ENGINEERING CHEMISTRY HANDBOOK

I / II Semester BE Program

Effective from the academic year 2022 - 2023

- 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, $n = no\ of\ electrons$

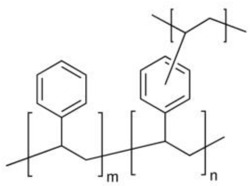
8. **Glass Electrode**

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

9. Determination of p^H using the Glass Electrode

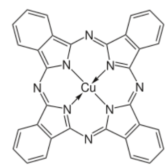
$$\boxed{p^H = \frac{E_G^0 - E_{cell} - E_{SCE}}{0.0591}}$$

10. Organic/ Polymer Electronic devices

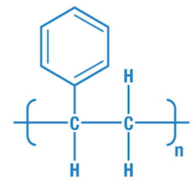


Polydivinylbenzene

Tetracene

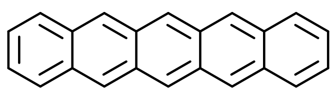


phthalocyanine

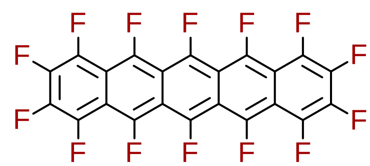


Polystyrene

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** $(\overline{M}_W)$ **:**

$$\overline{M}_W = \frac{m_1 M_1 + m_2 M_2 + m_3 M_3 \ldots.}{m_1 + m_2 + m_3 + \ldots} \text{ or } = \frac{\sum m_i M_i}{\sum m_i}$$

But $m_i = N_i M_i$, so that $\overline{M}_W = \dfrac{\sum N_i M_i^2}{\sum N_i M_i}$

Where N_i is the number of molecules of mass M_i.

13. Corrosion

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

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

15. Corrosion Penetration Ratio,

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

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

16. Gross Calorific value

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

$$\text{NCV} = \left[\frac{(W + w)\ X\ (\Delta t)\ \text{X s}}{m} - (0.09\ \text{X}\ \%\ \text{H}_2\ \text{X L})\right] \text{kJ/Kg}$$

17. Faraday's First Law of Electrolysis

m ∝ 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 ∝ E

Where w = mass of the substance

E = equivalent weight of the substance

It can also be expressed as, $\mathbf{w_1/w_2=E_1/E_2}$

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	$CuSO_4$ + 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,

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

25.

Left	Bridge	Right
Anode		Cathode
Oxidation		Reduction
Negative		Positive

26. Various Types of Half – cells

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

Increasing tendency to accept electrons Increasing strength as oxidising agent

Increasing strength as reducing agent Increasing tendency to lose electrons

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

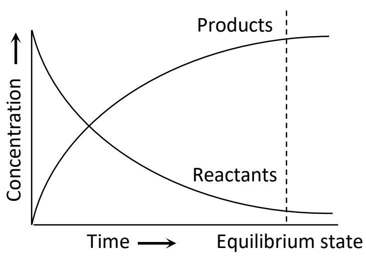
Name of constant	*Unit*	**Electron(e^-)**	**Proton(p^+)**	**Neutron(n)**
Mass (m)	Amu	0.000546	1.00728	1.00899
	Kg	9.109×10^{-31}	1.673×10^{-27}	1.675×10^{-27}
	Relative	1/1837	1	1

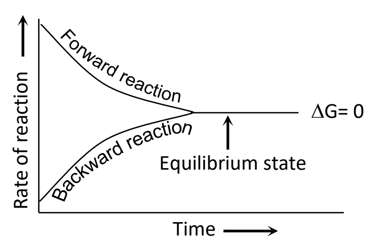
Charge(e)	Coulomb (C) Esu Relative	-1.602×10^{-19} -4.8×10^{-10} -1	$+1.602 \times 10^{-19}$ $+4.8 \times 10^{-10}$ $+1$	Zero Zero Zero
Specific charge (e/m)	C/g	1.76×10^{8}	9.58×10^{4}	Zero
Density	Gram / cc	2.17×10^{-17}	1.114×10^{14}	1.5×10^{-14}

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

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 ↑