FREE NOTES · NCERT + JEE/NEET LEVEL

Electrochemistry

Galvanic cell, electrode potential aur electrochemical series, Nernst equation, Gibbs energy, conductance aur Kohlrausch's law, electrolysis aur Faraday's laws, batteries, fuel cell aur corrosion.

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02 Electrode potential & SHE
03 Electrochemical series
04 Nernst equation & Gibbs energy
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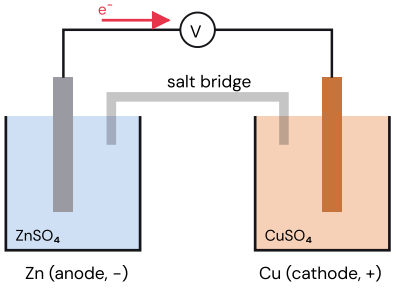
01 Galvanic (voltaic) cell

Galvanic cell ek **spontaneous redox reaction** ki chemical energy ko electrical energy me badalta hai. Example: **Daniell cell**.

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s),\ E^\circ_{cell} = 1.1\ V$$

- **Anode** = oxidation = negative (galvanic cell me).
- **Cathode** = reduction = positive.
- Bahar ke taar me electrons anode → cathode jaate.
- **Salt bridge** (agar me KCl/KNO_3) circuit poora karta aur dono solutions ko neutral rakhta.

Cell notation: $Zn \mid Zn^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu$ (anode left me).



Daniell cell: electrons Zn se Cu ki taraf

YAAD KARNE KA TAREEKA

AN OX aur **RED CAT**: anode-oxidation, reduction-cathode. Har cell me sach; electrolytic cell me sirf signs ulte hote hain.

02 Electrode potential & SHE

Metal aur uske ion solution ke beech ka potential difference = **electrode potential**. Akela naap nahi sakte, isliye **standard hydrogen electrode (SHE)** se compare karte: 1 M H^+ me Pt, 1 bar H_2 gas, E° = 0.00 V.

$$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = E^\circ_{right} - E^\circ_{left}$$

Dono ke liye **standard reduction potential** lo. $E^\circ_{cell} > 0 \Rightarrow$ reaction spontaneous.

03 Electrochemical series

Half reaction	E° (V)
$F_2 + 2e^- \rightarrow 2F^-$	+2.87 (sabse strong oxidising agent)
$Au^{3+} + 3e^- \rightarrow Au$	+1.40
$Cl_2 + 2e^- \rightarrow 2Cl^-$	+1.36
$Ag^+ + e^- \rightarrow Ag$	+0.80
$Cu^{2+} + 2e^- \rightarrow Cu$	+0.34
$2H^+ + 2e^- \rightarrow H_2$	0.00
$Zn^{2+} + 2e^- \rightarrow Zn$	-0.76
$Li^+ + e^- \rightarrow Li$	-3.05 (sabse strong reducing agent)

KAISE USE KAREIN

- E° zyada ⇒ aasani se reduce ⇒ achha oxidising agent.
- E° kam ⇒ achha reducing agent; E° < 0 wala metal dilute acid se H_2 nikalta.
- Metal apne neeche wale (zyada E°) metal ko uske salt solution se hata deta: Zn, Cu ko hatata.

04 Nernst equation & Gibbs energy

Reaction aA + bB → cC + dD, n electrons ke saath:

$$E_{cell} = E^\circ_{cell} - (0.059/n)\log Q \ \ (298\ K\ pe)$$

$Q = [C]^c[D]^d/[A]^a[B]^b$ (solid aur pure liquid = 1)

Single electrode $M^{n+} + ne^- \rightarrow M$: $E = E^\circ - (0.059/n)\log(1/[M^{n+}])$

EQUILIBRIUM AUR GIBBS ENERGY

Equilibrium pe $E_{cell} = 0 \Rightarrow E^\circ_{cell} = (0.059/n)\log K_c$

$$\Delta G^\circ = -nFE^\circ_{cell} = -2.303\ RT\log K_c$$

F = 96487 ≈ 96500 C/mol. $E^\circ > 0 \Rightarrow \Delta G^\circ < 0 \Rightarrow$ spontaneous aur $K > 1$.

05 Electrolytic solutions ka conductance

Quantity	Formula	Unit
Resistance	$R = \rho\, l/A$	Ω
Conductance	$G = 1/R$	S (siemens)
Conductivity κ	$\kappa = 1/\rho = G \times (l/A)$	S m^{-1} (ya S cm^{-1})
Cell constant G*	$G^* = l/A = R\,\kappa$	m^{-1}
Molar conductivity	$\Lambda_m = \kappa \times 1000 / M$ (κ S cm^{-1} me)	S cm^2 mol^{-1}

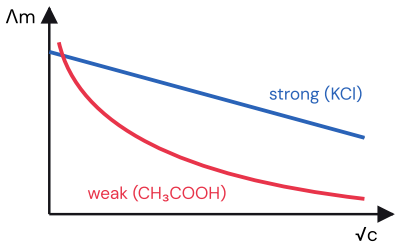
DILUTION KA ASAR

Dilute karne pe **κ ghatta** (har cm^3 me ions kam) par **Λ_m badhta** (ek mole electrolyte zyada volume me phailta, aur weak electrolyte zyada tootta). Conductivity AC se naapte (Wheatstone bridge) taaki electrolysis na ho.

06 Kohlrausch's law

Strong electrolyte: $\Lambda_m = \Lambda^\circ_m - A\sqrt{c}$ (Debye-Hückel-Onsager). Seedhi line; c = 0 tak badhao to Λ°_m mil jaata.

Weak electrolyte: kam c pe Λ_m tezi se badhta, isliye extrapolation se Λ°_m nahi milta. Kohlrausch's law use karo.



Λm vs √c: strong ke liye seedhi, weak ke liye tezi se uthi curve

LAW OF INDEPENDENT MIGRATION OF IONS

$$\Lambda^\circ_m = \nu_+\lambda^\circ_+ + \nu_-\lambda^\circ_-$$

$$\Lambda^\circ(CH_3COOH) = \Lambda^\circ(CH_3COONa) + \Lambda^\circ(HCl) - \Lambda^\circ(NaCl)$$

$$\alpha = \Lambda_m/\Lambda^\circ_m,\ K_a = c\alpha^2/(1-\alpha)$$

07 Electrolysis & Faraday's laws

Electrolytic cell me electrical energy se non-spontaneous reaction karwate hain. Anode **positive**, cathode **negative**; phir bhi oxidation anode pe, reduction cathode pe.

Pehla law: $w = Z\,I\,t = (M/nF) \times I\,t$

Doosra law: $w_1/w_2 = E_1/E_2$ (same charge, E = equivalent mass)

1 F = 1 mol electrons ka charge = 96500 C.

Electrolysis	Cathode	Anode
Molten NaCl	Na	Cl_2
Aqueous NaCl (brine)	H_2 (paani reduce hota, Na^+ nahi)	Cl_2 (O_2 ka overpotential)
Aqueous $CuSO_4$, Pt electrodes	Cu	O_2
Aqueous $CuSO_4$, Cu electrodes	Cu	Cu ghulta (refining)
Dilute H_2SO_4	H_2	O_2 (conc. acid me $S_2O_8^{2-}$)

08 Batteries, fuel cell & corrosion

Cell	Anode / Cathode	Notes
Dry (Leclanché) cell	Zn / MnO_2 + C	Primary, ~1.5 V, NH_4Cl + $ZnCl_2$ paste
Mercury cell	Zn-Hg / HgO + C	Primary, 1.35 V constant (ghadi, hearing aid)
Lead storage	Pb / PbO_2, 38% H_2SO_4	Secondary (recharge hota), car battery; discharge pe $PbSO_4$ banta
Ni-Cd	Cd / NiO(OH)	Secondary, lambi life
H_2-O_2 fuel cell	H_2 / O_2, KOH, porous C	~70% efficient, pollution-free, Apollo me use; product paani

CORROSION (ZANG LAGNA)

Ye ek electrochemical process hai. Anode: $Fe \rightarrow Fe^{2+} + 2e^-$. Cathode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$. Fe^{2+} aage oxidise hokar rust $Fe_2O_3 \cdot xH_2O$ banta. Namkeen paani aur acid ise tez karte. Bachav: paint, oil, **galvanisation** (Zn coating), **sacrificial anode** (Mg/Zn block), tin plating.

09 JEE Extra + Tricks

JEE LEVEL

- Nernst: 298 K pe $E = E^\circ - (0.059/n) \log Q$. Equilibrium pe $E = 0 \Rightarrow \log K = nE^\circ/0.059$.
- $\Delta G^\circ = -nFE^\circ$. Concentration cell: $E = (0.059/n) \log(C_2/C_1)$ ($E^\circ = 0$).
- Kohlrausch law: $\Lambda^\circ_m(CH_3COOH) = \Lambda^\circ(CH_3COONa) + \Lambda^\circ(HCl) - \Lambda^\circ(NaCl)$; $\alpha = \Lambda_m/\Lambda^\circ_m$.
- Faraday: $m = ZIt = (M/nF)\cdot Q$; same charge se masses equivalent weights ke ratio me.
- Electrolysis products: aqueous NaCl $\Rightarrow$ cathode pe H_2, anode pe Cl_2 (O_2 ka overpotential); patla $H_2SO_4 \Rightarrow$ anode pe O_2.
- Zyada E°(reduction) $\Rightarrow$ tez oxidising agent (F_2 sabse tez); kam $E^\circ \Rightarrow$ tez reducing agent (paani me Li sabse tez).

10 Solved numericals

Q1. $E°(Zn^{2+}/Zn) = -0.76$ V, $E°(Cu^{2+}/Cu) = +0.34$ V. $E°_{cell}$ aur $\Delta G°$ nikalo.

$E° = 0.34 - (-0.76) = 1.10$ V; $\Delta G° = -2 \times 96500 \times 1.10 = -212300$ J = **−212.3 kJ/mol**.

Q2. 298 K pe $Zn|Zn^{2+}(0.1\ M)||Cu^{2+}(0.01\ M)|Cu$ ka E nikalo.

$Q = [Zn^{2+}]/[Cu^{2+}] = 10 \Rightarrow E = 1.10 - (0.059/2) \log 10 = 1.10 - 0.0295 =$ **1.0705 V**.

Q3. $CuSO_4$ me 965 s tak 2 A current. Kitna Cu jama hoga? (Cu = 63.5)

$Q = 1930$ C = 0.02 F; Cu^{2+} ko per mol 2F chahiye ⇒ 0.01 mol ⇒ **0.635 g**.

Q4. 0.02 M KCl ka $\kappa = 0.0025$ S cm^{-1}. Λ_m nikalo.

$\Lambda_m = 0.0025 \times 1000/0.02 =$ **125 S cm^2 mol^{-1}**.

11 Mistakes, formula sheet & practice

- $E°_{cell} = E°_{anode} - E°_{cathode}$ likhna. Sahi hai cathode minus anode.
- Balance karte waqt E° ko coefficients se multiply karna. E° intensive hai, kabhi multiply nahi hota.
- Sochna ki dilution pe κ aur Λ_m dono ghatte hain.
- Brine electrolysis me cathode pe Na likh dena.

Cell emf	$E° = E°_c - E°_a$
Nernst	$E = E° - (0.059/n) \log Q$
Gibbs / K	$\Delta G° = -nFE°;\ E° = (0.059/n) \log K$
Molar conductivity	$\Lambda_m = 1000\kappa/M$
Weak electrolyte	$\alpha = \Lambda_m/\Lambda°_m$
Faraday	$w = MIt/(nF)$

1. Salt bridge kyun chahiye?
2. Kya $CuSO_4$ solution zinc ke bartan me rakh sakte hain?
3. Weak electrolyte ka $\Lambda°$ kisse nikalte hain?
4. 1 mol Al^{3+} ko Al banane me kitna charge?

ANSWERS

1) Circuit poora karta aur solutions neutral rakhta · 2) Nahi, Zn, Cu ko hata dega (Zn ka E° kam) · 3) Kohlrausch's law · 4) 3F = 289500 C

12 Quick revision: exam se 5 minute pehle

CELLS

- AN OX, RED CAT.
- Galvanic: anode −; electrolytic: anode +.
- $Zn|Zn^{2+}||Cu^{2+}|Cu$, E° = 1.1 V.

EQUATIONS

- $E = E° - (0.059/n) \log Q$.
- $\Delta G° = -nFE°$.
- F = 96500 C.

CONDUCTANCE

- Dilution: κ ↓, Λ_m ↑.
- $\Lambda_m = 1000\kappa/M$.
- Weak ka Λ° Kohlrausch se.

APPLICATIONS

- Lead battery: rechargeable.
- Fuel cell: $H_2 + O_2$ → paani.
- Zang se bachav: Zn coating.

Koi doubt? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.