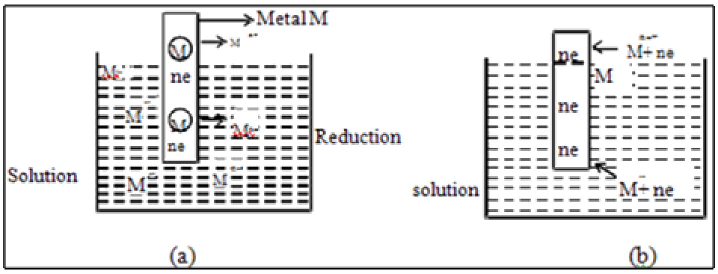
FlexiPrep

Electrochemistry: Electrode Potential and Standard Electrode Potential (For CBSE, ICSE, IAS, NET, NRA 2022)

Electrode Potential

- Electrode potential is a measure of the tendency of metal atoms to gain or lose electrons when in contact with a solution of its own ions.
- When a metal strip M is immersed in a solution of its salt containing ions $\left(M^{n+}\right)$, one of the processes as show in in Fig. (a) or (b) can occur.



The dissolution process where atoms of metal electrode M may lose some electrons to the electrode and enter the solution as M^{n+} .

$M \rightarrow M^{n+} + \text{ne}$ (metal is oxidised)

The deposition process where metal cations M^{n+} from the solution may come in contact with the metal strip, gain some electrons and get converted into metal atoms M , which get deposited on the surface of metal strip.

$M^{n+} + \text{ne}^{-} \rightarrow M$ (the ion is reduced)

Standard Electrode Potential

- Electrode Potential is said to be in the standard electrode potential if electrode is in standard state, i.e.. the concentration of the electrolyte is one molar and the temperature is $298K$.
- It is denoted by E° .
- If any gas is used to make the electrode, then the pressure of the gas should be 1 bar.

Measurement of Electrode Potential

- It is not possible to measure single electrode potential because oxidation or reduction cannot take place in isolation.
- It can be measured with respect to a reference electrode.
- The electrode used as reference electrode is standard hydrogen electrode (SHE) .

Standard Hydrogen Electrode

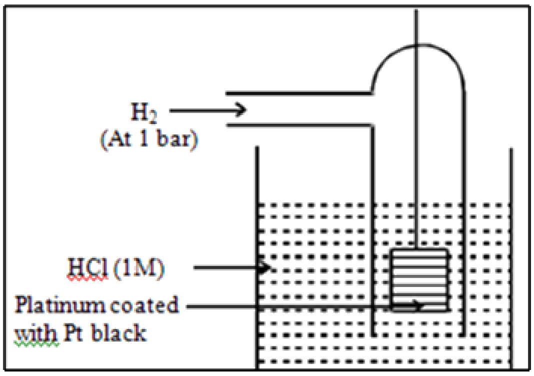
- Standard Hydrogen Electrode (SHE) consists of a container, containing $1M$ HCl solution kept at $298K$.

- A wire containing Platinum electrode coated with platinum black is immersed in the solution.
- Pure hydrogen gas is bubbled in the solution at 1bar pressure.
- The potential of SHE ($E°$) is taken as zero volt at all temperatures.
- Standard hydrogen electrode may act as anode or cathode depending upon the nature of the other electrode.
- If its acts as anode, the oxidation reaction taking place is

$$H_2\ (g) \rightarrow 2H^+\ (\text{aq}) + 2e^-$$

If it acts as cathode then the reduction half reaction occurring is

$$2H^+\ (\text{aq}) + 2e^- \rightarrow H_2\ (g)$$



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Determination of Magnitude of Electrode Potential

- The standard electrode potential of an electrode can be measured by combining it with standard hydrogen electrode.
- The cell emf is the electrode potential of electrode.

Sign of Electrode Potential

- The galvanic cell formed by the combination of SHE and electrode under study, the polarity of the electrode is determined with the help of a voltmeter.
- If the given electrode is found to be positive electrode, its electrode potential is given the positive sign and vice-versa.

Application of Electrochemical Series

Cell Emf and Potential Difference

- The difference in potential of the two electrodes (or half cells) of a galvanic cell, when measured in the open circuit is called the cell electromotive force or cell emf.
- When it is measured in a closed circuit with some external load it is called potential difference.

Standard Cell Emf

- The emf of a cell has a standard value if both its half cells are in their standard states.
- It is denoted by $E°$ cell.

Cell Emf and Electrode Potential

The standard cell emf is related to the standard electrode potentials of its anode and cathode.

$$E°\text{cell} = E°\text{cathode} - E°\ \text{anode}$$

$$= E°\text{Right} - E°\ \text{left}$$

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Electrochemical Series

Standard potential of a large number of electrodes have been measured and they have been listed in the increasing order of electrode potential in a series called electro chemical series.

Standard Electrode Potential

Element	*Electrode rection*	*E°(V)*
Li	$Li + e^- \rightarrow Li$	– 3.045
K	$K^+ + e^- \rightarrow K$	– 2.925
Cs	$Cs^+ + e^- \rightarrow Cs$	– 2.923
Ba	$Ba^{2+} + 2e^- \rightarrow Ba$	– 2.906
Ca	$Ca^{2+} + 2e^- \rightarrow Ca$	– 2.866
Na	$Na^+ + e^- \rightarrow Na$	– 2.714
Mg	$Mg^{2+} + 2e^- \rightarrow Mg$	– 2.363
Al	$Al^{3+} + 3e^- \rightarrow Al$	– 1.662
H_2	$H_2O + 2e^- \rightarrow H_2 + 2OH^-$	– 0.829
Zn	$Zn^{2+} + 2e^- \rightarrow Zn$	– 0.763
Fe	$Fe^{2+} + 2e^- \rightarrow Fe$	– 0.440
Cd	$Cd^{2} + 2e^- \rightarrow Cd$	– 0.403

Pb	$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	-0.310
Co	$Co^{2+} + 2e^- \rightarrow Co$	-0.280
Ni	$Ni^{2+} + 2e^- \rightarrow Ni$	-0.250
Sn	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.136
Pb	$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
Fe	$Fe^{3+} + 3e^- \rightarrow Fe$	-0.036
H_2	$2H^+ + 2e^- \rightarrow H_2$ (SHE)	0
Cu	$Cu^{2+} + e^- \rightarrow Cu^+$	$+0.153$
S	$S_4O_6^{2-} + 2e^- \rightarrow 2S_2O_3^{2-}$	$+0.170$
Cu	$Cu^{2+} + 2e^- \rightarrow Cu$	$+0.337$
I_2	$I_2 + 2e^- \rightarrow 2I^-$	$+0.534$
Fe	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	$+0.77$
Ag	$Ag^+ + e^- \rightarrow Ag$	$+0.799$
Hg	$Hg^{2+} + 2e^- \rightarrow Hg$	$+0.854$
Br_2	$Br_2 + 2e^- \rightarrow 2Br^-$	$+1.066$
O_2	$O_2 + 4H^+ + 2e^- \rightarrow 2H_2O$	$+1.230$
Cr_2	$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	$+1.330$
Cl_2	$Cl_2 + 2e^- \rightarrow 2Cl^-$	$+1.359$
Au	$Au^{3+} + 3e^- \rightarrow Au$	$+1.498$
Mn	$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	$+1.510$
F_2	$F_2 + 2e^- \rightarrow 2F^-$	$+2.870$