ENGINEERING CHEMISTRY HANDBOOK

I / II Semester BE Program

Effective from the academic year 2022 - 2023

VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI
590 018

- Sensor: A chemical sensor is device it is capable of giving real time analytical information about a test sample.

- Electro chemical sensor of DO, $M^{n+} + O_2 + H_2O \rightarrow M(OH)_2$

- Li-Ion Batteries

  {(Li / Li^+, C / $LiPF_6$ in ethylene carbonate / Li^+ - MO_2/ Li-MO_2)}

Types of Electrodes

1. $Cu|CuSO_4$, $Zn|ZnSO_4$ 2023
2. Hydrogen electrode
3. $Hg|Hg_2Cl_2|Cl^-$
4. Glass electrode
5. Pb-Hg/Pb^{2+})
6. Nernst Equation

$$E = E^0 + \frac{0.0591}{n}\log_{10}[M^{n+}]$$

Where, $n = no\ of\ electrons$

7. Concentration cell

$$E = \frac{0.0591}{n}\log_{10}\frac{[cathode]}{[anode]}$$

Where, $n = no\ of\ electrons$

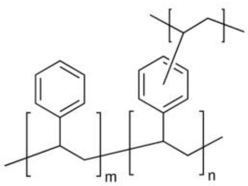
8. Glass Electrode

$$\mathbf{E_G = E^0_G - 0.0591pH}$$

9. Determination of p^H using the Glass Electrode

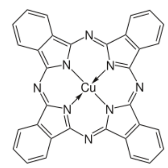
$$p^H = \frac{E^0_G - E_{cell} - E_{SCE}}{0.0591}$$

10. Organic/ Polymer Electronic devices

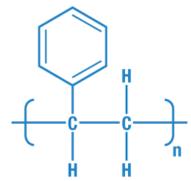


Polydivinylbenzene

Tetracene

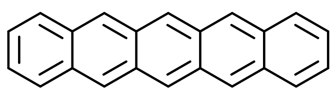


phthalocyanine

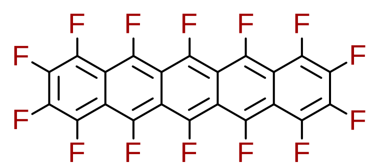


Polystyrene

11. Organic memory materials



Pentacene



Perfluoropentacene

12.

(i) **Number average molecular mass ($\overline{M}_N$) :**

$$\overline{M}_N = \frac{N_1M_1 + N_2M_2 + N_3M_3 + \ldots}{N_1 + N_2 + N_3 \ldots}$$

$$\overline{M}_N = \frac{\sum N_iM_i}{\sum N_i}$$

Where N_i is the number of molecules of the *i*th type with molecular mass M_i.

(ii) **Weight average molecular mass** $(\overline{M}_w)$ **:**

$$\overline{M}_W = \frac{m_1M_1 + m_2M_2 + m_3M_3 ....}{m_1 + m_2 + m_3 + ...} \text{ or } = \frac{\sum m_iM_i}{\sum m_i}$$

But $m_i = N_iM_i$, so that $\overline{M}_W = \frac{\sum N_iM_i^2}{\sum N_iM_i}$

Where N_i is the number of molecules of mass M_i.

13. Corrosion

$$4Fe(OH)_2 + O_2 + 2H_2O \longrightarrow 2[Fe_2O_3.3H_2O] \text{ (Rust)}$$

14. Anodization $2Al + 3H_2O \longrightarrow Al_2O_3 + 3H_2$

15. Corrosion Penetration Ratio,

$$\mathbf{CPR = \frac{k \ x \ W}{D(\rho) \ x \ A \ x \ T}}$$

Where,

W- is weight loss after exposure time.
T- is exposure time in corrosive medium.
D- is the density of metal.
A -is surface area of exposed specimen.
K - is constant.

Where 1mile is equal to 0.001inch

	CPR in mpy	CPR in mmpy
K	534	87.6
W (wt loss)	mg	Mg
(D)ρ	g/cm^3	g/cm^3
A	$inch^2$	cm^2
t	hrs	Hrs

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16. Gross Calorific value

$$\text{GCV} = \frac{(W + w)\ X\ (\Delta t)\ \ \text{X s}}{m}\text{kJ/Kg}$$

$$\text{NCV} = \left[\frac{(W + w)\ X\ (\Delta t)\ \ \text{X s}}{m} - (0.09\ \text{X}\ \%\ \ H_2\ \text{X L}\ )\right]\text{kJ/Kg}$$

17. Faraday's First Law of Electrolysis

$m \propto Q$ (1)

Where: m = mass of a substance (in grams) deposited or liberated at an electrode.

Q = amount of charge (in coulombs) or electricity passed through it

On removing the proportionality in above equation (1)

m=ZQ

Where Z is the proportionality constant, Its unit is grams per coulomb (g/C). It is also called the electrochemical equivalent. Z is the mass of a substance deposited at electrodes during electrolysis by passing 1 coulomb of charge.

Faraday's Second Law of Electrolysis

$w \propto E$

Where w = mass of the substance

E = equivalent weight of the substance

It can also be expressed as, **$w_1/w_2=E_1/E_2$**

The equivalent weight or chemical equivalent of a substance can be defined as the ratio of its atomic weight and valency

One **mole** of electrons is required for the reduction of one mole of ions. As we know, the Charge on one electron is equal to, 1.6021×10^{-19}

18. Throwing Power

$$\%\ of\ throwing\ power = \frac{100\ (A - B)}{A + B - 2}$$

Where A= d_1/d_2 (where $d_1 > d_2$) and B= w_2/w_1

19.

Electrochemical Series:

Standard reduction electrode potential VALUES

M^{n+}/M	E^O (V)
Li^+/Li	-3.05
Mg^{2+}/Mg	-2.37
Zn^{2+}/Zn	-0.76
Fe^{2+}/Fe	-0.44
Cd^{2+}/Cd	-0.40
Mn^{++}/Mn	E^O (V)
H^+/H_2	00
Cu^{2+}/Cu	0.34
Ag^+/Ag	0.8
Pt^{2+}/Pt	1.20
Au^{3+}/Au	1.38

20. Galvanic Series

Mg	**Base metals**
Mg alloys	
Zn	
Al	
Cd	
Al alloys	
Mild steel	
Cast steel	
Pb	
Sn	
Brass	
Cu	
Ni	
Stainless steel (18% Cr & 8% Ni)	
Ag	**Noble metals**
Ti	
Au	
Pt	

21. $[-NH-(CH_2)_6-NH-CO-(CH_2)_4-CO-]_n + nH_2O$

Nylon 6,6

22. **Ziegler–Natta catalyst -** such as $Et_3Al/Ti\ (OC_3H_7)_4$.

23.

For electroplating	Anode	Cathode	Electrolyte
With copper	*Cu*	Object	$CuSO_4 + \text{dilute } H_2SO_4$
With silver	*Ag*	Object	$K[Ag(CN)_2]$
With nickel	*Ni*	Object	*Nickel ammonium sulphate*
With gold	*Au*	Object	$K[Au(CN)_2]$
With zinc	*Zn*	Iron objects	$ZnSO_4$
With tin	*Sn*	Iron objects	$SnSO_4$

24. Molar conductivity,

$$\Lambda = \frac{\kappa}{M}$$

where, M is the molar concentration.

If M is in the units of molarity *i.e.*, moles per litre $(mol\ L^{-1})$, the Λ may be expressed as,

$$\Lambda = \frac{\kappa \times 1000}{M}$$

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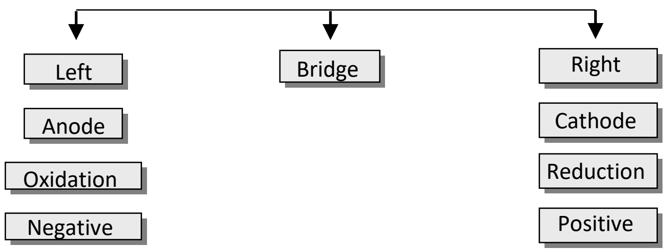
25.



26. Various Types of Half – cells

Type	Example	Half – cell reaction	Q =	Reversible to	Electrode Potential (oxidn), E =
Gas ion half - cell	$Pt(H_2)\mid H^+(aq)$ $Pt(Cl_2)\mid Cl^-(aq)$	$\frac{1}{2}H_2(g) \rightarrow H^+(aq) + e^-$ $Cl^-(aq) \rightarrow \frac{1}{2}Cl_2(g) + e^-$	$[H^+]$ $\frac{1}{[Cl^-]}$	H^+ Cl^-	$E^0 - 0.0591 \log[H^+]$ $E^0 + 0.0591 \log[Cl^-]$
Metal – metal ion half – cell	$Ag\mid Ag^+(aq)$	$Ag(s) \rightarrow Ag^+(aq) + e^-$	$[Ag^+]$	Ag^+	$E^0 - 0.0591 \log[Ag^+]$
Metal insoluble salt anion half – cell	$Ag, AgCl\mid Cl^-(aq)$	$Ag(s) + Cl^-(aq) \rightarrow AgCl(s) + e^-$	$\frac{1}{[Cl^-]}$	Cl^-	$E^0 + 0.0591 \log[Cl^-]$
Calomel electrode	$Hg, Hg_2Cl_2\mid Cl^-(aq)$	$2Hg(l) + 2Cl^-(aq) \rightarrow Hg_2Cl_2(s) + 2e^-$	$\frac{1}{[Cl^-]^2}$	Cl^-	$E^0 + 0.0591 \log[Cl^-]$
Metal – metal oxide hydroxide half - cell	$Hg, HgO\mid OH^-(aq)$	$Hg(l) + 2OH^-(aq) \rightarrow HgO(s) + H_2O(l) + 2e^-$	$\frac{1}{[OH^-]^2}$	OH^-	$E^0 + 0.0591 \log[OH^-]$
Oxidation – reduction half – cell	$Pt\mid Fe^{2+}_{(aq)}, Fe^{3+}_{(aq)}$	$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$	$\frac{[Fe^{3+}]}{[Fe^{2+}]}$	Fe^{2+}, Fe^{3+}	$E^0 - 0.0591 \log\frac{[Fe^{3+}]}{[Fe^{2+}]}$

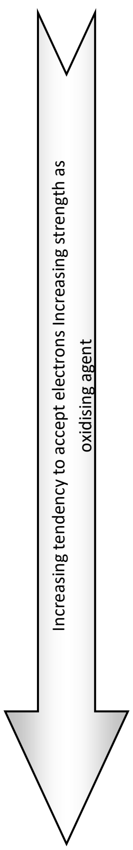
27. **Cell EMF and the spontaneity of the reaction:**

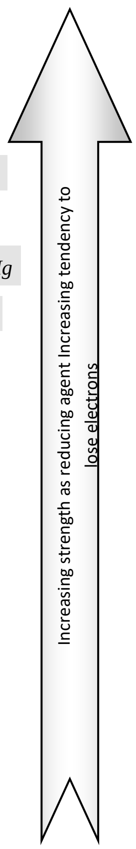
Nature of reaction	ΔG(or ΔG^o)	E_{cell} (or E^o_{cell})
Spontaneous	–	+

Equilibrium	0	0
Non – spontaneous	+	–

28. Electro Chemical Series

Element	Electrode Reaction (Reduction)	Standard Electrode Reduction potential E^0, volt
Li	$Li^+ + e^- = Li$	–3.05
K	$K^+ + e^- = K$	–2.925
Ba	$Ba^{++} + 2e = Ba$	–2.90
Sr	$Sr^{++} + 2e = Sr$	–2.89
Ca	$Ca^{2+} + 2e^- = Ca$	–2.87
Na	$Na^+ + e^- = Na$	–2.714
Mg	$Mg^{2+} + 2e^- = Mg$	–2.37
Al	$Al^{3+} + 3e^- = Al$	–1.66
Mn	$Mn^{++} + 2e = Mn$	–1.18
Zn	$Zn^{2+} + 2e^- = Zn$	–0.7628
Cr	$Cr^{3+} + 3e^- = Cr$	–0.74
Fe	$Fe^{2+} + 2e^- = Fe$	–0.44
Cd	$Cd^{2+} + 2e^- = Cd$	–0.403
Co	$Co^{++} + 2e = Co$	–0.27
Ni	$Ni^{2+} + 2e^- = Ni$	–0.25
Sn	$Sn^{2+} + 2e^- = Sn$	–0.14
Pb	$Pb^{++} + 2e = Pb$	–0.12
H_2	**$2H^+ + 2e^- = H_2$**	**0.00**
Cu	$Cu^{2+} + 2e^- = Cu$	+0.337
I_2	$I_2 + 2e^- = 2I^-$	+0.535
Hg	$Hg^{2+} + 2e^- = Hg$	+0.885
Ag	$Ag^+ + e^- = Ag$	+0.799
Br_2	$Br_2 + 2e^- = 2Br^-$	+1.08
Pt	$Pt^{++} + 2e = Pt$	+1.20
Cl_2	$Cl_2 + 2e^- = 2Cl^-$	+1.36
Au	$Au^{3+} + 3e^- = Au$	+1.50
F_2	$F_2 + 2e^- = 2F^-$	+2.87





29. Seven basic S.I. units

Length	Mass	Time	Temperature	Electric Current	Luminous Intensity	Amount of substance
metre (*m*)	Kilogram (*kg*)	Second (*s*)	Kelvin (*K*)	Ampere (*A*)	Candela (*Cd*)	Mole (*mol*)

30. Derived Units

Physical quantity	**Unit**	**Symbol**
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity	metre per second	ms^{-1}
Acceleration	metre per second square	ms^{-2}
Density	kilogram per cubic metre	$kg\ m^{-3}$
Molar mass	kilogram per mole	$kg\ mol^{-1}$
Molar volume	cubic metre per mole	$m^3\ mol^{-1}$
Molar concentration	mole per cubic metre	$mol\ m^{-3}$
Force	newton (*N*)	$kg\ m\ s^{-2}$
Pressure	pascal (*Pa*)	$N\ m^{-2}$
Energy work	joule (*J*)	$kg\ m^2\ s^{-2}$, Nm

31. Standard prefixes use to reduce the basic units

Multiple	**Prefix**	**Symbol**	**Submultiple**	**Prefix**	**Symbol**
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	µ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a

10^{2}	hecto	h	10^{-21}	zeto	z
10^{1}	deca	da	10^{-24}	yocto	y

32. Conversion factors

1 m = 39.37 inch	1 cal = 4.184 J	1 e.s.u. = 3.3356×10^{-10} C	1 mole of a gas = 22.4 L at STP
1 inch = 2.54 cm	1 eV = 1.602×10^{-19} J	1 dyne = 10^{-5} N	1 mole a substance = N_0 molecules
1 litre = 1000 mL	1 eV/atom =96.5 kJ mol^{-1}	1 atm = 101325 Pa	1 g atom = N_0 atoms
1 gallon (US) = 3.79 L	1 amu = 931.5016 MeV	1 bar = 1×10^{5} N m^{-2}	t (ºF) = 9/5 t (ºC) + 32
1 lb = 453.59237 g	1 kilo watt hour = 3600 kJ	1 litre atm = 101.3 J	1 g cm^{-3} = 1000 kg m^{-3}
1 newton =1 kg m s^{-2}	1 horse power = 746 watt	1 year = 3.1536×10^{7} s	1Å = 10^{-10} m
1 J = 1 Nm =1 kg m^{2} s^{-2}	1 joule = 10^{7} erg	1 debye (D) = 1×10^{-18} esu cm	1nm = 10^{-9} m

33. Molecular mass

$$\left[\text{Molecular mass} = \frac{\text{Mass of one molecule of the substance}}{1/12 \times \text{Mass of one atom of C-12}}\right]$$

34.

$$\text{Normality}\left[= x \times \text{No. of millimoles}\right]$$

$$= x \times \text{Molarity} = \frac{\text{Strength in } gm\ litre^{-1}}{\text{Eq. wt.}}$$

35. Normality formula, $N_1V_1 = N_2V_2$

36. Comparison of mass, charge and specific charge of electron, proton and neutron

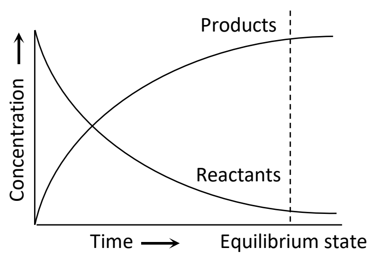
Name of constant	*Unit*	**Electron(e^-)**	**Proton(p^+)**	**Neutron(n)**
Mass (*m*)	Amu *Kg* Relative	0.000546 9.109×10^{-31} 1/1837	1.00728 1.673×10^{-27} 1	1.00899 1.675×10^{-27} 1

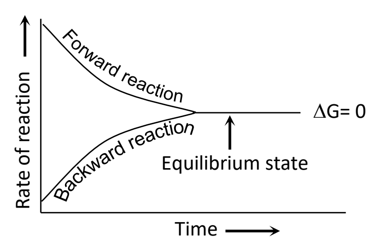
Charge(*e*)	Coulomb (*C*) Esu Relative	-1.602×10^{-19} -4.8×10^{-10} -1	$+1.602 \times 10^{-19}$ $+4.8 \times 10^{-10}$ $+1$	Zero Zero Zero
Specific charge (*e*/*m*)	C/g	1.76×10^{8}	9.58×10^{4}	Zero
Density	Gram / cc	2.17×10^{-17}	1.114×10^{14}	1.5×10^{-14}

37. Standard ambient temperature and pressure

Condition	**T**	**P**	**V_m (Molar volume)**
S.T.P./N.T.P.	273.15 *K*	1 *atm*	22.414 *L*
S.A.T.P*.	298.15 *K*	1 *bar*	24.800 *L*

38. Chemical Equilibrium





39. P^H Scale

	$[H^+]$	$[OH^-]$	*pH*	*pOH*
Acidic solution	$> 10^{-7}$	$< 10^{-7}$	< 7	> 7
Neutral solution	10^{-7}	10^{-7}	7	7
Basic solution	$< 10^{-7}$	$> 10^{-7}$	> 7	< 7

***pH* of some materials**

Material	*pH*	Material	*pH*
Gastric juice	1.4	Rain water	6.5
Lemon juice	2.1	Pure water	7.0
Vinegar	2.9	Human saliva	7.0
Soft drinks	3.0	Blood plasma	7.4
Beer	4.5	Tears	7.4

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Black coffee	5.0	Egg	7.8
Cow's milk	6.5	Household ammonia	11.9

40. Thermodynamics

$E_2 - E_1 =$

$\Delta E = q + w$

41.

- $13.7\ Kcal/mol = 57\ KJ/mol$ (because of $1\,cal$ =4.2 Joule)
- Enthalpy of fusion of ice per mole is $6KJ$.
- Order of bond energy in halogen $Cl_2 > Br_2 > F_2 > I_2$.

42. Equivalent weight of few oxidising/reducing agents

Agents	O. N.	Product	O. N.	Change in O. N. per atom	Total Change in O. N. per mole	Eq. wt.
$Cr_2O_7^{2-}$	+ 6	Cr^{3+}	+ 3	3	3 × 2 = 6	Mol. wt./6
$C_2O_4^{2-}$	+ 3	CO_2	+ 4	1	1 × 2 = 2	Mol. wt./2
$S_2O_3^{2-}$	+ 2	$S_4O_6^{2-}$	+ 2.5	0.5	0.5 × 2 = 1	Mol. wt./1
H_2O_2	– 1	H_2O	– 2	1	1 × 2 = 2	Mol. wt./2
H_2O_2	– 1	O_2	0	1	1 × 2 = 2	Mol. wt./2
MnO_4^- **(Acidic medium)**	+ 7	Mn^{2+}	+ 2	5	5 × 1 = 5	Mol. wt./5
MnO_4^- **(Neutral medium)**	+ 7	MnO_2	+ 4	3	3 × 1 = 3	Mol. wt./3
MnO_4^- **(Alkaline medium)**	+ 7	MnO_4^{2-}	+ 6	1	1 × 1 = 1	Mol. wt./1

43. Products of electrolysis of some electrolytes

Electrolyte	Electrode	Product at cathode	Product at anode
Aqueous $NaOH$	Pt or Graphite	$2H^+ + 2e^- \rightarrow H_2$	$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$
Fused $NaOH$	Pt or Graphite	$Na^+ + e^- \rightarrow Na$	$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$
Aqueous $NaCl$	Pt or Graphite	$2H^+ + 2e^- \rightarrow H_2$	$2Cl^- \rightarrow Cl_2 + 2e^-$
Fused $NaCl$	Pt or Graphite	$Na^+ + e^- \rightarrow Na$	$2Cl^- \rightarrow Cl_2 + 2e^-$
Aqueous $CuSO_4$	Pt or Graphite	$Cu^{2+} + 2e^- \rightarrow Cu$	$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$
Aqueous $CuSO_4$	Cu electrode	$Cu^{2+} + 2e^- \rightarrow Cu$	Cu oxidised to Cu^{2+} ions
Dilute H_2SO_4	Pt electrode	$2H^+ + 2e^- \rightarrow H_2$	$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$
Conc. H_2SO_4	Pt electrode	$2H^+ + 2e^- \rightarrow H_2$	Peroxodisulphuric acid $(H_2S_2O_8)$
Aqueous $AgNO_3$	Pt electrode	$Ag^+ + e^- \rightarrow Ag$	$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$
Aqueous $AgNO_3$	Ag electrode	$Ag^+ + e^- \rightarrow Ag$	Ag oxidised to Ag^+ ions

44. Ohm's law

$$I = \frac{V}{R} \quad \text{or} \quad V = IR$$

45. Electro chemical series

Top

(Strongest reducing agent)

Highest negative reduction potential

or

(Minimum reduction potential)

(Strongest oxidising agent)

Highest positive value of reduction potential

Bottom

Oxidising nature ↓ Reducing nature ↑

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