

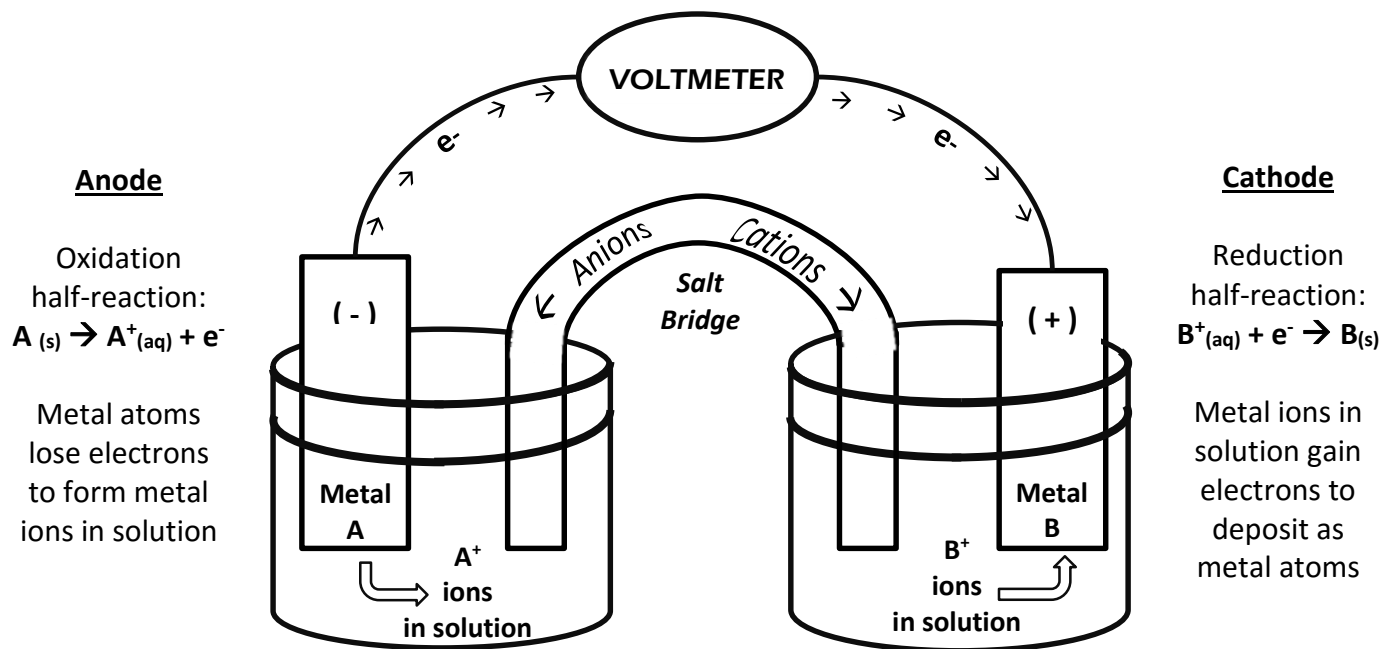
Electrochemistry

Galvanic or Voltaic Cell

Energy released from spontaneous redox reactions is converted to electrical energy

$$\Delta G < 0$$

$$E_{\text{cell}} > 0$$

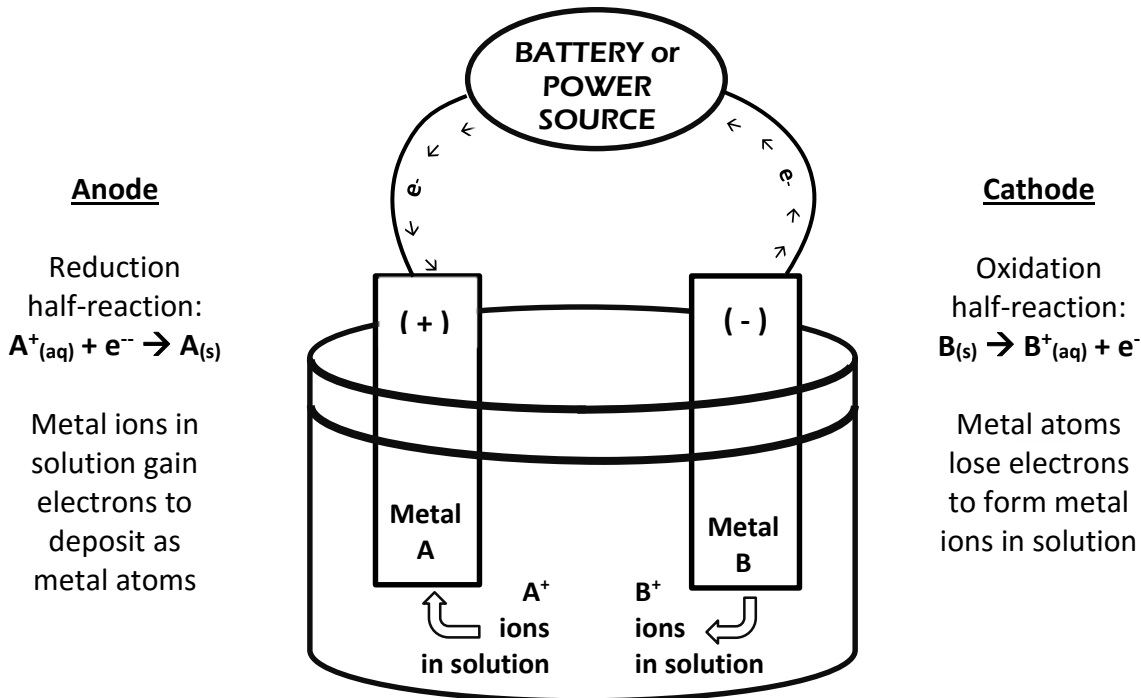


Electrolytic cell

Electrical energy is used to drive nonspontaneous redox reactions

$$\Delta G > 0$$

$$E_{\text{cell}} < 0$$



Standard Reduction Potentials at 25° C

| Half-reaction | E° (V) | Half-reaction | E° (V) |
|---|--------|--|--------|
| $F_2(g) + 2e^- \rightarrow 2F^-(aq)$ | +2.87 | $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ | +0.337 |
| $O_3(g) + 2H^+(aq) + 2e^- \rightarrow O_2(g) + H_2O(l)$ | +2.07 | $BiO^+(aq) + 2H^+(aq) + 3e^- \rightarrow Bi(s) + H_2O(l)$ | +0.32 |
| $Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$ | +1.842 | $AgCl(s) + e^- \rightarrow Ag(s) + Cl^-(aq)$ | +0.222 |
| $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$ | +1.776 | $HSO_4^-(aq) + 3H^+(aq) + 2e^- \rightarrow H_2SO_3(aq) + H_2O(l)$ | +0.17 |
| $PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$ | +1.685 | $Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$ | +0.154 |
| $HClO(aq) + H^+ + e^- \rightarrow Cl_2(g) + H_2O(l)$ | +1.63 | $Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$ | +0.153 |
| $Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq)$ | +1.61 | $S(s) + 2H^+(aq) + 2e^- \rightarrow H_2S(g)$ | +0.141 |
| $BrO_3^-(aq) + 6H^+(aq) + 5e^- \rightarrow Br_2(l) + 3H_2O(l)$ | +1.52 | $AgBr(s) + e^- \rightarrow Ag(s) + Br^-(aq)$ | +0.095 |
| $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ | +1.51 | $Ag(S_2O_3)_2^{3-}(aq) + e^- \rightarrow Ag(s) + 2S_2O_3^{2-}(aq)$ | +0.01 |
| $Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$ | +1.359 | $2H^+(aq) + 2e^- \rightarrow H_2(g)$ | 0.000 |
| $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ | +1.33 | $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ | -0.126 |
| $MnO_2(s) + 4H^+(aq) + 2e^- \rightarrow Mn^{2+}(aq) + 2H_2O(l)$ | +1.23 | $CrO_4^{2-}(aq) + 4H_2O(l) + 3e^- \rightarrow Cr(OH)_3(s) + 5OH^-(aq)$ | -0.13 |
| $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ | +1.23 | $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$ | -0.136 |
| $IO_3^-(aq) + 6H^+(aq) + 5e^- \rightarrow I_2(s) + 3H_2O(l)$ | +1.195 | $AgI(s) + e^- \rightarrow Ag(s) + I^-(aq)$ | -0.151 |
| $Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$ | +1.065 | $CuI(s) + e^- \rightarrow Cu(s) + I^-(aq)$ | -0.185 |
| $HNO_2(aq) + H^+(aq) + e^- \rightarrow NO(g) + H_2O(l)$ | +1.00 | $N_2(g) + 5H^+(aq) + 4e^- \rightarrow N_2H_5^+(aq)$ | -0.23 |
| $VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$ | +1.00 | $Co^{2+}(aq) + 2e^- \rightarrow Co(s)$ | -0.277 |
| $NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(l)$ | +0.96 | $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ | -0.28 |
| $2Hg^{2+}(aq) + 2e^- \rightarrow Hg_2^{2+}(aq)$ | +0.920 | $Ag(CN)_2^-(aq) + e^- \rightarrow Ag(s) + 2CN^-(aq)$ | -0.31 |
| $ClO^-(aq) + H_2O(l) + 2e^- \rightarrow Cl^-(aq) + 2OH^-(aq)$ | +0.89 | $PbSO_4(s) + H^+(aq) + 2e^- \rightarrow Pb(s) + HSO_4^-(aq)$ | -0.356 |
| $HO_2^-(aq) + H_2O(l) + 2e^- \rightarrow 3OH^-(aq)$ | +0.88 | $Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$ | -0.403 |
| $Hg_2^{2+}(aq) + 2e^- \rightarrow Hg(l)$ | +0.854 | $Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$ | -0.41 |
| $Ag^+(aq) + e^- \rightarrow Ag(s)$ | +0.799 | $Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$ | -0.440 |
| $Hg_2^{2+}(aq) + 2e^- \rightarrow 2Hg(l)$ | +0.789 | $2CO_2(g) + 2H^+(aq) + 3e^- \rightarrow H_2C_2O_4(aq)$ | -0.49 |
| $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ | +0.771 | $Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$ | -0.74 |
| $PtCl_4^{2-}(aq) + 2e^- \rightarrow Pt(s) + 4Cl^-(aq)$ | +0.73 | $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ | -0.763 |
| $O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O_2(aq)$ | +0.68 | $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ | -0.83 |
| $MnO_4^-(aq) + 2H_2O(l) + 3e^- \rightarrow MnO_2(s) + 4OH^-(aq)$ | +0.59 | $N_2(g) + 4H_2O(l) + 4e^- \rightarrow 4OH^-(aq) + N_2H_4(aq)$ | -1.16 |
| $H_3AsO_4(aq) + 2H^+(aq) + 2e^- \rightarrow H_3AsO_3(aq) + H_2O(l)$ | +0.559 | $Mn^{2+}(aq) + 2e^- \rightarrow Mn(s)$ | -1.18 |
| $I_2(s) + 2e^- \rightarrow 2I^-(aq)$ | +0.536 | $Al^{3+}(aq) + 3e^- \rightarrow Al(s)$ | -1.66 |
| $Cu^+(aq) + e^- \rightarrow Cu(s)$ | +0.521 | $Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$ | -2.37 |
| $H_2SO_3(aq) + 4H^+(aq) + 4e^- \rightarrow S(s) + 3H_2O(l)$ | +0.45 | $Na^+(aq) + e^- \rightarrow Na(s)$ | -2.71 |
| $Ag_2CrO_4(s) + 2e^- \rightarrow 2Ag(s) + CrO_4^{2-}(aq)$ | +0.446 | $Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$ | -2.87 |
| $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ | +0.40 | $Ba^{2+}(aq) + 2e^- \rightarrow Ba(s)$ | -2.90 |
| $Fe(CN)_6^{3-}(aq) + e^- \rightarrow Fe(CN)_6^{4-}(aq)$ | +0.36 | $K^+(aq) + e^- \rightarrow K(s)$ | -2.925 |
| | | $Li^+(aq) + e^- \rightarrow Li(s)$ | -3.05 |