

Oxidation-Reduction Reactions

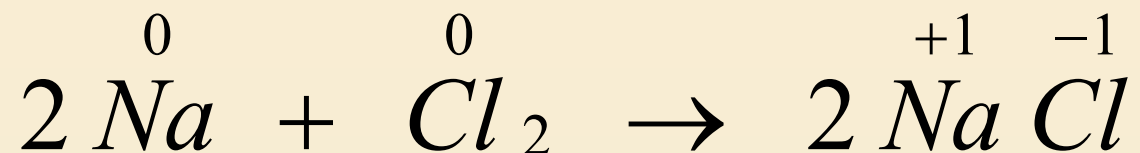


LEO SAYS GER

Oxidation and Reduction (Redox)

- ❑ Electrons are transferred
- ❑ Spontaneous redox rxns can transfer energy
 - ❑ Electrons (electricity)
 - ❑ Heat
- ❑ Non-spontaneous redox rxns can be made to happen with electricity

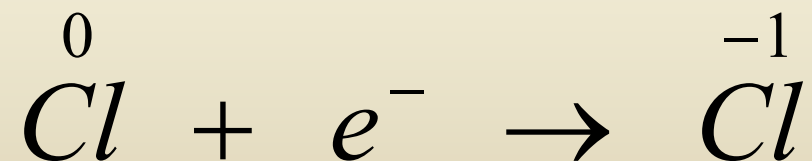
Oxidation Reduction Reactions (Redox)



Each sodium atom loses one electron:

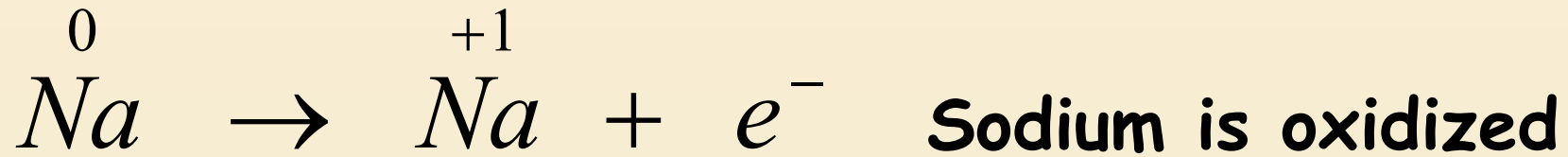


Each chlorine atom gains one electron:

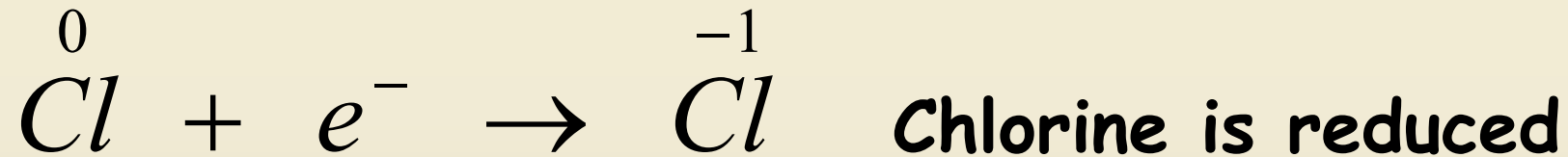


LEO says GER :

Lose Electrons = Oxidation



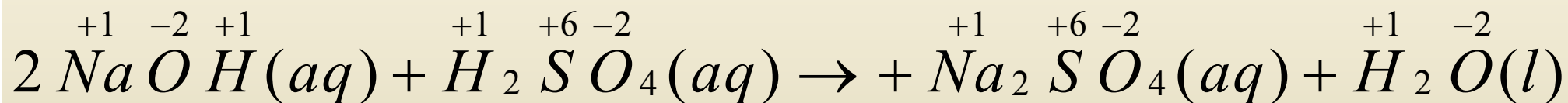
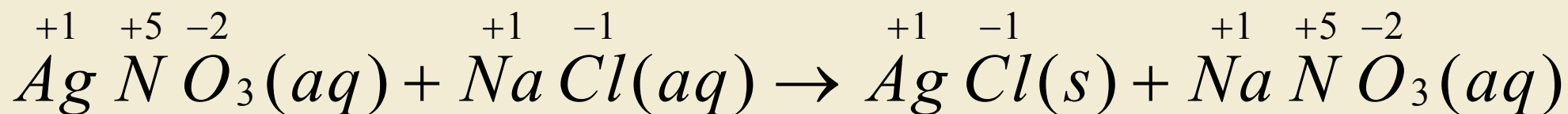
Gain Electrons = Reduction



Not All Reactions are Redox Reactions

Reactions in which there has been no change in oxidation number are not redox rxns.

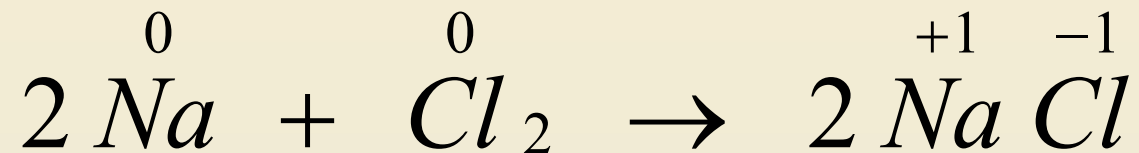
Examples:



Rules for Assigning Oxidation Numbers

Rules 1 & 2

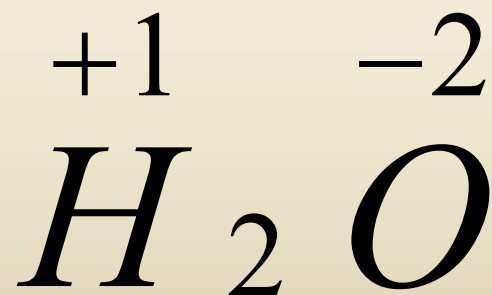
1. The oxidation number of any uncombined element is zero
2. The oxidation number of a monatomic ion equals its charge



Rules for Assigning Oxidation Numbers Rules 3 & 4

3. The oxidation number of oxygen in compounds is -2

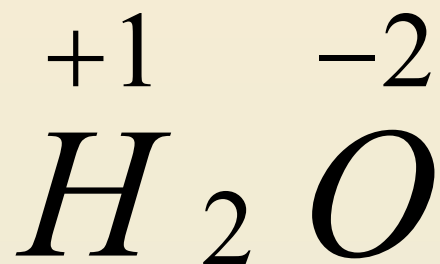
4. The oxidation number of hydrogen in compounds is +1



Rules for Assigning Oxidation Number

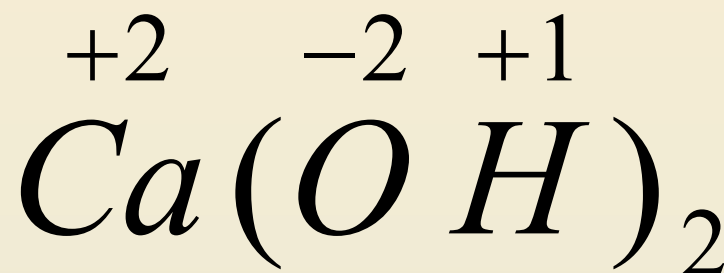
Rule 5

5. The sum of the oxidation numbers in the formula of a compound is 0



$$2(+1) + (-2) = 0$$

H O



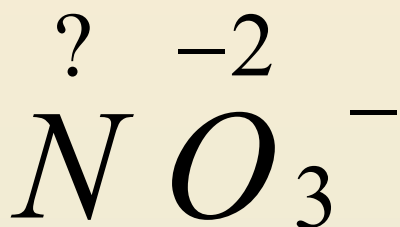
$$(+2) + 2(-2) + 2(+1) = 0$$

Ca O H

Rules for Assigning Oxidation Numbers

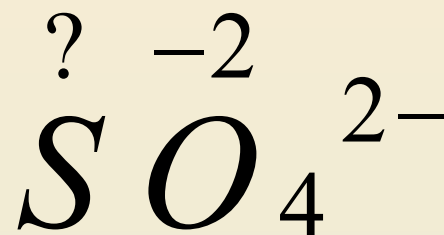
Rule 6

6. The sum of the oxidation numbers in the formula of a polyatomic ion is equal to its charge



$$\begin{array}{c} \text{X} + 3(-2) = -1 \\ \text{N} \quad \quad \text{O} \end{array}$$

$$\therefore \text{X} = +5$$



$$\begin{array}{c} \text{X} + 4(-2) = -2 \\ \text{S} \quad \quad \text{O} \end{array}$$

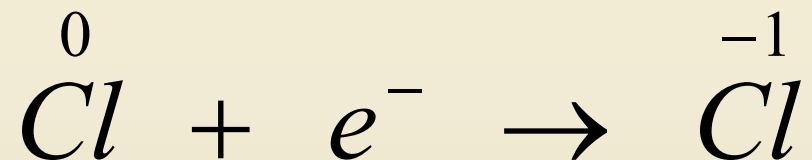
$$\therefore \text{X} = +6$$

Reducing Agents and Oxidizing Agents

- The substance reduced is the oxidizing agent
- The substance oxidized is the reducing agent



Sodium is oxidized - it is the reducing agent



Chlorine is reduced - it is the oxidizing agent

Trends in Oxidation and Reduction

Active metals:

- Lose electrons easily
- Are easily oxidized
- Are strong reducing agents

Active nonmetals:

- Gain electrons easily
- Are easily reduced
- Are strong oxidizing agents

Electrochemical Terminology

Electrode: A conductor used to establish contact with a nonmetallic part of a circuit, such as an electrolyte

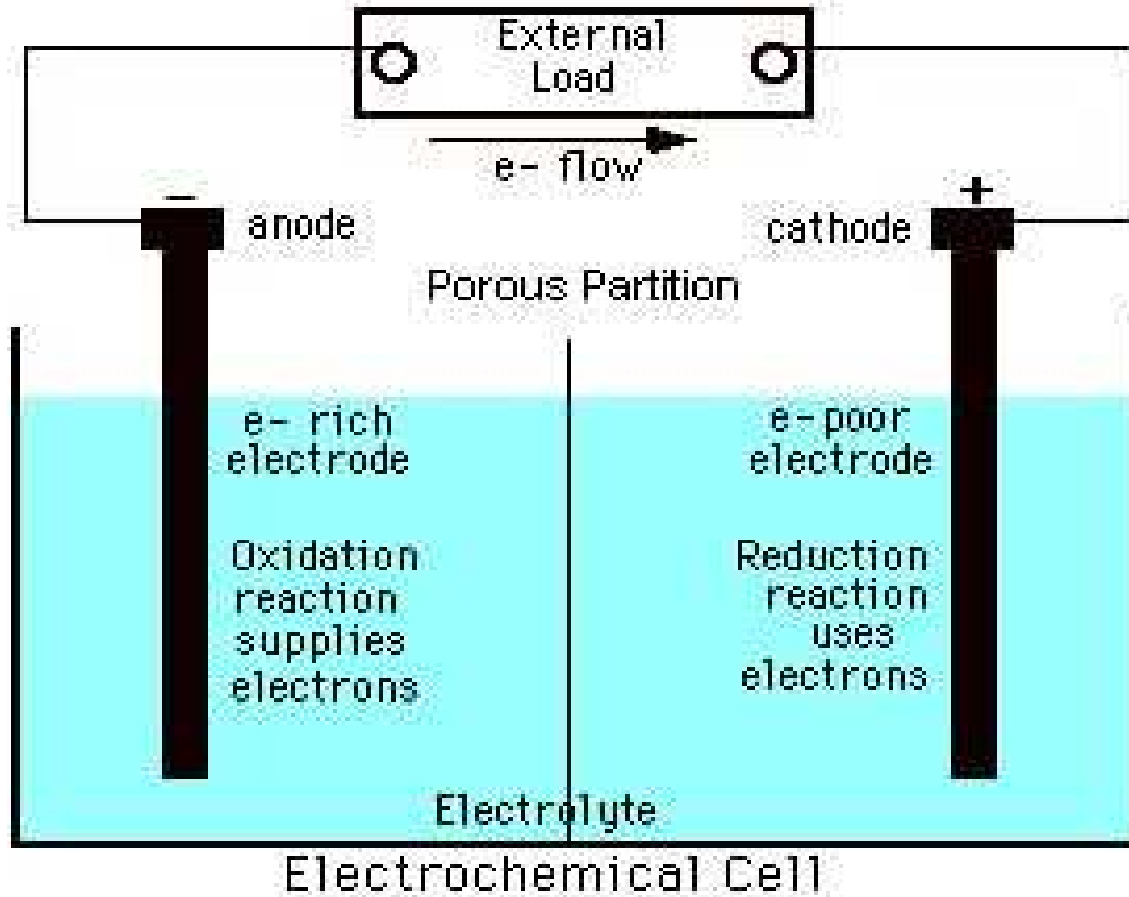
Half-cell: a metal electrode in contact with a solution of its own ions

Anode: The electrode where oxidation takes place

Cathode: The electrode where reduction takes place

Voltaic Cells

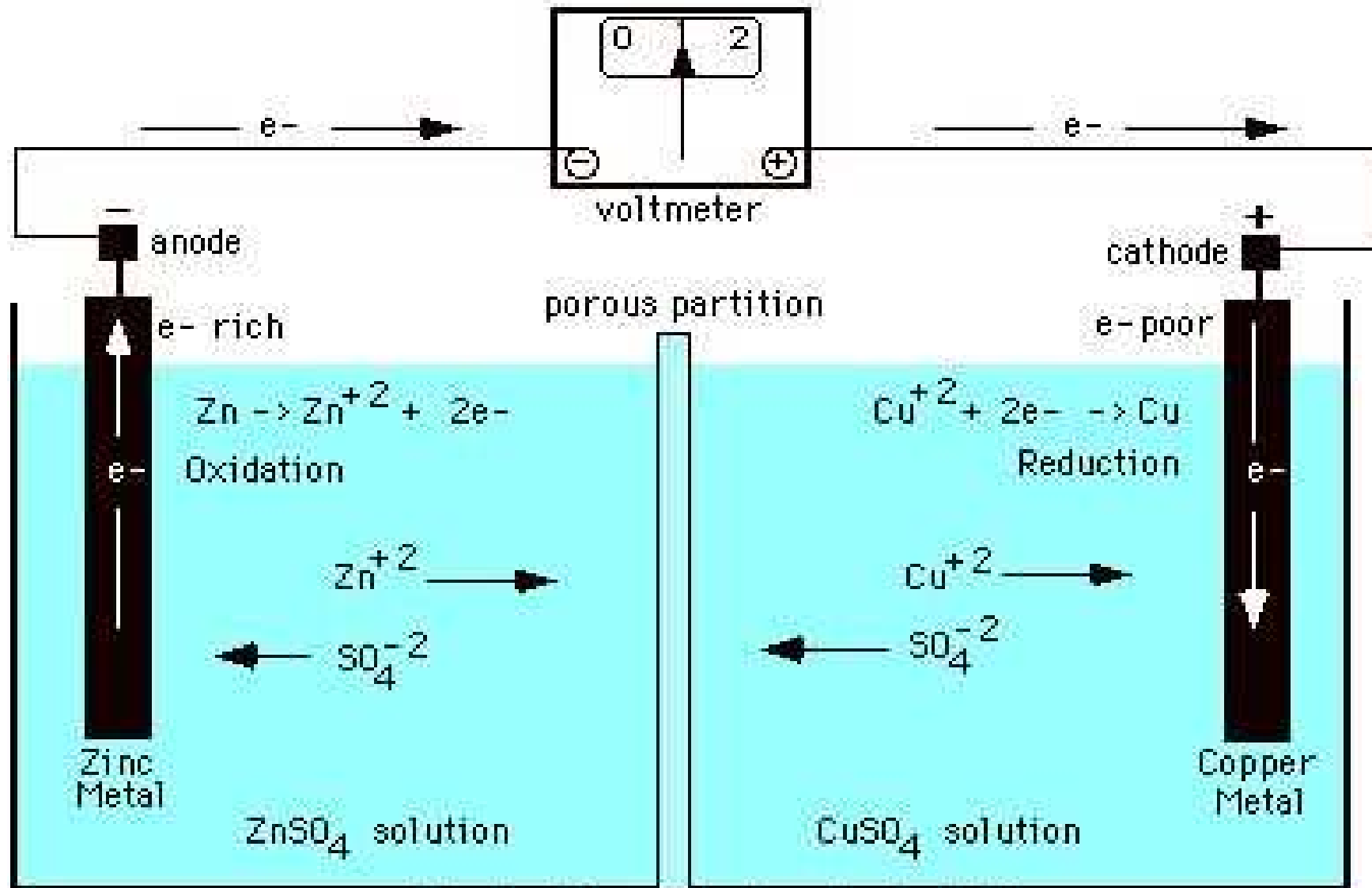
Anode:
negative



Cathode:
positive

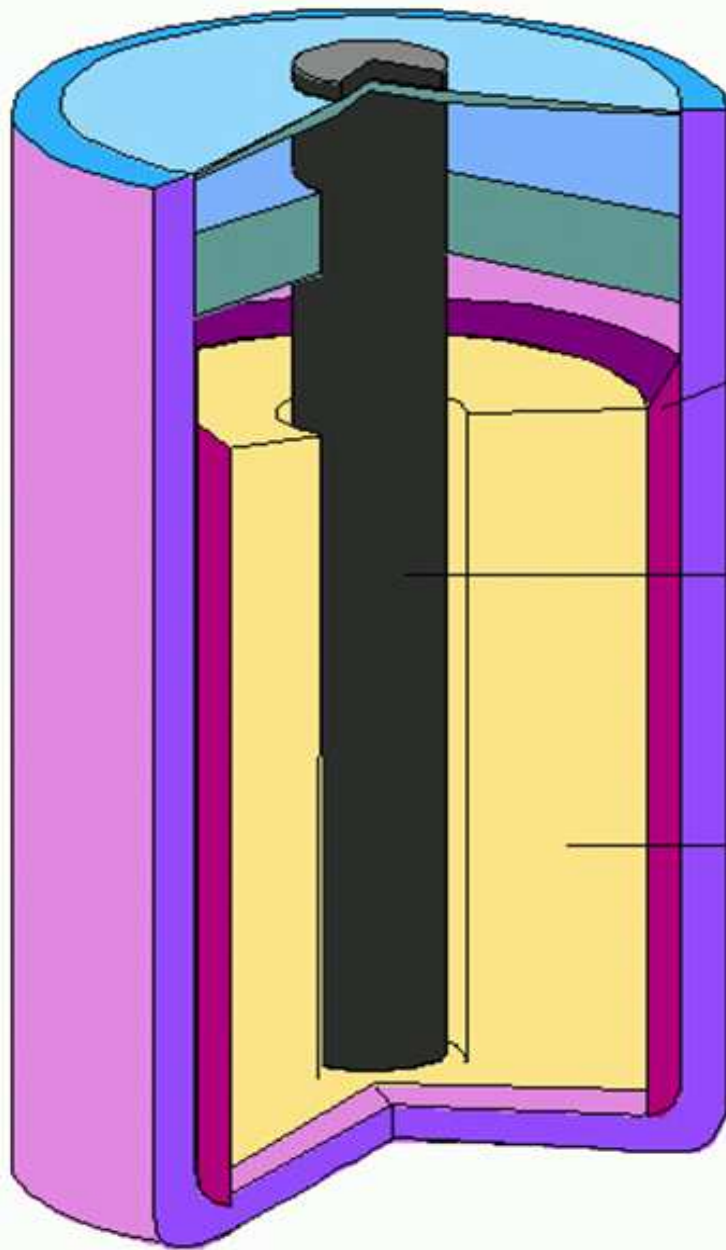
Voltaic cells: Electrochemical cells in which a spontaneous redox reaction can be harnessed to produce an electric current.

Zinc - Copper Battery



Zn-Cu Electrochemical Cell

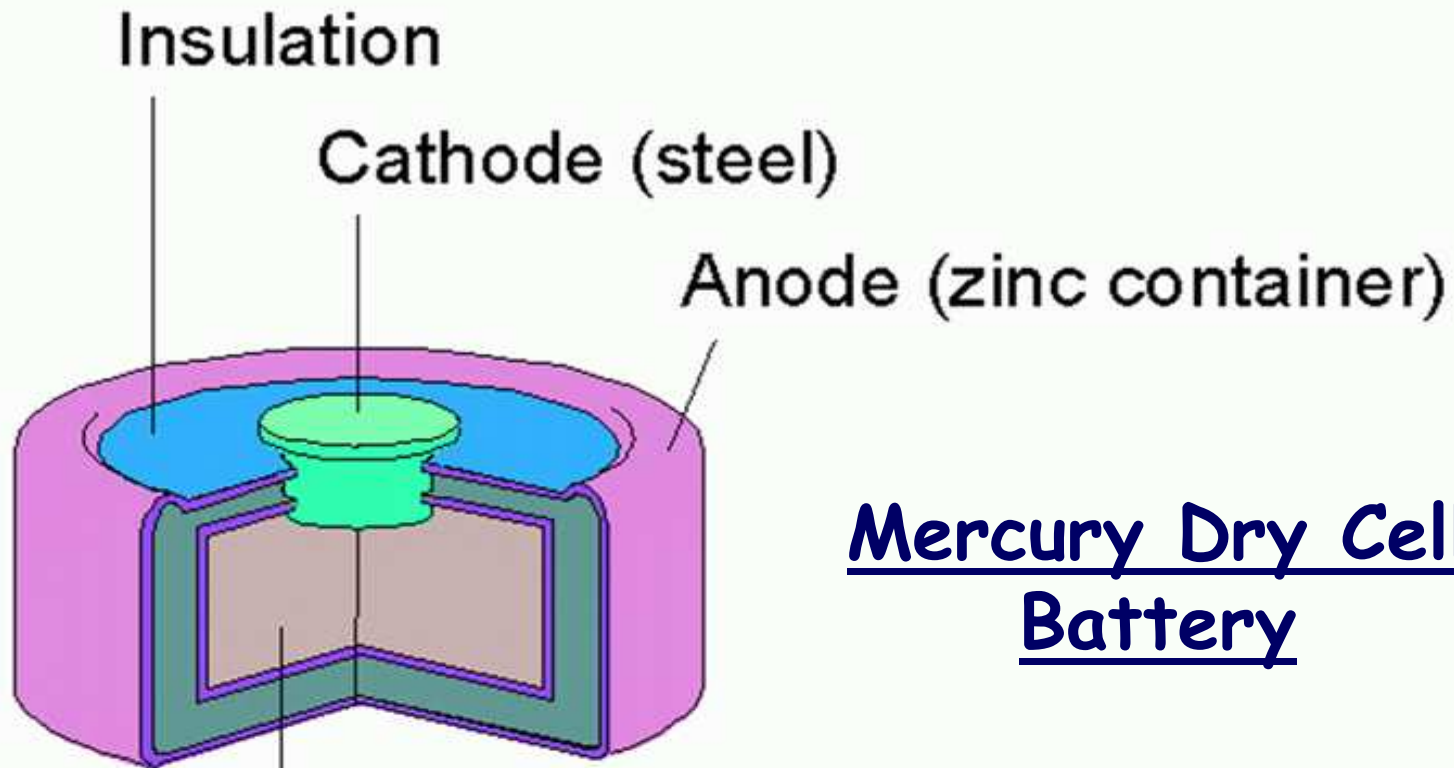
Zinc-Carbon Dry Cell Battery



Anode
(zinc inner case)

Cathode
(graphite rod)

Paste of MnO_2 ,
 NH_4Cl , and
carbon



Mercury Dry Cell
Battery

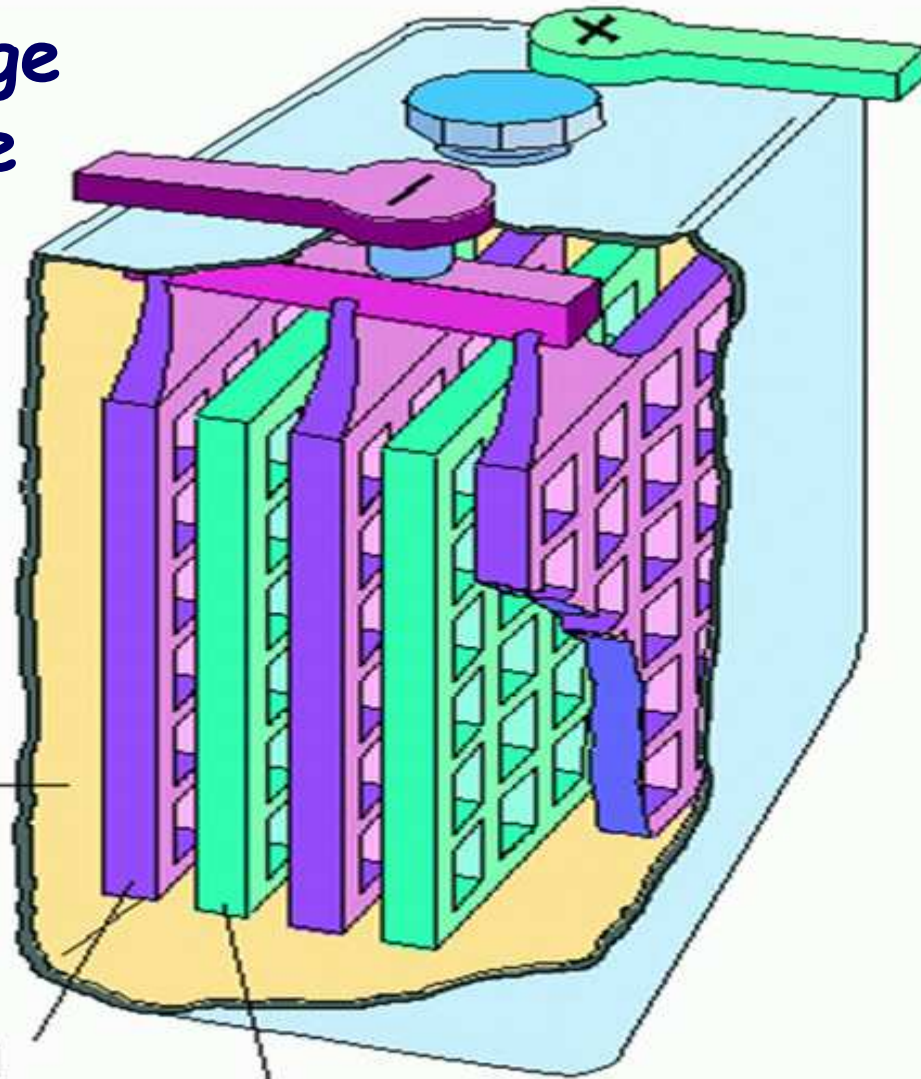
Solution of HgO (oxidizing agent) in a basic medium (KOH and Zn(OH)₂)

Lead Storage Automotive Battery

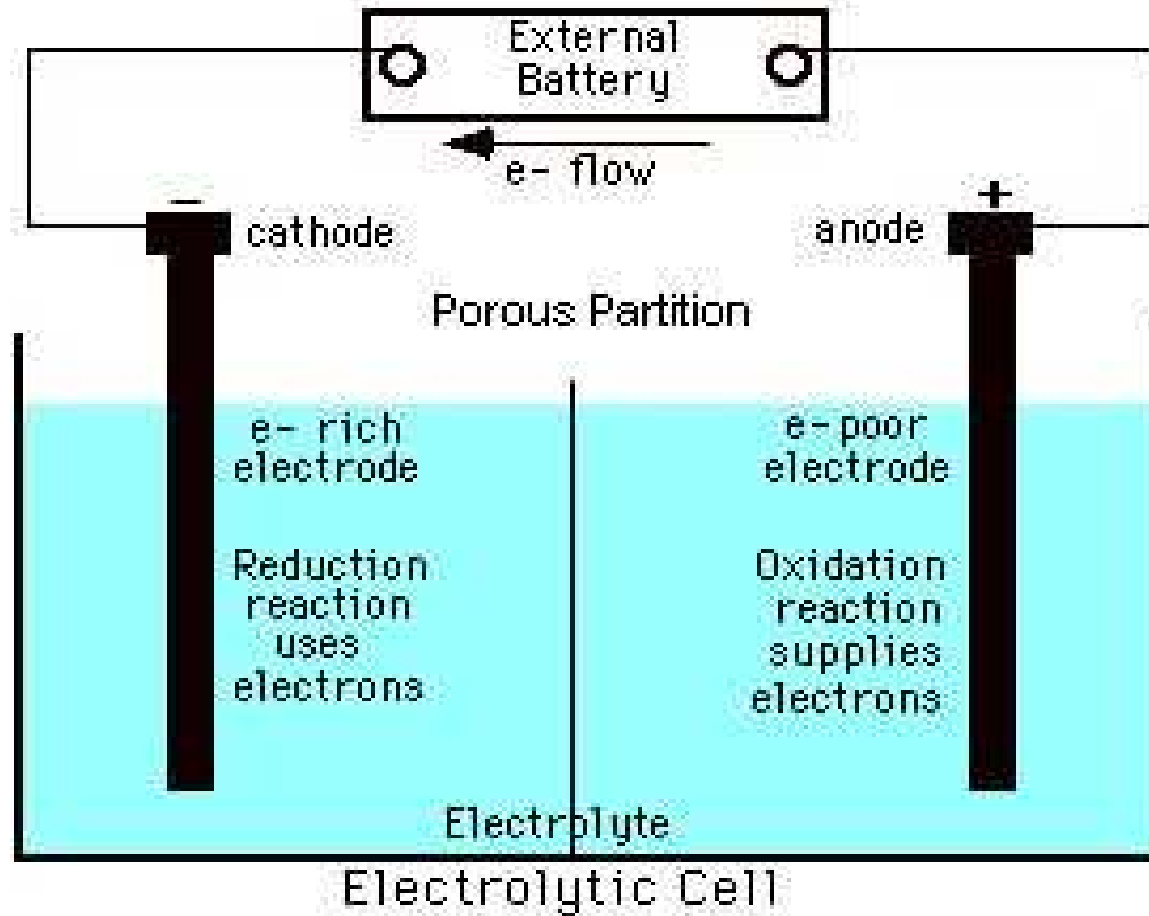
H_2SO_4
electrolyte
solution

Anode (lead
grid filled with
spongy lead)

Cathode (lead
grid filled with
spongy PbO_2)



Electrolytic Cells



**Cathode:
negative**

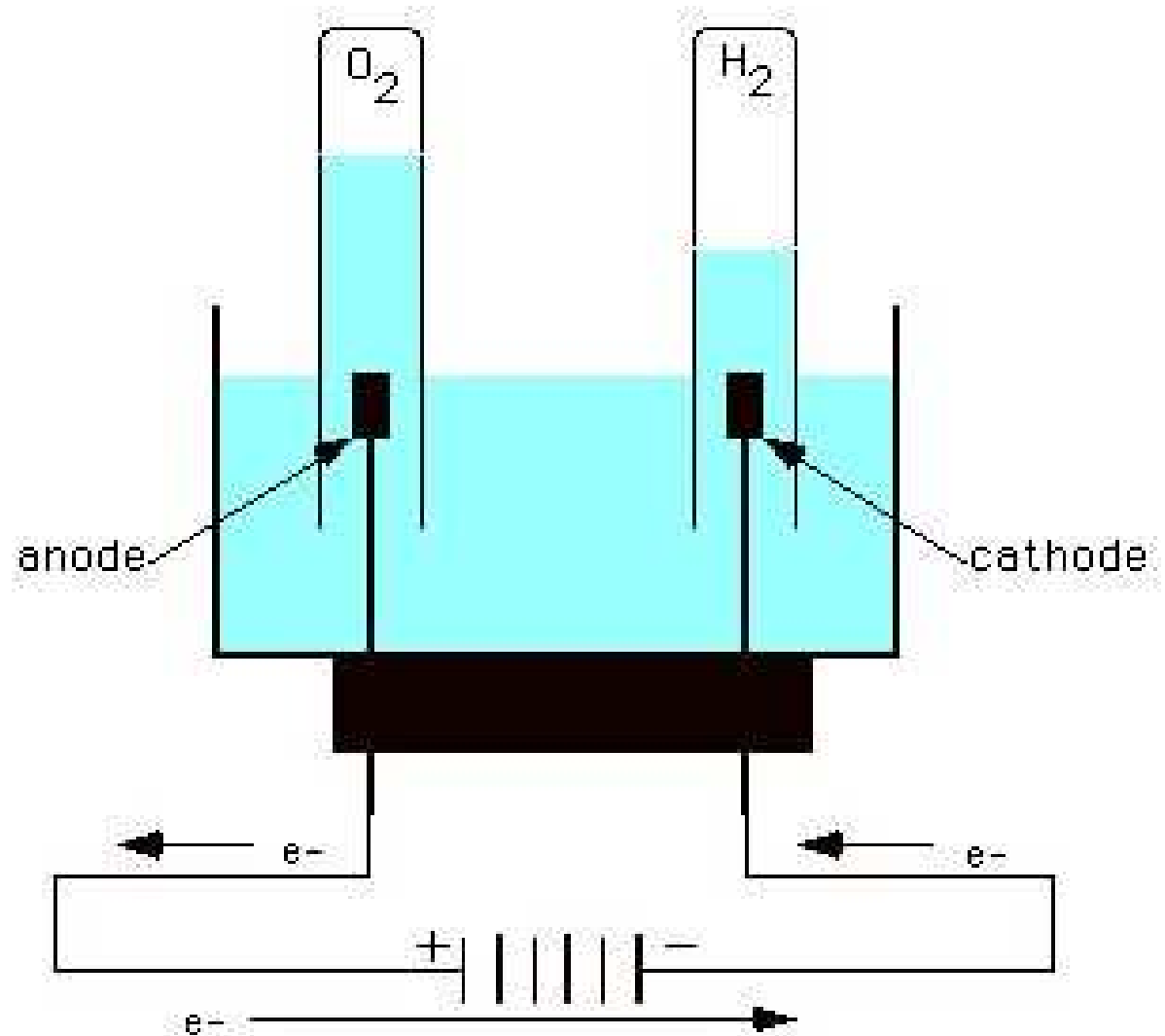
**Anode:
positive**

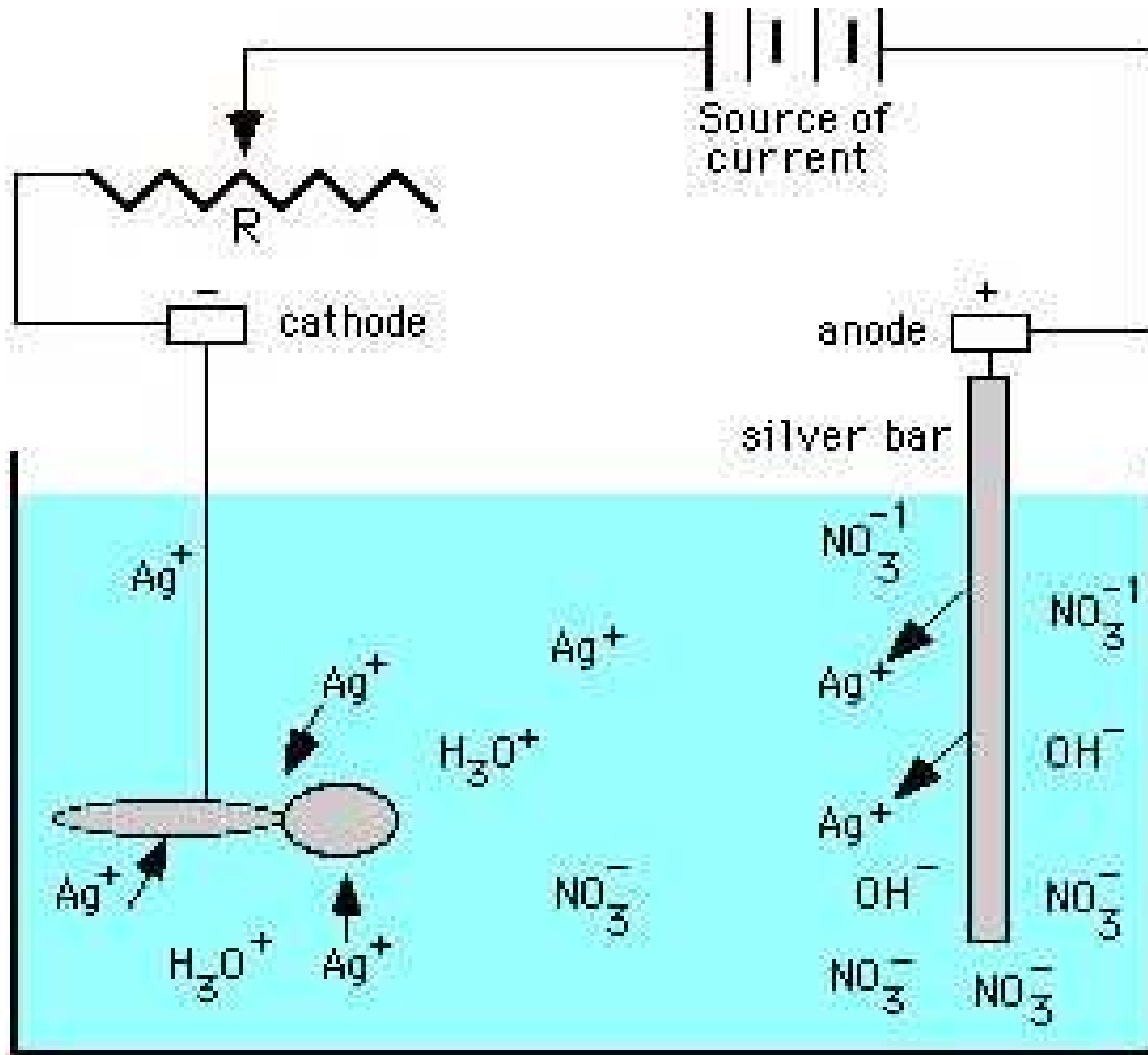
Electrolytic cells: Electrochemical cell in which an electric current is used to drive a non-spontaneous process

Electrolysis of H_2O



Electrolyte is usually dilute sulfuric acid





Electroplating of Silver

Cathode is the object to be plated

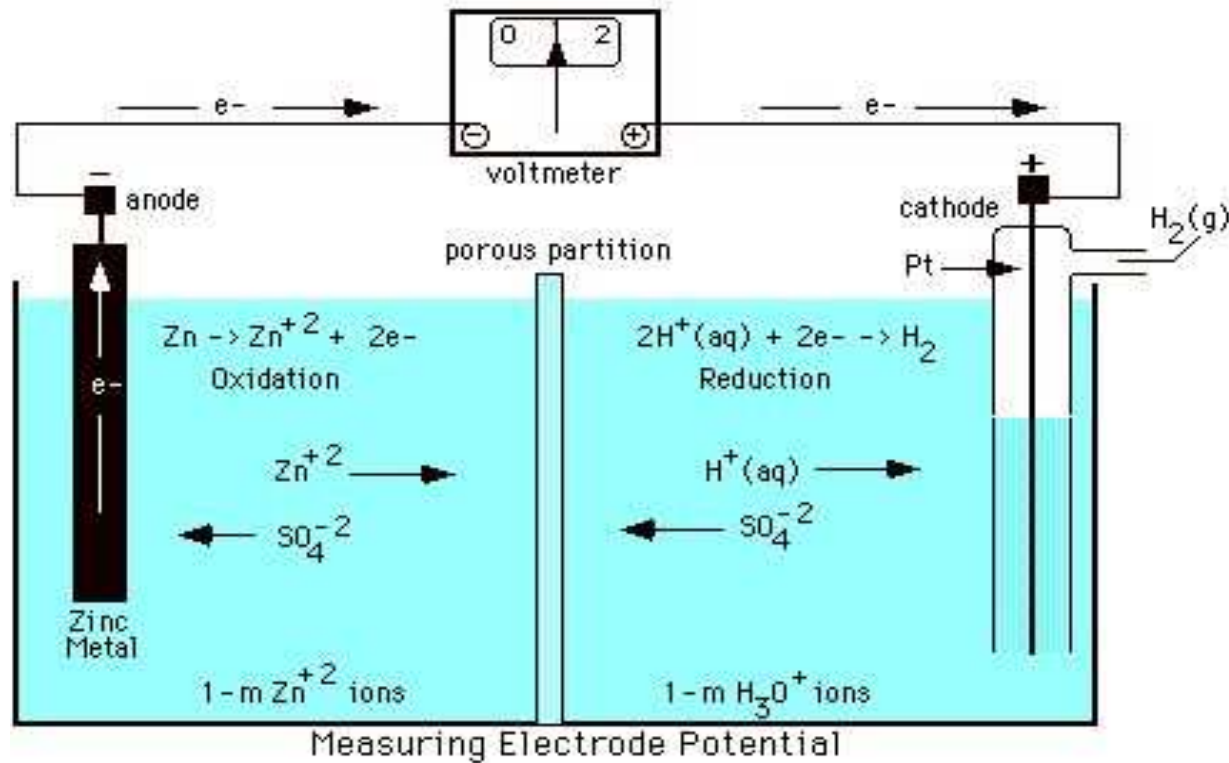
Anode is a piece of the plating metal

Solution contains ions of the plating metal

Table 17.1 Standard Reduction Potentials at 25°C (298 K) for Many Common Half-reactions

Half-reaction	ξ° (V)	Half-reaction	ξ° (V)
$F_2 + 2e^- \rightarrow 2F^-$	2.87	$O_2 + 2H_2O + 4e^- \rightarrow 4HO^-$	0.40
$Ag^{2+} + e^- \rightarrow Ag^+$	1.99	$Cu^{2+} + 2e^- \rightarrow Cu$	0.34
$Co^{3+} + e^- \rightarrow Co^{2+}$	1.82	$Hg_2Cl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$	0.34
$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$	1.78	$AgCl + e^- \rightarrow Ag + Cl^-$	0.22
$Ce^{4+} + e^- \rightarrow Ce^{3+}$	1.70	$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3 + H_2SO_3 + H_2O$	0.20
$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$	1.69	$Cu^{2+} + e^- \rightarrow Cu^+$	0.16
$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$	1.68	$2H^+ + 2e^- \rightarrow H_2$	0.00
$2e^- + 2H^+ + IO_4^- \rightarrow IO_3^- + H_2O$	1.60	$Fe^{3+} + 3e^- \rightarrow Fe$	-0.036
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	1.51	$Pb^{2+} + 2e^- \rightarrow Pb$	-0.13
$Au^{3+} + 3e^- \rightarrow Au$	1.50	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.14
$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$	1.46	$Ni^{2+} + 2e^- \rightarrow Ni$	-0.23
$Cl_2 + 2e^- \rightarrow 2Cl^-$	1.36	$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	-0.35
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	1.33	$Cd^{2+} + 2e^- \rightarrow Cd$	-0.40
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.23	$Fe^{2+} + 2e^- \rightarrow Fe$	-0.44
$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	1.21	$Cr^{3+} + e^- \rightarrow Cr^{2+}$	-0.50
$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2}I_2 + 3H_2O$	1.20	$Cr^{3+} + 3e^- \rightarrow Cr$	-0.73
$Br_2 + 2e^- \rightarrow 2Br^-$	1.09	$Zn^{2+} + 2e^- \rightarrow Zn$	-0.76
$VO_2 + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$	1.00	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	-0.83
$AuCl_4^- + 3e^- \rightarrow Au + 4Cl^-$	0.99	$Mn^{2+} + 2e^- \rightarrow Mn$	-1.18
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	0.96	$Al^{3+} + 3e^- \rightarrow Al$	-1.66
$ClO_2 + e^- \rightarrow ClO_2^-$	0.954	$H_2 + 2e^- \rightarrow 2H^-$	-2.23
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.91	$Mg^{2+} + 2e^- \rightarrow Mg$	-2.37
$Ag^+ + e^- \rightarrow Ag$	0.80	$La^{3+} + 3e^- \rightarrow La$	-2.37
$Hg_2^{2+} + 2e^- \rightarrow 2Hg^+$	0.80	$Na^+ + e^- \rightarrow Na$	-2.71
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77	$Ca^{2+} + 2e^- \rightarrow Ca$	-2.76
$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$	0.68	$Ba^{2+} + 2e^- \rightarrow Ba$	-2.90
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	0.56	$K^+ + e^- \rightarrow K$	-2.92
$I_2 + 2e^- \rightarrow 2I^-$	0.54	$Li^+ + e^- \rightarrow Li$	-3.05
$Cu^+ + e^- \rightarrow Cu$	0.52		

Measuring Electrode Potential



1. H_2 Electrode is assigned a potential of zero volts
2. Second electrode is placed in a solution of its own ions
3. Reduction potential of second electrode is measured.