H^+Gl^- + Na^+$$

H^+Gl^-, further dissociates to different magnitudes on two sides & results in development of boundary potential.

$$H^+Gl^- \rightleftharpoons H^+ + Gl^-$$

Boundary potential (from thermodynamic equation) is given by —

$$E_b = E_1 - E_2$$

$$= \frac{RT}{nF} \ln \frac{C_1}{C_2}$$

$$= \frac{2.303RT}{nF} \log \frac{C_1}{C_2}$$

$$= -0.0591 \log C_2 + 0.0591 \log C_1$$

1M

Q.No.	Solution and Scheme	Marks

$$E_b = L - 0.0591(-\log C_1)$$
$$= L - 0.0591(-\log[H^+])$$
$$= L - 0.0591\,pH$$

where, pH is referred to the pH of the test solution.

→ Glass membrane electrode potential

$$E_R = E_q = E_{Ref\text{-}2} + E_b + E_{asy}$$

where, E_{asy} is the asymmetric potential

$E_{asy} = E_b$ when $C_1 = C_2$

$$= E_{Ref2} + (L - 0.0591\,pH) + E_{asy}$$ 1M

$$= (E_{Ref2} + L + E_{asy}) - 0.0591\,pH$$

$$= E^\circ_q - 0.0591\,pH$$

where, $E^\circ_q = E_{Ref\text{-}2} - 0.0591 \log C_2 + E_{asy}$

$$= \text{constant.}$$

→ Cell potential is given by

$$E_{cell} = E_R - E_L$$ 1M

$$= E_q - E_{Ref\text{-}1}$$

$$= E^\circ_q - 0.0591\,pH - E_{Ref\text{-}1}$$

→ $$pH = \frac{E^\circ_q - E_{Ref\text{-}1} - E_{cell}}{0.0591}$$ 1M

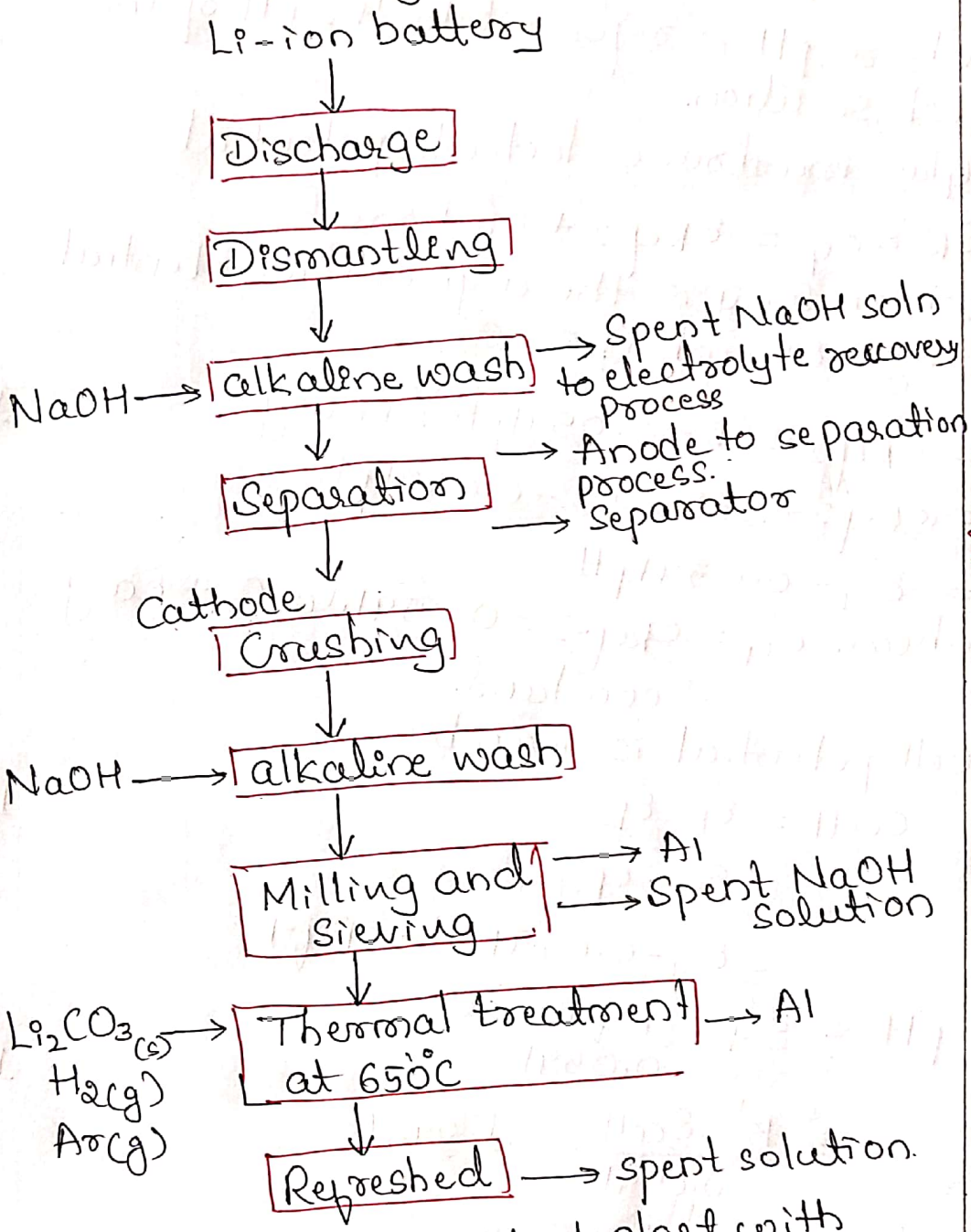
$$= \frac{K' - E_{cell}}{0.0591} \quad \text{at } 298\,K$$

→ $K' = 0.0591\,pH + E_{cell}$

K' is glass membrane electrode assembly constant.

Q.No.	Solution and Scheme	Marks
1c	Write briefly the recycling of Li-ion battery by direct recycling method.	6M

→ Direct recycling method

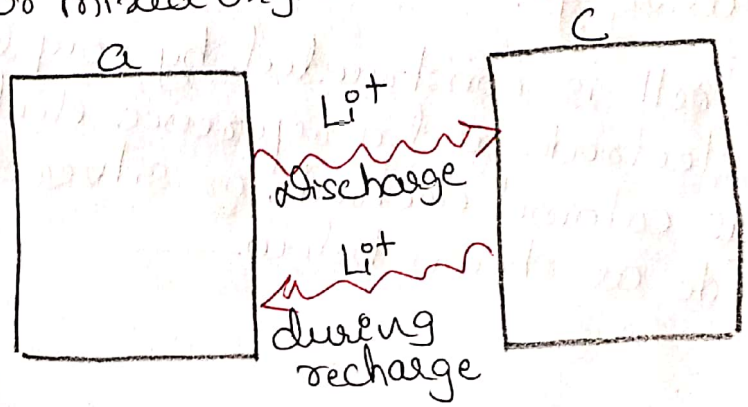


2M

Direct recycling method start with dismantling or shedding the cells. This step enables immediate recovery of the copper and aluminium foils as metals, while retaining their original compound structure.

2M

Q.No.	Solution and Scheme	Marks
	Al and Li could be recovered by leaching. After leaching with acid, the dissolved constituents can be separated from each other and reused to manufacture new cathode material.	
→	Advantages:	
1	Direct recycling of Li-ion is a promising cost effective process	
2.	Direct recycling are low temperature & low energy processes	2M
3	Do not require large scale and therfore could be used locally or for home scrap, avaiding the reused to manufacture new cathode material	
2a	Explain the construction, working and applications of Li-ion batteries	6M
	Li-ion battery	
	Construction	
	schematically represented as	
	Li_xC_6 | Li-salt (in mixed org. solvents) | $Li^+_{1-x}Co^{3+}_{1-x}Co^{4+}_xO_2$	
	However, actual construction refers	
	Cu,C_6 | $LiPF_6, LiBF_4, LiClO_4$ etc in org. solvent such as ether or mixed org. solvents | $LiCoO_2$, Al	1M



Q.No.	Solution and Scheme	Marks

→ Anode material:
Highly-crystallised specialty carbon

→ Cathodic material:
$LiCOO_2$ – Lithium cobalt oxide

→ Electrolyte : $LiPF_6$, $LiBF_4$, $LiClO_4$ mixed in org. solvents such as ether

→ Separator : Micro-porous polypropylene
This serves the purpose of an insulated separator between the electrodes and as electrolyte absorbent.

1M

Working:
Discharge
At anode: $C_6Li_x \rightleftharpoons C_6 + xLi^+ + xe^-$
At cathode: $Li^+_{1-x}Co^{3+}_{1-x}Co^{+4}_{x}O_2 + xLi^+ + xe^- \rightleftharpoons LiCoO_2$
Reactions in the backward direction occur during recharge.
Cell potential: 3.7V

2M

→ Applications
Used in calculators, cameras, cellular phones medical instruments, television sets, Laptop computers, camcorders etc

1M

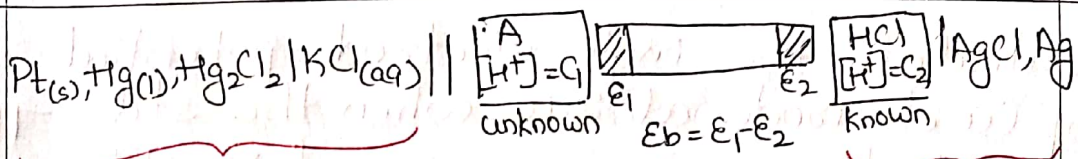
2b. Explain the experimental determination of pH of using glass

7M

A cell is constructed by coupling glass electrode and a reference electrode such as calomel electrode or silverchloride electrode as shown below——

P.T.O

Q.No.	Solution and Scheme	Marks



—1M

Cell potential is calculated as —

$$E_{cell} = E_R - E_L$$

$E_R = E_q$ (Right side electrode potential)

$= E^\circ_q - 0.0591\,pH$ at 298 K

where E°_q is constant

2M

Left side electrode potential $E_L = E_{Ref\,1}$

$$E_L = E_{Ref\,1} = E_{SCE}$$

2M

Cell potential $E_{cell} = E^\circ_q - 0.0591\,pH - E_{SCE}$

$$pH = \frac{E^\circ_q - E_{SCE} - E_{cell}}{0.0591}$$

$$pH = \frac{K' - E_{cell}}{0.0591} \text{ at } 298\,K$$

2M

K' is called glass electrode membrane assembly constant.

In this way the pH of the test solution is measured.

Q.No.	Solution and Scheme	Marks
2c	Calculate the single electrode potential of Cu electrode at 27°C when the std potential of Cu is 0.34V and $[Cu^{2+}]$ = 0.1M	1M
	Solution:	
	$T = 27° + 273 = 300K$	
	$E^{\circ}_{Cu} = 0.34V$ $\quad Cu \rightleftharpoons Cu^{2+} + 2e^-$	2M
	$[Cu^{2+}] = 0.1M$ $\quad n = 2$	
	$E_{Cu} = E^{\circ}_{Cu} + \frac{2.303RT}{nF} \log [Cu^{2+}]$	1M
	$= 0.34 + \frac{2.303 \times 8.314 \times 300}{2 \times 96500} \times \log [0.1]$	
	$= 0.34 + 0.0295 \cdot \log [0.1]$	3M
	$= 0.34 + (0.0295)(-1)$	
	$= 0.34 - 0.02955$	
	$\boxed{E_{Cu} = 0.31045V}$	
	Nernst equation is used.	
	$E = E^{\circ} + \frac{2.303RT}{nF} \log [M^{n+}]$	1M
	$R = 8.314$ $\quad E^{\circ} = 0.34V$	
	$n = 2$ ($\because Cu^{2+}$) $\quad [M^{n+}] = [Cu^{2+}]$	
	$F = 96500$ $\quad = 0.1M$	

Q.No.	Solution and Scheme	Marks

Module 2

3a. Explain the following factors which affecting rate of corrosion
i) Ratio of anodic and cathodic areas
ii) Nature of corrosion product — 7M

→ Ratio of anodic and cathodic area

→ Small anode and large cathode, the rate of corrosion increases $a \not< c$ — 1M

Ex: Steel tap and Brass tank

Steel tap acts as anode which is small compared to brass tank as it acts as cathode. — 1M

Here the corrosion is more aggressive and localised.

→ Large anode and small cathode, the rate of corrosion decreases. — 1M

Ex: Steel tank and brass tap

In the above example steel tank acts as large anode and brass tap acts as small cathode. It leads to decreased corrosion. $a > c$ — ½M

In this case, the corrosion is less aggressive and it is uniform.

→ Nature of corrosion product.

Some metals and alloys exhibit an inherent property of forming a protective coating of their compounds when exposed to different media. — 1M

Q.No.	Solution and Scheme	Marks
	When the corrosion product film over the object metal surface —— i) inert to the metal surface & medium ii) Continuous (non porous) iii) Adherent to the metal surface, it starts acting as barrier between the metal and medium. Further corrosion of the metal is prevented. This is known as passivation of metal. Ex: Mild steel – H_2SO_4 aluminium – fuming HNO_3 lead – dil. H_2SO_4.	2M ½M
3b	What is anodizing? Explain the process of anodizing of Al	6M
→	Anodizing It is a type of chemical conversion coating method of surface conversion coating method where surface metal atoms of the object are chemically converted into a protective, barrier material.	1
→	Process Aluminium article is made an anode in an electrolytic bath containing oxidizing agent such as chromic acid, sulphuric acid, phosphoric acid, boric acid oxalic acid etc.	

Q.No.	Solution and Scheme	Marks
	→ Cathode is made of lead or stainless steel or copper.	
	→ Moderate temperature and current densities are maintained to have better barrier material between the metal and medium.	2
	→ There is formation of aluminium oxide coating over aluminium, which grows in thickness with time.	
	$2Al + 3[O] \longrightarrow Al_2O_3 \downarrow$	1
	→ Outer, porous oxide film is made non-porous through "sealing process" by immersion into boiling water or metal salt solution. There is hydration of Al_2O_3 into $Al_2O_3 \cdot H_2O$, which will have expanded size and thus, seal the pores.	2
	→ It is only applicable for nonferrous metals.	
	Applications	
	→ Used for many design or architectural purposes	
	→ Used for making of window frames, soapboxes etc	
3c	What is electroplating? Distinguish between electro and electrolessplating.	7M
	The process of electrolytic deposition of a layer of metal onto conducting object surface. or	1M
	The process of deposition of a thin and uniform layer of a metal or metal alloy onto the electrically conducting object surface by electrolysis is known as electroplating.	

Q.No.	Solution and Scheme			Marks
	Property	Electroplating	Electroless plating	
1	Driving force	power supply	Autocatalytic redox reaction	
2.	Site of oxidation reaction	Separate anode	object surface to be coated	
3.	Site of reduction reaction	Object surface to be plated	surface activated object	
4	Oxidation Reaction	When anode is active $M \longrightarrow M^{n+} + ne^-$ When anode is inert $\frac{n}{2}H_2O \rightarrow nH^+ + \frac{n}{2}O_2 + ne^-$	$R \longrightarrow O + ne^-$ where R = Reducing agent O = Oxidized species	6M
5.	Reduction Reaction	$M^{n+} + ne^- \longrightarrow M$	$M^{n+} + ne^- \longrightarrow M$	
6.	Time taken for deposition	Short	Long	
7	Throwing power	Low	High	
8.	Plating cost	Low	High	
9	Nature of deposit	Pure metal or definite alloy, hard deposit	Usually metal contaminated with R or O derived species harder deposit.	
10	Features of deposit	May be porous & less corrosion resistant	Non porous, Relatively hard & more corrosion resistant.	

Q.No.	Solution and Scheme	Marks
4a	What is meant by metal finishing? Mention (any five) technological importance of metal finishing.	6M
	→ Metal finishing Process of surface modification by way of deposition of another metal or alloy or polymer or ceramic or oxide layer to bring about intended surface characteristics is known as metal finishing.	6M (5+1)
	→ Technological importance	
	i Better corrosion resistance	
	ii Better optical reflectance	
	iii Better hardness, strength, wear or abrasion resistance, impact resistance	
	iv Better electrical conductance or insulation	
	v Electroforming or reforming of articles	
	vi Electrotyping	
	vii Electrochemical machining, electropolishing and electrochemical etching	
	viii Manufacturing printed circuit boards, capacitors, contacts etc.	
4b	A thick steel sheet of area 400 cm^2 is exposed to air near the ocean. After a one year period it was found to experience a weight loss 375g due to corrosion. If the density of the brass is 7.9 g/cm^2 calculate the corrosion penetrating rate in mpy and mmly (given K = 534 in mpy and 87.6 in mmly)	7M

Q.No.	Solution and Scheme	Marks

To calculate CPR in mpy

	Given	CPR in mpy
K		534
W(wt loss)	375g	375 x 1000 mg
P	7.9 g/cm^3	7.9 g/cm^3
A	400 cm^2	400 x 0.155 inch^2
T	1 year	365 x 24 hrs
CPR	-	?

1M

$$CPR = \frac{K \times W}{D \times P \times A \times T}$$

$$= \frac{534 \times 375 \times 1000}{7.9 \times 400 \times 0.155 \times 365 \times 24}$$

2½

$$= \frac{200250000}{4290648}$$

$$= 46.6712 \text{ mpy}$$

To calculate CPR in mm/y

	Given	CPR in mm/y
K		87.6
W(wt loss)	375g	375 x 1000 mg
P	7.9 g/cm^3	7.9 g/cm^3
A	400 cm^2	400 cm^2
T	1 year	365 x 24 hrs
CPR		?

1M

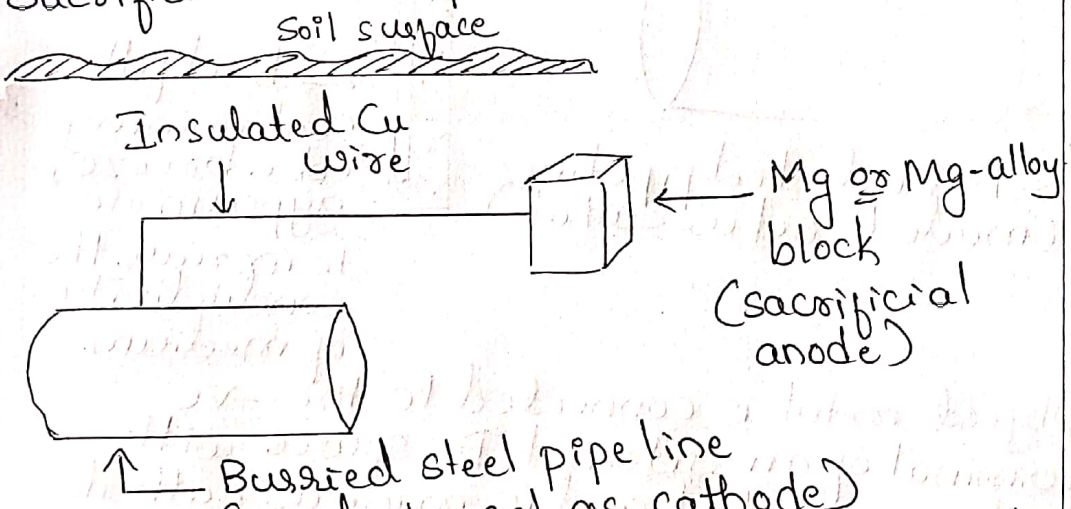
$$CPR = \frac{KW}{D \times P \times A \times T}$$

$$= \frac{87.6 \times 375 \times 1000}{7.9 \times 400 \times 365 \times 24}$$

2½

$$= 1.186 \text{ mmpy} \cong \text{mm/y}$$

Q.No.	Solution and Scheme	Marks
4c.	What is cathodic protection? Explain sacrificial anode and impressed voltage methods of cathodic protection	7M
→	Cathodic protection Metals undergo corrosion by oxidation or anodic reaction. They do not undergo corrosion or destruction by reduction or cathodic reaction. Therefore, they can be protected from corrosion if they are forced to act as cathode. Protection of the metal by forcefully making it to act as cathode is referred to as cathodic protection.	7M 3½
→	Sacrificial anodic protection method	



→ Object metal (such as steel) is connected to a block of an anodic metal such as Zn, Al Mg, or their alloys.

→ Whenever there is demand of electrons by the corrosives in the medium, anodic metal will sacrificially undergo oxidation & release the electrons. Thus the object metal is protected.

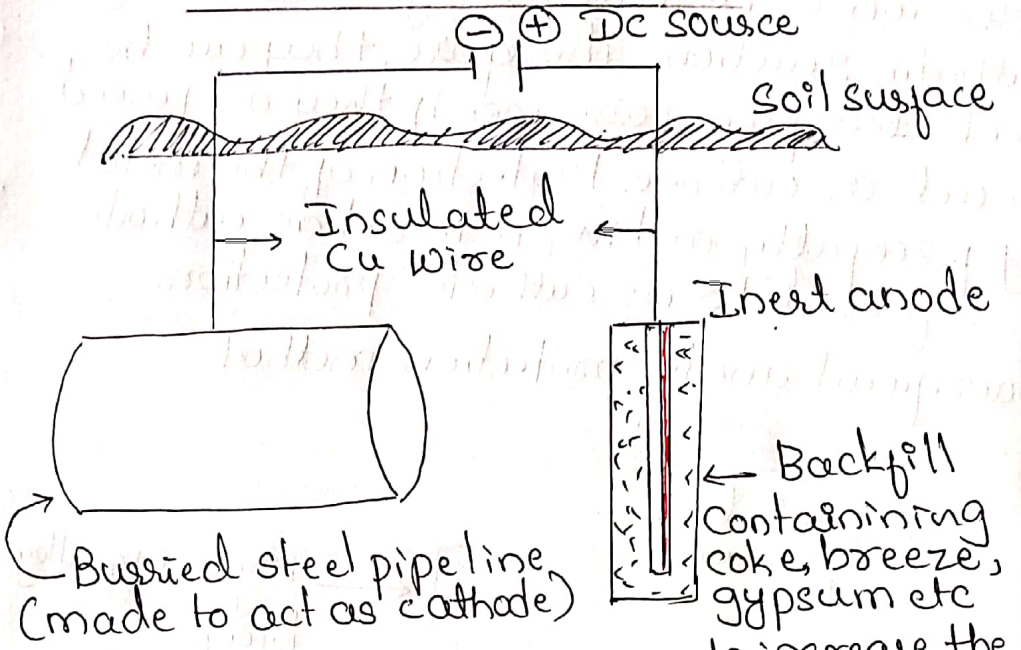
→ As long as anodic metal block is existent, protection is achieved. When it disappears fresh block is replaced.

Q.No.	Solution and Scheme	Marks

Applications

→ Employed for bussried pipelines used for water or oil, water tanks, ocean going ships, piers etc.

b) Impressed voltage (current) cathodic protection of metals.



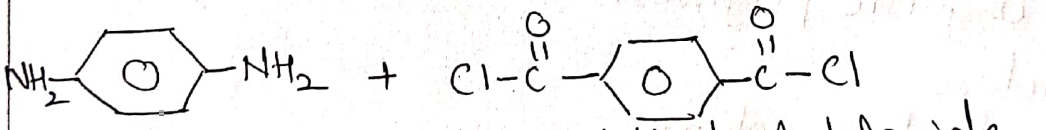
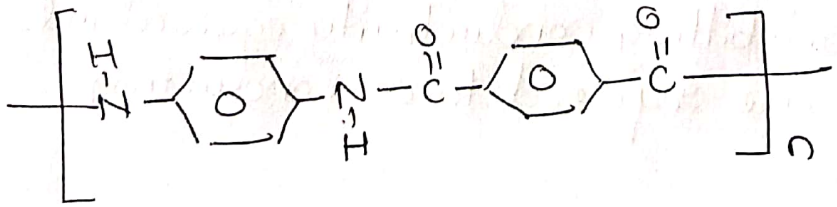
3½

→ Object metal is connected to the -ve terminal of an external DC source with higher potential and is made as cathode.

→ An inert anode such as graphite or platinum immersed in a backfill containing coke breeze gypsum etc. is connected to the positive terminal. Backfill is used to increase the conductivity.

→ Electrons are demanded by corrosive medium at the object surface, are supplied from the external battery and object metal is protected. As and when battery potential decreases, it is recharged.

→ Application: Employed for bussried pipe lines used for water or oil, ships etc.

Q.No.	Solution and Scheme	Marks
	Module - 3	
5a.	What are polymer composites? Explain the synthesis and applications of Kevlar fibre.	7M
→	Polymer composites Harmonius combination of two or more materials, at least one of them being a polymer and another being reinforcing material is refered to as polymer composite.	1M
→	Synthesis of Kevlar fibre. Kevlar is polyamide, in which all the amide groups are separated by paraphenylene groups. The chemical composition of Kevlar is polypara-phenylene terephthalamide.	3M
→	It is synthesized by reacting para-phenylene diamine with terephthloyl chloride with elimination HCl. It is condensation polymerization reaction.	
	 PPD terephthaloyl chloride (TDC) −HCl | condensation polymerization	1M
		

Q.No.	Solution and Scheme	Marks
	properties of Kevlar → High tensile strength at low weight → Low elongation to break → High modulus → Low electrical conductivity → High cut resistance → Flame resistant, high toughness Applications → Body armour: Bullet proof vests & helmets → Ropes & cables → Belts and hoses for industrial applications → Composites for aircraft body parts, boats and sporting goods. → Fibre-optic cables for communication, data transmission & ignition → Sailing motor cycle outer wear → Adhesives and sealants.	2M
5b.	What are conducting polymers? Explain the various factors influencing the conduction in organic polymers.	7M
	→ ~~Factors~~ → Conducting polymers Linear, organic polymers with conjugate single and double bonds with suitable doping by oxidation or reduction or proton etc. with delocalised π electron system, exhibiting conductivity equivalents of metals are referred to as conducting polymers.	1M
1	Effect of dopant	

Q.No.	Solution and Scheme	Marks
	It has been observed that conductivity is increases by doping. The conductivity of doped poly acetylene is comparable to that of copper on an equal weight basis. Doping is the oxidation or reduction of polymer molecules to yeild poly cations or polyanions. The kind of oxidative or reductive dopand, proton dopant, their proportion, solvent used in synthesis will all be the influencing the conductivity of the polymers to different levels. Some common oxidizing agents are $HClO_4$, $FeCl_3$, AsF_5, I_2, NH_4BF_4, SO_3CF_3, HCl, HNO_3 and some reductants are Li, K, Na etc.	3½
2.	Effect of Temperature The conductivity of semiconducting materials increases with rise in temperature because higher thermal excitation releases more of the electrons from inter atomic bonds. Under the applied electric field these higher numbers of electrons in the polymeric substance give rise to increased electronic conduction with rise in temperature.	3½
3.	Effect of Band gap The conductivity of conducting polymers increases with decrease in band gap. The band gap represents the amount of energy required to excite and promote an electron from the highest occupied energy level or valence band to the next empty band	

Q.No.	Solution and Scheme	Marks
	immediately above it. Metals have zero band gaps. Polymers have large band-gaps. and are insulators. Conducting polymers have lower band gaps. A band gap of ~1eV is reported for conducting polymers	
5c	Briefly explain the carbon nanotubes with properties and applications	6M
	Carbon nanotubes are allotropes of carbon with a cylindrical shape. They are nanoscale tube like structures, which are like nanowires, interms of aspect of ratio but unlike wires, tubes are hollow. Nano tubes may be single walled or multiwalled Carbon nanotubes, composed of interlocking carbon atoms, are 1000 times thinner than human hair and can be 100 times stronger than steel.	1M
	→ Properties CNT's have very high surface areas, aspect ratios and mechanical strength. The tensile strength of CNTs is nearly 100 times greater than when compared to steel. The electrical conductivity reaches that of copper and thermal conductivity reaches that of diamond.	2M
	Structures 1D C-C bond length : 1.42 A° Density : 1.2 - 2.0 g/cm^3 Electrical conductivity CNT with arm chair structure give good conductivity, zig-zag or chiral structure gives semi conductivity.	

Q.No.	Solution and Scheme	Marks

Thermal conductivity : Higher than diamond
Strength : Many fold stronger than steel
Hardness : Harder than diamond
Exhibit hydrophobic property and oil absorption property.

Applications

→ CNT's are used for reinforcing different structures where lightness and strength of materials required.

→ CNT's are used as hydrogen storage material for fuel cells and some secondary batteries — 3M

→ They catalyse many organic reactions.

→ Used for filtering air and water for purification purposes.

→ Functionalized CNT's are used as sensors and used for diagnosis and therapeutic applications.

6a. Explain optical and electrical properties of nanomaterials. — 7M

→ Optical properties

Nanomaterials have unique optical properties as a result of the way light interacts with their nanostructure. Due to interference, scattering, surface plasmons and quantum fluorescence.

Nanoparticles will have quantized energy states. Excitation or deexcitation of electrons from / to these discrete energy

Q.No.	Solution and Scheme	Marks
	states happens by certain definite wave length. Quantum confinement causes the energy gap to increase; therefore, more energy is needed. Higher energy means shorter wavelength (blue shift) or lower energy means longer wavelength (red shift). This is how one can control the size and shape of nanoparticles and control the color. Nanoparticles of metals exhibit surface plasmon resonance (SPR). when light strikes the nanoparticle, electrons on the surface start oscillating about their position in a small space and depending on the frequency of oscillation, resonating electrons absorb/scatter radiation of different wavelength.	3½
→	Electrical properties Substances can be classified as good conductors, semiconductors and insulators depending upon their electrical conductivity or resistivity. The energy gap between the valence band and conduction band and the presence and number of electrons in the conduction band decides the conductivity of the material. In a good conductor like a metal, there is overlapping of VB and CB i.e. valence band and conducting band. Larger the number of atoms in a bulk metal and overlapping of their orbitals results in overlapping of VB with CB and	

Q.No.	Solution and Scheme	Marks
	energy levels are continuous and the metals are very good conductors. Some metals which are good conductors become semiconductors or insulators as their size is reduced to nanoscale. When the number of atoms decreases like in a nanomaterial, very few orbitals overlap and the energy levels separate or become discontinuous. This is sometimes known as quantum confinement. Electrons do not find space to move around; instead they are confined to very small space or nanospace. Thus, with the increased discontinuity, nanomaterials tend to become semiconductors or insulators. Nanomaterials also show very interesting tunnelling effect. An electron is seen on the other side of the barrier without enough kinetic energy because of the wave property of the particles. Though, the intensity gets lowered. Also some of the nanostructures exhibit exceptional electrical conductivity like carbon nanotubes or graphene because of their unique structure.	3½
6b	What are nanomaterials? Explain the synthesis of nanomaterials by precipitation method.	6M
→	Nanomaterials. Nanomaterials are the materials having nanoscale dimension in at least one direction. Materials containing particles, in an unbound state or as an aggregate or as an agglomerate	1M

Q.No.	Solution and Scheme	Marks
	where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in size range 1nm to 100nm.	
→	Precipitation method This method relies on precipitation of nanosized particles within a continuous fluid solvent. An inorganic metal salt, such as chloride, nitrate and so on is dissolved in water. Metal cations exist in the form of metal hydrate species. Ex: $Al(H_2O)^{3+}$ The ppt is washed, dried & calcined. The typical example of synthesis of synthesis of CuO nanomaterials is explained as follows.	1M
→	Synthesis of CuO nanoparticles CuO nanoparticles were synthesized by aqueous precipitation method. using 55g of $CuSO_4$ penta hydrate mixed with 25g of hydroxyl ammonium chloride in 125mL distilled water. The mixture was allowed to cool in a cold water bath with swirling well and solution of 40g of NaOH in 750mL distilled water was added. The ppt was allowed to settle down and and supernatent liquid was poured off. The oxide is transfered to 250mL flask and the volume is made up. The content is washed by repeated decantation until the	4M

Q.No.	Solution and Scheme	Marks

rinsing is chloride free. The suction filteration is applied and residue is washed with 95% alcohol and ether. The residue is dried at 200-250°C in air oxidized conditions to obtain Cu_2O and then further the temp is increased to 300°C which leads to the formation of CuO. For the formation of Cu_2O nanoparticles from Cu_2O precipitant, the following reaction mechanism can be formulated and represented as ——

$$2CuSO_4 + 2NH_2OH\cdot HCl + 6NaOH \downarrow$$

$$Cu_2O + N_2 + 2NaCl + 2Na_2SO_4 + 7H_2O$$

$$Cu_2O \xrightarrow[\Delta]{300^\circ C} CuO$$

Advantages:

→ It is very simple and rapid method of precipitation of nanoparticles.

→ Particle size and crystallinity can be controlled by optimizing conditions.

6c What are biodegradable polymers? Explain the properties & applications of polylactic acid — 7M

→ Biodegradable polymers. — 1M

The polymers which breakdown after their intended use by microbial decomposition into biocompatible CO_2, nitrogen, methane, water, biomass and inorganic

Q.No.	Solution and Scheme	Marks
	Compounds are called as biodegradable polymers.	
	Properties of Polylactic acid	
→	Is an amorphous or crystalline thermoplastic polymer.	
→	Glass transition temperature, Tg = 60-65°C	
→	Melting point, MP = 130-180°C	3M
→	Soluble in ethyl acetate, propylene carbonate, pyridine, hot benzene, dioxane etc.	
→	Has high surface energy.	
→	Degrades on exposure to water, heat & light.	
	Applications	
→	PLA-based materials are employed for the biomedical, textile and packaging purposes	
→	Micro and nanoparticles are an important category of delivery systems used in medicine controlled drug delivery and fracture fixation devices like screws, resorbable sutures, plates, pins, rods, wires etc. and various molded articles.	3M
→	Porous PLA scaffolds have been found to be potential reconstruction matorces for damaged tissues & organs.	
→	Fibres for textile industry or sutures films and nonwoven textile for clothes.	
→	High surface-molded cups, spoons & forks, trays, paper coatings etc.	

Q.No.	Solution and Scheme	Marks
	Module-4	
7a	Briefly explain any six basic principles of green chemistry.	6M

1. Better to prevent than Cure

Design chemical synthesis to prevent waste. Leave no waste or treat or clean up. Waste prevention is necessary because of the following reasons.

→ If a process produces waste, it invokes the need for its treatment / disposal which in turn amounts to additional expenditure. 1

→ Secondly if the waste is toxic or hazardous the release of waste into the environment leads to its pollution which further invokes the need for treatment causing additional expenses.

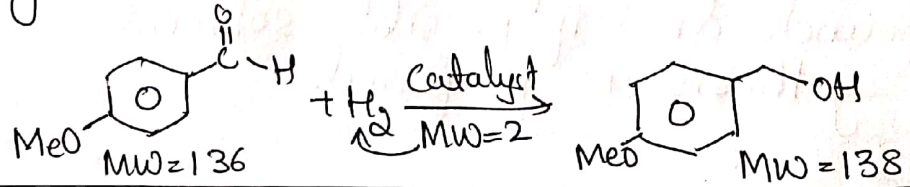
Ex: The bottom ash of thermal power station can be used as a raw material for cement and brick industry.

Effluent coming out from cleaning of machinery parts may be used as coolant water in thermal powerstations.

2. Atom economy

Design, synthesize so that the final product contains the maximum proportion of starting materials. 1

Ex: The % Atom economy of the reaction given below is _____



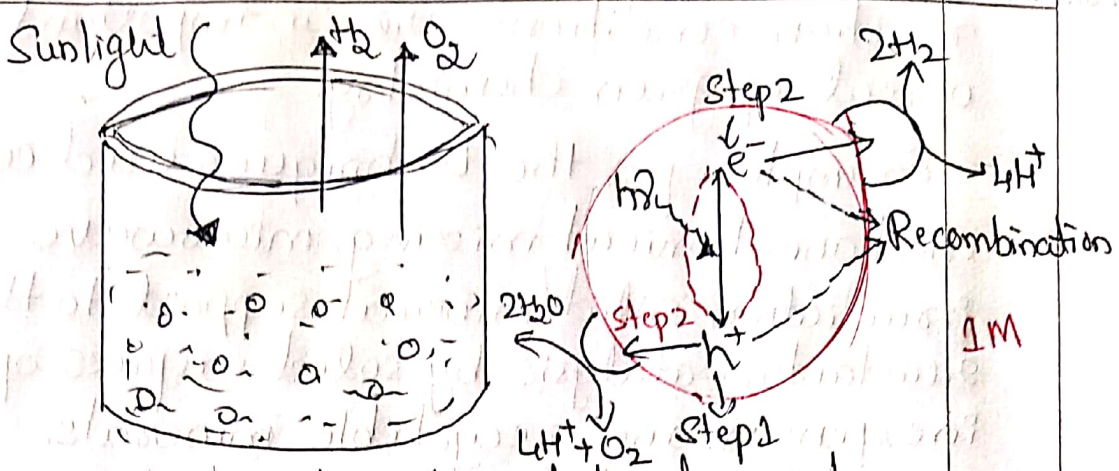
Q.No.	Solution and Scheme	Marks
	% Atom Economy = $\frac{\text{Relative MW of desired product}}{\text{Relative MW of all reactants}} \times 100$	
	$= \frac{138}{(136+2)} \times 100$	
	$= 100\%$	1
3.	Less hazardous chemical synthesis Design, synthesize to use and generate substances with little or no toxicity to either humans or the environment. An important example of concerning the use of safe chemicals is the manufacture of polystyrene foam sheet packaging material where in chemist have replaced the use of hazardous CFC by CO_2 as the blooming agent.	
4.	Designing safer Chemicals. Design chemical products that are fully effective & have little or no toxicity. Ex: Benzene is the starting material for the synthesis of adipic acid. Benzene is carcinogenic & being VOC it pollutes the air.	1
5.	Use safer solvents and reaction conditions. Avoid using solvents, separation agents or other supporting chemicals. If you must use these chemicals; use safer ones. This principle aims to use green solvents in place of volatile halogenated compounds and if possible solvent free synthesis is preferred.	1

Q.No.	Solution and Scheme	Marks
6.	Design for energy efficiency Run chemical reactions at room temperature and pressure wherever possible. Most commonly used energy is thermal energy, which is not targetted direct at a bond or ongoing reaction instead most of the energy is wasted in heating up reactors, solvents & surrounding environment This problem is avoided by using alternative sources such as photochemical, microwave or ultrasound energy.	1
7b	Explain the following i) Phase transfer catalyst ii) Solvent free reactions	7M
→	Phase transfer catalytic Reactions A phase transfer catalyst or PTC is a catalyst that facilitates the migration of a reactant from one phase into another phase where reaction occurs.	1M
→	Ionic reactants are often soluble in an aqueous phase but insoluble in an organic phase in the absence of phase transfer catalyst.	2M
→	Types of PTC 1) Quaternary ammonium salts Ex: benzyltrimethyl ammonium chloride methyl capryl ammonium chloride 2) Organic phosphonium salts Ex: Hexadecyl tributyl phosphonium bromide	

Q.No.	Solution and Scheme	Marks
	Phase transfer catalysis refers to the acceleration of the reaction upon the addition of the phase transfer catalyst. $R\text{-}Cl_{(org)} + NaCN_{(aq)} \longrightarrow R\text{-}CN_{(org)} + NaCl_{(aq)}$ catalysed by PTC Example: Cyanation of alkyl chloride - a major way to produce nitriles. The alkyl chlorides are poorly soluble in aqueous cyanide solution & the sodium cyanide does not dissolve well in organic solvent. In the presence of suitable PTC a rapid reaction ensures the production of alkylnitrile. → Advantages 1. Elimination of organic solvents 2. high yields and purity of products 3. Simplicity of procedure 4. Low investment cost. 5. Minimization of industrial waste. 6. high reactivity & selectivity of the active species. b) Solvent free Reactions Avoiding organic solvents during the reactions in organic synthesis leads to clean, efficient and economical technology. Use of organic solvents is objectionable from the standpoint of environmental hazard. This is why solvent free	4M

Q.No.	Solution and Scheme	Marks
	reaction conditions are an important object of green chemistry. Examples for the techniques used are mechanochemical mixing, microwave irradiation solid/mineral support to the reactants, catalysis by solid surfaces of inexpensive and recyclable minerals. (Eg: alumina, silica, clay, doped clay surface)	
→	Advantages	
1	A wide variety of industrially important compounds and intermediates such as enones, imines, enamines and nitroalkenes have been prepared by this environmentally friendly solvent free approach.	
2.	In these reactions, the organic compounds adsorbed on the surface of inorganic oxides such as ammonia, silica, clay or doped supports absorb microwaves where as the solid support does not absorb or restrict their transmission.	
3	The bulk temperature is relatively low in such solvent free reactions.	
7c	With a neat diagram explain the production of hydrogen by photocatalytic method	7M
→	Hydrogen production by photocatalytic Reaction. Input: Photocatalytic particles, sunlight & water Output: Oxygen & hydrogen	

Q.No.	Solution and Scheme	Marks



1M

→ Splitting of water to get hydrogen by using a photocatalyst & using solar energy is called photocatalytic water splitting.

→ The light energy excites an electron (e^-) in the catalyst.

Thus produced hole (h^+) will react with neighbouring water molecule. 6M

$$H_2O(l) + [h\nu] + 2h^+ \longrightarrow 2H^+_{(aq)} + \tfrac{1}{2}O_{2(g)}$$

→ The H^+ ions combine to produce hydrogen at the surface of the co-catalyst.

$$2H^+ + 2e^- \longrightarrow H_{2(g)}$$

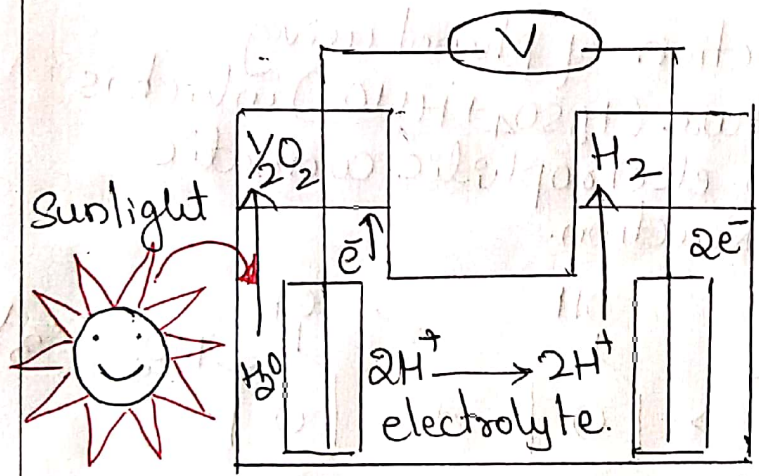
The produced hydrogen can be used as the fuel in the hydrogen fuel cell.

→ Here holes are oxidizing the waters & electrons reduces hydrogen ions to hydrogen gas.

8a. Describe the hydrogen production by photoelectrocatalytic method 7M

P.T.O

Q.No.	Solution and Scheme	Marks
→	H_2 production by photoelectrac catalytic water splitting Photoelectro (PEC) catalytic water splitting is artificial photosynthesis approaches for hydrogen fuel production. It involves photogenerated carriers on the surface and reactants adsorbed on the surface or in electrolyte. The reaction takes place at the electrode electrolyte interface. Input: Semiconductor photocatalyst (anode), sunlight, water Output: Hydrogen and Oxygen	3M

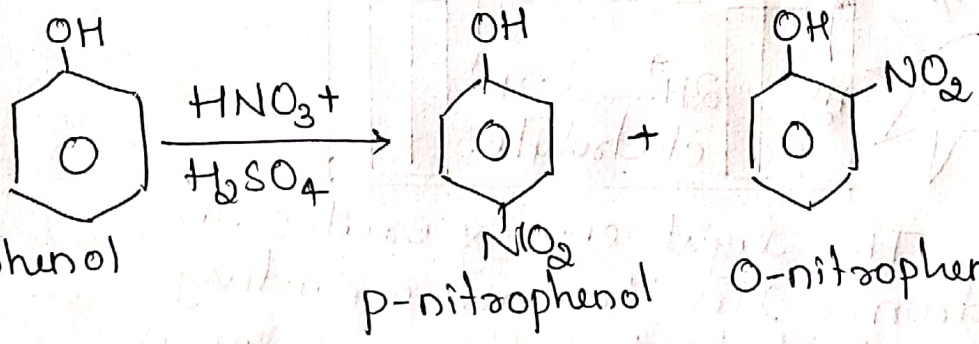


1M

The light energy excites an electron (e^-) in the semiconducting material (electrode). Thus produced hole (h^+) will react with the neighbouring H_2O molecule. 2M

$$H_2O + [h\nu] + 2h^+ + e^- \longrightarrow 2H^+ + \tfrac{1}{2}O_2 + e^-$$

P.T.O

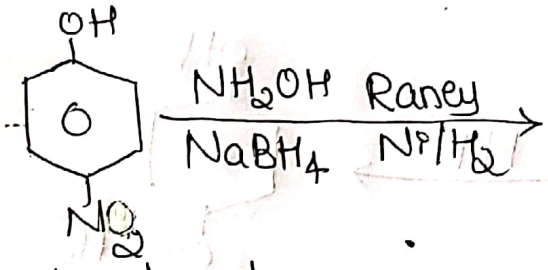
Q.No.	Solution and Scheme	Marks
	The H^+ ions formed will then bond with other proton and combine with two electrons to form H_2 gas $2H^+ + 2e^- \longrightarrow H_2(g)$ The produced H_2 gas can be used as the fuel in hydrogen fuel cell.	1M
8b	Explain synthesis of paracetamol by conventional and green route from phenol	7M
→	Synthesis of paracetamol by conventional route using phenol Step 1: Nitration reaction of phenol using nitrating mixture ($H_2SO_4 + HNO_3$) which is an example of electrophilic aromatic substitution Reaction.  phenol p-nitrophenol + O-nitrophenol p-nitrophenol is more stable than o-nitrophenol because of intermolecular hydrogen bonding. p-nitrophenol can be separated from o-nitrophenol by HPLC or column chromatography	3½

Q.No.	Solution and Scheme	Marks

Only p-nitrophenol is further used for synthesis of paracetamol.

Step II:

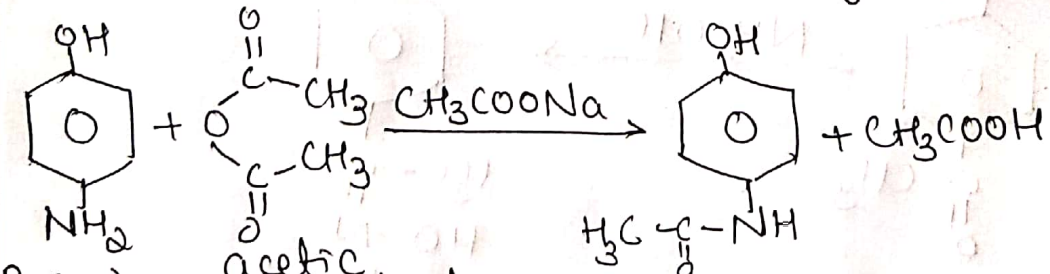
Reduction of nitro group ($-NO_2$) to amine group ($-NH_2$) using reducing agents such as sodium borohydride ($NaBH_4$), hydroxilamine (NH_2OH), metals in acidic medium (Sn/HCl) or Using Raney Ni in presence of $H_2(g)$



p-nitrophenol p-aminophenol

Step III:

Nucleophilic addition reaction of p-aminophenol with acetic anhydride in presence of sodium acetate. The N' atom (of NH_2) is more nucleophilic than the 'O' atom of (OH) & hence the reaction occurs with NH_2 group



p-amino-phenol acetic anhydride paracetamol

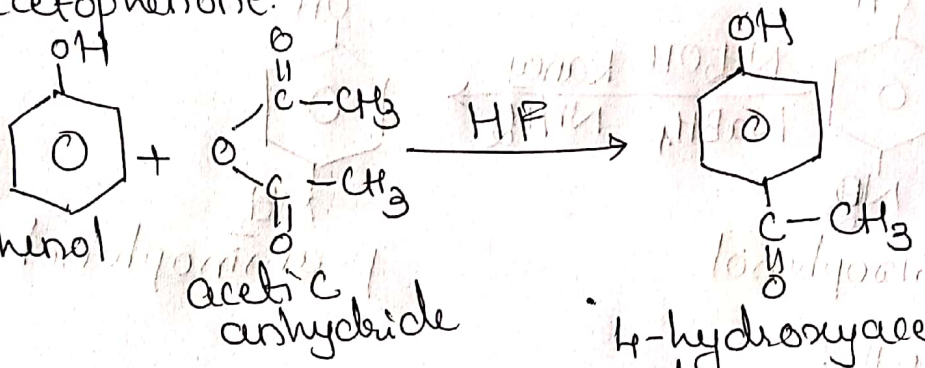
Q.No.	Solution and Scheme	Marks

The drawback of this method is the % atom economy calculated for this synthesis is ≅ 36 %.

→ Synthesis of paracetamol by Green Route

Step 1:

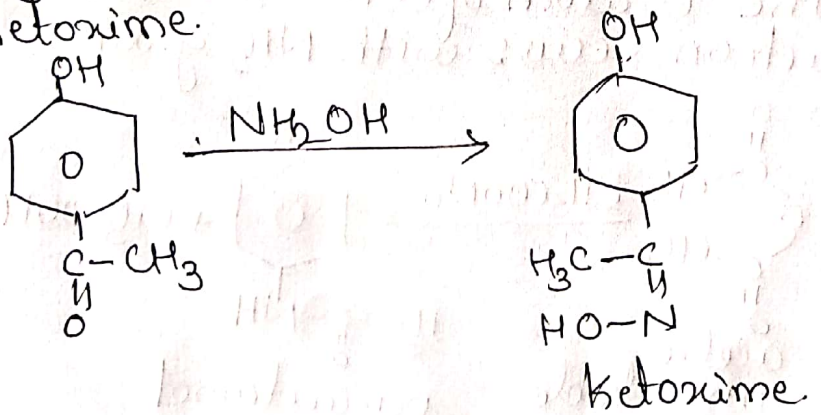
Phenol Reacts with acetic anhydride in the presence of strong acid HF to undergo acylation reaction which is an electrophilic substitution, to produce 4-hydroxy acetophenone.



3½

Step II:

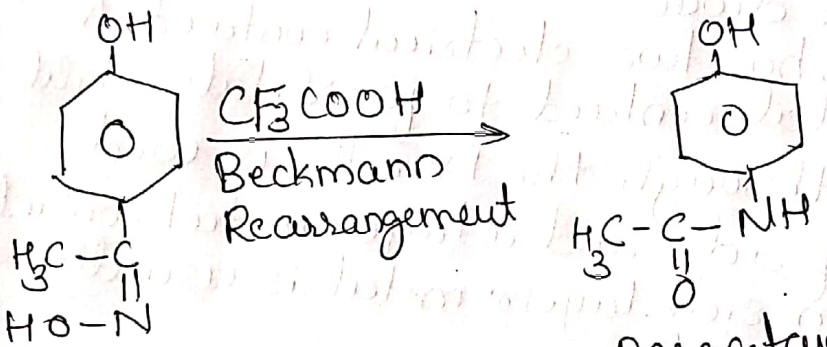
4-hydroxyacetophenone reacts with hydroxylamine to give corresponding ketoxime.



Q.No.	Solution and Scheme	Marks

Step III:

Oximes in acidic medium (trifluoro acetic acid) undergoes "Beckmann - reassrangement" to produce substitute amides. Beckmann reassrangement of the above ketoxime gives paracetamol.

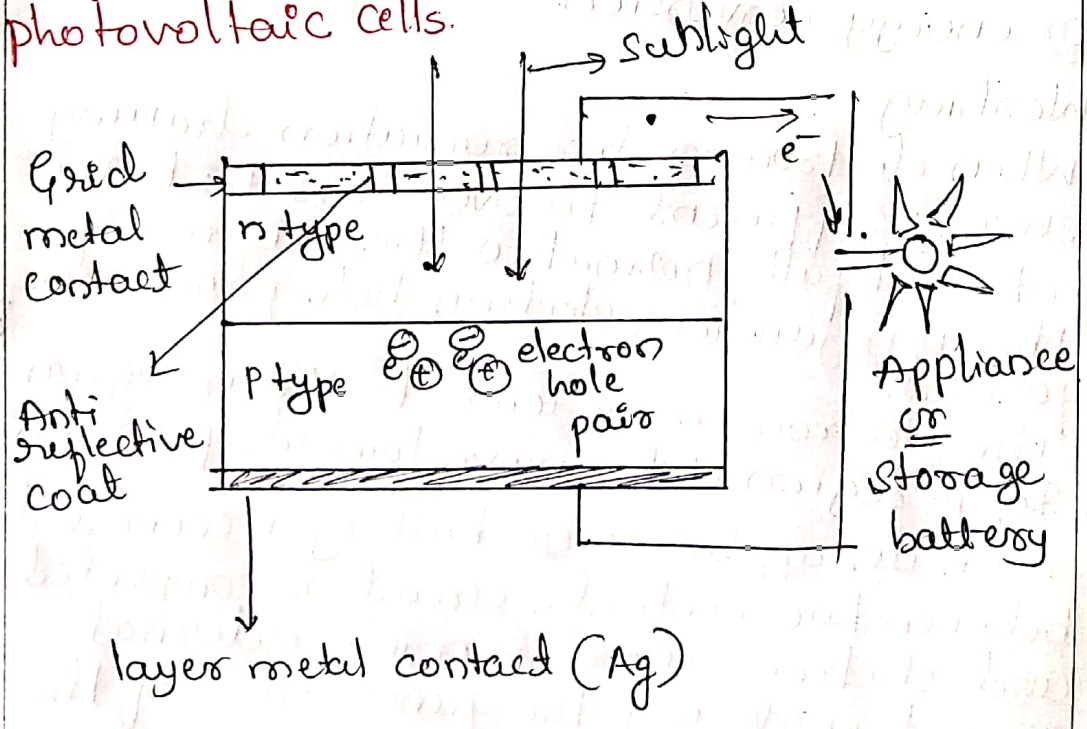


Ketoxime

Paracetamol

% Atom economy calculated for this green synthesis ≒ 58%.

8c. Explain construction and working of photovoltaic cells. 6M



Q.No.	Solution and Scheme	Marks
	Photovoltaic cells are the devices that convert solar energy directly into electrical energy from semiconductor diode.	
	Construction	
→	Photovoltaic cells are made of semi-conductor diode	
→	The diode has two electrical contact. A grid metal contact to facilitate light to pass through the PV cells is used on top of side and a layer metal contact on bottom side. layer metal is usually made up of silver.	3M
→	The metal grid permits the light to fall on the diode between the grid lines.	
→	An antireflective coat (Si_3N_4 & TiO_2) is used between the grid lines to increase the efficiency of light absorbance or energy conversion.	
	Working	
→	When electromagnetic radiation having energy sufficient to overcome the barrier potential falls normal to the surface of the p-n junction, electron-hole pairs are formed.	3M
→	The electrons move towards the n-region	
→	Holes move towards p-region	
→	When an appliance or battery is connected between two contacts, circuit is completed and electrons are driven into external circuit enabling the functioning of the appliances or charging of the battery.	

Q.No.	Solution and Scheme	Marks
	Charged battery is used for application such as lighting and telecommunication	
→	Depending on the energy requirement PV cells are connected either in series or parallel and designed to make modules or panels or arrays.	
	Module 5	
9a	Explain the theory, instrumentation and application of flame photometry	7M
→	Theory An analysis by way of measurement of emission intensities of characteristic light by the element when a solution of element is sprayed into the flame is flame photometry. The wavelength of light emitted is function of nature of the substance and the amount of light emitted is a function of concentration.	3M
	Emission of characteristic radiation by an element and the co-relation of emission intensity with concentration of element, form the basis of flame photometry. When a solution containing the sample element is aspirated into the flame; solvent evapourated. Further, solid salt is also evapourated into flame, dissociated into ~~ions etc~~ its constituent atoms. A fraction of metal atom is excited Being unstable in the excited state, excited atoms revert back to their ground state by emitting light radiation	

Q.No.	Solution and Scheme	Marks

of specific element.
The intensity of emitted light is proportional to the number of atoms in the [illegible] excited state, which inturn is proportional to the concentration of element in the solution fed into the flame. Thus, by measuring the emission intensity of the analyte, concentration of sample element determined.

Sequential changes that take place when a metal salt solution is aspirated into the flame are summarized below.

M^+X^- (soln) $\rightleftharpoons$ M^+X^- (Mist) $\xrightleftharpoons{\text{evaporat}^n}$ MX (solid)

MX (solid) $\rightleftharpoons$ MX (salt vapour) — vapourizat^n

$M_{(g)} + X_{(g)} \rightleftharpoons MX$ — dissociat^n

$M_{(g)}$ (ground state) $\rightleftharpoons$ $M^*_{(g)}$ — thermal excitat^n / $h\nu$ → flame emission

($M^*_{(g)}$: gaseous atom in excited state)

½

The intensity of the emitted radiation, measured as detector response is related to the analyte concentration by an expression:

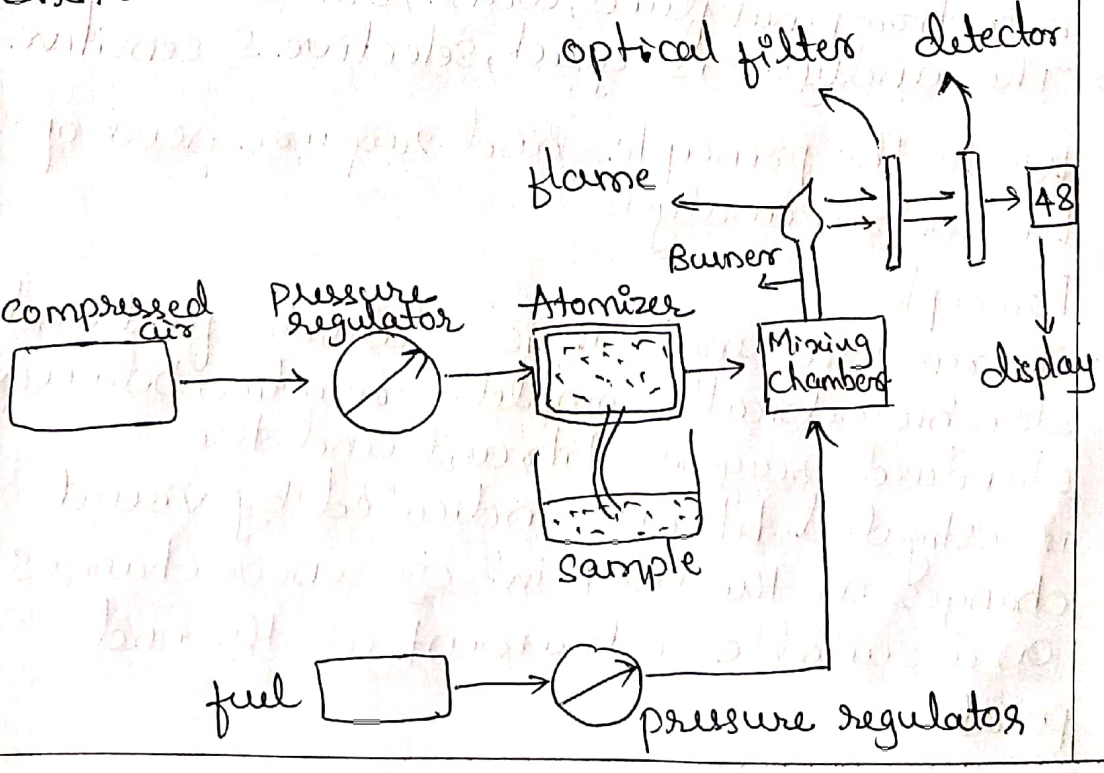
$$\varepsilon = k \alpha c$$

Q.No.	Solution and Scheme	Marks

where E is the detector response, K is a constant, α is the efficiency of atomic excitation and 'c' is the concentration of metal salt solution.

Quantitative analysis can be carried out by preparing a series of standard solutions of metals to be analyzed, aspirating into the flame and measuring the emission intensity of each solution in a flame photometer. A calibration curve is obtained by plotting emission intensity against the concentration of metal in the standard solutions. The test solution also is aspirated into the flame & emission intensity is measured. Emission intensity is compared on calibration curve and concentration of metal in the test solution is determined. 3M

Instrumentation



½

Q.No.	Solution and Scheme	Marks
	The flame photometer consists of an atomizer, mixing chamber, burner, filter, detector and read out device. Air at certain pressure is passed into an atomizer and the ~~solution~~ suction. this produces, draws a solution of sample to atomizer. Here it join's the air stream as a fine mist and passes into the mixing chamber where, it mixes with the fuel gas and gets dissociated in the burner flame. Radiation from the resulting flame passes through a lens, and through an optical filter which permits only the radiation characteristic of element under investigation to pass through the photocell. The output from the photo cell is measured on a suitable digital read out system.	
	Applications	
	→ The flame photometer may be used for determination of Ca in blood serum, cerebrospinal fluid, urine, bile etc.	
	→ The analysis is quick, selective & sensitive	
9b	Write the principles and requirement of titrimetric analysis	7M
	Principle	
	→ Titrimetric analysis is relatively fast and stoichiometrically complete reaction between standard reagent - titrant and the investigated titrand; indicated by visual changes at the endpoint or sensor changes on a suitable instrument at the end point.	2

Q.No.	Solution and Scheme	Marks
	Requirements for titrimetric analysis.	
	→ The reaction between titrant and titrand should be possible to be written as a stoichiometric equation and it should go to completion in stoichiometric proportions.	
	→ The reaction between two should be relatively fast. Many ionic reactions between titrant and titrand are relatively fast.	
	→ End of the reaction between titrant and titrand should be indicated by a color change or formation of a precipitate or a change in chemical property indicating the stoichiometric equivalence point.	5
	→ An indicator should be available and it should sharply indicate the endpoint of reaction or titration by changes stated above. Especially when the detection of equivalence point is required to be known without color or visual changes it is achieved by following course of the reaction or titration by — i) potentiometry ii) conductometry or iii) amperometry iv) Spectrometry etc.	
9c	In a COD test 30.5cm^3 and 15.5cm^3 of 0.05N FAS solutions were consumed for blank & sample titration respectively The volume of test sample used was 25cm^3. Calculate COD of sample.	6M
	Solution:	
	Sample water taken for analysis (Z) = 25ml	

Q.No.	Solution and Scheme	Marks

Mean titre value (P) = 15.5 cm^3

Blank titral value (Q) = 30.5 cm^3

$(Q-P) = (30.5 - 15.5)$ — 1M

$= 15.0\ cm^3$

Concentration of FAS (Y) = 0.05 N

COD = ?

1000 mL of 1N FAS = 8 g oxygen — 2M

1 mL of 1N FAS = $\frac{8}{1000}$ g of O_2

$(Q-P)$ mL of Y N FAS = $\frac{8}{1000} \times (Q-P) \times Y$

Expression in terms of ppm the above equation becomes

$$COD = \frac{8}{1000} \times (Q-P) \times Y \times \frac{10^6}{Z} \text{ ppm} \quad \text{— 3M}$$

$$= \frac{8}{1000} \times (30.5 - 15.5) \times 0.05 \times \frac{10^6}{25}$$

$$= \frac{8}{1000} \times 15.0 \times 0.05 \times \frac{10^6}{25}$$

$$= \frac{8 \times 15.0 \times 10^3 \times 0.05}{25}$$

$$= 0.24 \times 10^3$$

$= 240$ ppm $\cong$ mg/L

Q.No.	Solution and Scheme	Marks
10a	Explain the determination of hardness by EDTA method Determination of hardness → Hardness is determined by EDTA - complexometric method. The method involves the titration of known volume of hardwater against std. EDTA solution using EBT as metal ion indicator at pH = 10. The complexation reaction is complete at this pH and color change happens to be sharp at the end point. The indicator forms relatively less stable wine red colored Ca-EBT & Mg-EBT complexes. When EDTA solution is added initially it will react with freely available Mg^{2+} & Ca^{2+} ions & towards the endpoint, it snatches Ca^{2+} & Mg^{2+} ions from the less stable Ca-EBT & Mg-EBT complexes to form more stable colorless Ca-EDTA & Mg-EDTA complexes. Free EBT is liberated which is blue color in pH-10 medium. This marks the end of the titration. On adding indicator Ca^{2+}, Mg^{2+} + EBT ⟶ Ca-EBT, Mg-EBT complex (wine red) During titration Ca^{2+} + EDTA $\xrightarrow{pH-10}$ Ca-EDTA Mg^{2+} + EDTA ⟶ Mg-EDTA Colorless	7M 4 2

Q.No.	Solution and Scheme	Marks

At the endpoint

$$\text{Ca-EBT / Mg-EBT} + \text{EDTA} \xrightarrow{\text{pH-10}} \text{Ca-EDTA / Mg-EDTA complex} + \text{EBT (blue)}$$

Knowing the molarity and the volume of EDTA consumed, hardness of water is calculated.

Calculations:

Sample water volume taken for analysis = Z mL

Volume of EDTA consumed = P mL

Strength of EDTA soln (std) = Y M

Molecular weight of $CaCO_3$ = 100 g 1M

It is known that ——

1000 mL of 1M EDTA = 100 g $CaCO_3$

1 mL of 1M EDTA = $\frac{100}{1000}$ g $CaCO_3$

P mL of Y M EDTA = $\frac{100}{1000} \times P \times Y$ g

By expt

Z mL of hard water = P mL of Y M EDTA

$= \frac{100}{1000} \times P \times Y$ g $CaCO_3$

10^6 mL of hard water ——

$= \frac{100}{1000} \times P \times Y \times \frac{10^6}{Z}$ g $CaCO_3$

Total hardness = $\frac{100}{1000} \times P \times Y \times \frac{10^6}{Z}$ ppm

Q.No.	Solution and Scheme	Marks
10b	Define the following units of standard solution i) Molarity ii) Normality iii) ppm.	5M
	→ Molarity Number of gram moles of substance in one litre of solution $1M = \frac{\text{Number of gram moles of substance}}{1000mL \text{ of solvent.}}$	5M
	→ Normality Number of gram equivalent of substance in one litre of solution. $N = \frac{\text{No. of equivalents of solute}}{\text{Vol. of solution in litre}}$	
	→ ppm A part per million is one part of solute per million parts of the solution. $ppm = \frac{\text{No. of parts of components (solute)}}{\text{Total number of parts of all components of the solution}} \times 10^6$	
10c	Explain the theory and instrumentation of potentiometry	7M
	Theory Change in the electrode potential with changing ionic species or their molar concentration and corresponding quantitative change in cell potential is the principle behind the potentiometric analysis	

Q.No.	Solution and Scheme	Marks

When a metal M is immersed in a solution containing its own ions M^{n+}, the electrode potential is given by Nernst equation

$$E = E^\circ + \frac{0.0591}{n} \log [M^{n+}] \text{ at } 298\,K$$

A suitable indicator electrode and a reference electrode are coupled & dipped in the analyte to construct a galvanic cell.

→ Cell potential measured is a function of the concentration of the ions in the analyte 3

→ Cell potential changes abruptly at equivalence point as the nature of ions changes abruptly.

→ From the equivalents points, the concentration of ions in the analyte.

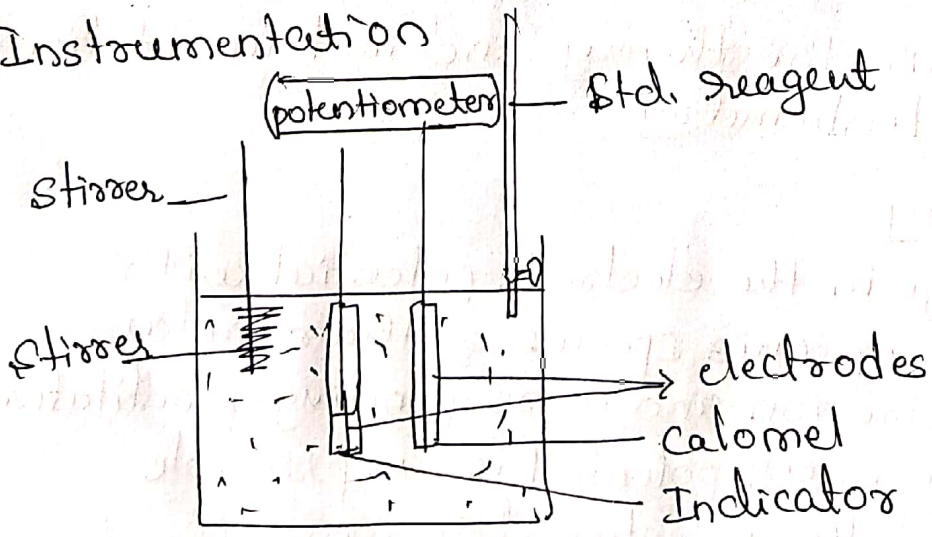
→ Cell potentiometry is used to determine the equivalence points in

i) Redox reaction

ii) Acid-base titration

iii) Precipitation titration

Instrumentation



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Q.No.	Solution and Scheme	Marks
	Potentiometer consists of one indicator electrode, a reference electrode & a potentiometer to measure the cell potential	
→	The cell responds to the changes in concentration of analyte or titrant or the reaction products.	
→	A simple arrangement of potentiometric titration is shown in the figure. The solution to be titrated is taken in the beaker.	3
→	Indicator electrode which helps in identifying the concentration of analyte in test solution or indicating the endpoint of reaction	
→	Reference electrode will have known potential which will not change with time or will regain its potential after drawing or passing small current. Usually Ag-AgCl electrode or Calomel is used as reference electrode	

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