

## STANDARD ELECTRODE POTENTIALS

## Ionic Concentrations 1 M Water At 298 K, 1 atm

$F_{2}(g) + 2e^{-} \rightarrow 2F^{-} \\ 8H^{+} + MnO_{4}^{-} + 5e^{-} \rightarrow Mn^{2+} + 4H_{2}O \\ Au^{3+} + 3e^{-} \rightarrow Au(s) \\ Cl_{2}(g) + 2e^{-} \rightarrow 2Cl^{-} \\ 4H^{+} + Cr_{2}O_{7}^{-2} + 6e^{-} \rightarrow 2Cr^{3+} + 7H_{2}O \\ 4H^{+} + O_{2}(g) + 4e^{-} \rightarrow 2H_{2}O \\ 4H^{+} + MnO_{2}(s) + 2e^{-} \rightarrow Mn^{2+} + 2H_{2}O \\ H^{2} + 2e^{-} \rightarrow Hg(\ell) \\ Ag^{+} + e^{-} \rightarrow Ag(s) \\ Hg_{2}^{2+} + 2e^{-} \rightarrow Hg(\ell) \\ Fe^{3+} + e^{-} \rightarrow Fe^{2+} \\ Cu^{+} + e^{-} \rightarrow Cu(s) \\ Cu^{2+} + 2e^{-} \rightarrow Cu(s) \\ Cu^{2+} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O \\ Ag^{+} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O \\ Ag^{+} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O \\ Fe^{3+} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O \\ Ag^{+} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2$		
$F_{2}(g) + 2e^{-} \rightarrow 2F^{-}$ $8H^{+} + MnO_{4}^{-} + 5e^{-} \rightarrow Mn^{2+} + 4H_{2}O$ $Au^{3+} + 3e^{-} \rightarrow Au(s)$ $Cl_{2}(g) + 2e^{-} \rightarrow 2Cl^{-}$ $14H^{+} + Cr_{2}O_{7}^{-2} + 6e^{-} \rightarrow 2Cr^{3+} + 7H_{2}O$ $4H^{+} + O_{2}(g) + 4e^{-} \rightarrow 2H_{2}O$ $4H^{+} + MnO_{2}(s) + 2e^{-} \rightarrow Mn^{2+} + 2H_{2}O$ $Br_{2}(\ell) + 2e^{-} \rightarrow 2Br^{-}$ $Hg^{2+} + 2e^{-} \rightarrow Hg(\ell)$ $Ag^{+} + e^{-} \rightarrow Ag(s)$ $Hg_{2}^{2+} + 2e^{-} \rightarrow Hg(\ell)$ $Fe^{3+} + e^{-} \rightarrow Fe^{2+}$ $Cu^{+} + e^{-} \rightarrow Cu(s)$ $Cu^{2+} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O$ $Fe^{3+} + 2e^{-} \rightarrow Sn(s)$ $AH^{+} + SO_{4}^{2-} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O$ $Sn^{4+} + 2e^{-} \rightarrow H_{2}(g)$ $Pb^{2+} + 2e^{-} \rightarrow Pb(s)$ $Sn^{2+} + 2e^{-} \rightarrow Fe(s)$ $Co^{2+} + 2e^{-} \rightarrow Sn(s)$ $Ni^{2+} + 2e^{-} \rightarrow Fe(s)$ $Co^{2+} + 2e^{-} \rightarrow Sn(s)$ $Co^{$	Half-Reaction	
$8H^{+} + MnO_{4}^{-} + 5e^{-} - Mn^{2+} + 4H_{2}O$ $Au^{3+} + 3e^{-} - Au(s)$ $Cl_{2}(g) + 2e^{-} - 2Cl^{-}$ $14H^{+} + Cr_{2}O_{7}^{2-} + 6e^{-} - 2Cr^{3+} + 7H_{2}O$ $4H^{+} + O_{2}(g) + 4e^{-} - 2H_{2}O$ $4H^{+} + MnO_{2}(s) + 2e^{-} - Mn^{2+} + 2H_{2}O$ $H^{2+} + 2e^{-} - Hg(\ell)$ $H^{2+} + 2e^{-} - Hg(\ell)$ $Ag^{+} + e^{-} - Ag(s)$ $Hg_{2}^{2+} + 2e^{-} - 2Hg(\ell)$ $Fe^{3+} + e^{-} - Fe^{2+}$ $1_{2}(s) + 2e^{-} - 2I^{-}$ $Cu^{+} + e^{-} - Cu(s)$ $Cu^{2+} + 2e^{-} - Cu(s)$ $Cu^{2+} + 2e^{-} - SO_{2}(aq) + 2H_{2}O$ $Sn^{4+} + 2e^{-} - Sn(s)$ $2H^{+} + 2e^{-} - H_{2}(g)$ $Pb^{2+} + 2e^{-} - Sn(s)$ $Ni^{2+} + 2e^{-} - Sn(s)$ $Cr^{3+} + 3e^{-} - Cr(s)$ $Cr^{3+} + 3e^{-} - Cr(s)$ $2H_{2}O + 2e^{-} - 2OH^{-} + H_{2}(g)$ $Mn^{2+} + 2e^{-} - Mn(s)$ $Al^{3+} + 3e^{-} - Al(s)$ $Mg^{2+} + 2e^{-} - Mg(s)$ $Na^{+} + e^{-} - Na(s)$ $Ca^{2+} + 2e^{-} - Sn(s)$ $Na^{+} + e^{-} - Na(s)$ $Ca^{2+} + 2e^{-} - Sn(s)$ $Na^{+} + e^{-} - Sn(s)$ $2H_{2}O + 2e^{-} - 2OH^{-} + H_{2}(g)$ $2H_{2}O + 2e^{-} - 2OH^{-} + H_{2}(g)$ $2H_{2}O + 2e^{-} - Sn(s)$ $2H_{2$		(volts)
$Au^{3+} + 3e^{-} \rightarrow Au(s)$ $Cl_{2}(g) + 2e^{-} \rightarrow 2Cl^{-}$ $14H^{+} + Cr_{2}O_{7}^{2-} + 6e^{-} \rightarrow 2Cr^{3+} + 7H_{2}O$ $4H^{+} + O_{2}(g) + 4e^{-} \rightarrow 2H_{2}O$ $4H^{+} + MnO_{2}(s) + 2e^{-} \rightarrow Mn^{2+} + 2H_{2}O$ $Hg^{2+} + 2e^{-} \rightarrow Hg(\ell)$ $Ag^{+} + e^{-} \rightarrow Ag(s)$ $Hg_{2}^{2+} + 2e^{-} \rightarrow 2Hg(\ell)$ $Fe^{3+} + e^{-} \rightarrow Fe^{2+}$ $Cu^{+} + e^{-} \rightarrow Cu(s)$ $Cu^{2+} + 2e^{-} \rightarrow Sn^{2+}$ $2H^{+} + 2e^{-} \rightarrow Hg(g)$ $Pb^{2+} + 2e^{-} \rightarrow Sn^{2+}$ $2H^{+} + 2e^{-} \rightarrow Sn(s)$ $Ni^{2+} + 2e^{-} \rightarrow Fe(s)$ $Co^{2+} + 2e^{-} \rightarrow Fe(s)$ $Cr^{3+} + 3e^{-} \rightarrow Cr(s)$ $2H_{2}O + 2e^{-} \rightarrow Cn(s)$ $2H_{2}O + 2e^{-} \rightarrow Cn(s)$ $2H_{2}O + 2e^{-} \rightarrow Cn(s)$ $2H_{2}O + 2e^{-} \rightarrow Al(s)$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $Al^{3+} + 2e^{-} \rightarrow Ba(s)$ $Cs^{+} + 2e^{-} \rightarrow Sr(s)$ $Sr^{2+} + 2e^{-} \rightarrow Sr(s)$		+2.87
$\begin{array}{c} \text{Cl}_2(g) + 2e^ 2\text{Cl}^- \\ 14\text{H}^+ + \text{Cr}_2\text{O}_7^{-2} + 6e^ 2\text{Cr}^{-3+} + 7\text{H}_2\text{O} \\ 4\text{H}^+ + \text{O}_2(g) + 4e^ 2\text{H}_2\text{O} \\ 4\text{H}^+ + \text{MnO}_2(s) + 2e^ \text{Mn}^{2+} + 2\text{H}_2\text{O} \\ \text{Br}_2(\ell) + 2e^ 2\text{Br}^- \\ \text{Hg}^{2+} + 2e^ \text{Hg}(\ell) \\ \text{Ag}^+ + e^ \text{Ag}(s) \\ \text{Hg}_2^{-2} + 2e^ 2\text{Hg}(\ell) \\ \text{Fe}^{-3+} + e^ \text{Fe}^{-2+} \\ \text{Cu}^+ + e^ \text{Cu}(s) \\ \text{Cu}^2 + 2e^ 2\text{I}^- \\ \text{Cu}^+ + 2e^ \text{Sn}^{2+} \\ \text{Cu}^+ + 2e^ \text{Sn}^{2+} \\ \text{Cu}^+ + 2e^ \text{Sn}^{2+} \\ \text{O.70} \\ \text{Sn}^{4+} + 2e^ \text{Sn}(s) \\ \text{Sn}^{2+} + 2e^ \text{Sn}(s) \\ \text{Ni}^{2+} + 2e^ \text{Ni}(s) \\ \text{Co}^{2+} + 2e^ \text{Ni}(s) \\ \text{Co}^{2+} + 2e^ \text{Fe}(s) \\ \text{Cr}^{3+} + 3e^ \text{Cr}(s) \\ \text{Cr}^{3+} + 3e^ \text{Cr}(s) \\ \text{Ch}^{2+} + 2e^ \text{Ch}(s) \\ \text{Ch}^{2+} + 2e^ \text{Ch}^{2+} \\ \text{Ch}^{$	$8H^{+} + MnO_{4}^{-} + 5e^{-} \rightarrow Mn^{2+} + 4H_{2}O$	+1.51
$\begin{array}{c} \text{Cl}_2(g) + 2e^ 2\text{Cl}^- \\ 14\text{H}^+ + \text{Cr}_2\text{O}_7^{-2} + 6e^ 2\text{Cr}^{-3+} + 7\text{H}_2\text{O} \\ 4\text{H}^+ + \text{O}_2(g) + 4e^ 2\text{H}_2\text{O} \\ 4\text{H}^+ + \text{MnO}_2(s) + 2e^ \text{Mn}^{2+} + 2\text{H}_2\text{O} \\ \text{Br}_2(\ell) + 2e^ 2\text{Br}^- \\ \text{Hg}^{2+} + 2e^ \text{Hg}(\ell) \\ \text{Ag}^+ + e^ \text{Ag}(s) \\ \text{Hg}_2^{-2} + 2e^ 2\text{Hg}(\ell) \\ \text{Fe}^{-3+} + e^ \text{Fe}^{-2+} \\ \text{Cu}^+ + e^ \text{Cu}(s) \\ \text{Cu}^2 + 2e^ 2\text{I}^- \\ \text{Cu}^+ + 2e^ \text{Sn}^{2+} \\ \text{Cu}^+ + 2e^ \text{Sn}^{2+} \\ \text{Cu}^+ + 2e^ \text{Sn}^{2+} \\ \text{O.70} \\ \text{Sn}^{4+} + 2e^ \text{Sn}(s) \\ \text{Sn}^{2+} + 2e^ \text{Sn}(s) \\ \text{Ni}^{2+} + 2e^ \text{Ni}(s) \\ \text{Co}^{2+} + 2e^ \text{Ni}(s) \\ \text{Co}^{2+} + 2e^ \text{Fe}(s) \\ \text{Cr}^{3+} + 3e^ \text{Cr}(s) \\ \text{Cr}^{3+} + 3e^ \text{Cr}(s) \\ \text{Ch}^{2+} + 2e^ \text{Ch}(s) \\ \text{Ch}^{2+} + 2e^ \text{Ch}^{2+} \\ \text{Ch}^{$	$Au^{3+} + 3e^{-} \rightarrow Au(s)$	+1.50
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$Cl_2(g) + 2e^- \rightarrow 2Cl^-$	+1.36
$\begin{array}{llllllllllllllllllllllllllllllllllll$		+1.23
$\begin{array}{c} Br_{2}(\ell) + 2e^{-} - 2Br^{-} \\ Hg^{2+} + 2e^{-} + Hg(\ell) \\ Ag^{+} + e^{-} - Ag(s) \\ Hg_{2}^{2+} + 2e^{-} - 2Hg(\ell) \\ Fe^{3+} + e^{-} - Fe^{2+} \\ L_{2}(s) + 2e^{-} - 2I^{-} \\ Cu^{+} + e^{-} - Cu(s) \\ Cu^{2+} + 2e^{-} - SO_{2}(aq) + 2H_{2}O \\ Sn^{4+} + 2e^{-} - Fe(s) \\ 2H^{+} + 2e^{-} - Fe(s) \\ 2H^{+} + 2e^{-} - Fe(s) \\ Co^{2+} + 2e^{-} - Co(s) \\ Pb^{2+} + 2e^{-} - Fe(s) \\ Co^{2+} + 2e^{-} - Fe(s) \\ Cr^{3+} + 3e^{-} - Cr(s) \\ 2H_{2}O + 2e^{-} - 2OH^{-} + H_{2}(g) \\ Mn^{2+} + 2e^{-} - Mn(s) \\ Al^{3+} + 3e^{-} - Al(s) \\ Mg^{2+} + 2e^{-} - Mg(s) \\ Na^{+} + e^{-} - Na(s) \\ Ca^{2+} + 2e^{-} - Fe(s) \\ Ca^{2+} + 2e^{-} - Fe(s) \\ Ca^{2+} + 2e^{-} - Sr(s) \\ Rb^{2+} + 2e^{-} - Ba(s) \\ -2.37 \\ Ca^{2+} + 2e^{-} - Ba(s) \\ -2.89 \\ Ba^{2+} + 2e^{-} - Ba(s) \\ -2.91 \\ Cs^{+} + e^{-} - K(s) \\ Rb^{+} + e^{-} - Rb(s) \\ -2.98 \\ -$		+1.23
$\begin{array}{c} Hg^{2+} + 2e^{-} \rightarrow Hg(\ell) \\ Ag^{+} + e^{-} \rightarrow Ag(s) \\ Hg_{2}^{2+} + 2e^{-} \rightarrow 2Hg(\ell) \\ Fe^{3+} + e^{-} \rightarrow Fe^{2+} \\ L_{2}(s) + 2e^{-} \rightarrow 2I^{-} \\ Cu^{+} + e^{-} \rightarrow Cu(s) \\ Cu^{2+} + 2e^{-} \rightarrow Cu(s) \\ + 0.34 \\ 4H^{+} + SO_{4}^{2-} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O \\ Sn^{4+} + 2e^{-} \rightarrow Sn^{2+} \\ 2H^{+} + 2e^{-} \rightarrow H_{2}(g) \\ Pb^{2+} + 2e^{-} \rightarrow Pb(s) \\ Sn^{2+} + 2e^{-} \rightarrow Sn(s) \\ + Ni^{2+} + 2e^{-} \rightarrow Fe(s) \\ Co^{2+} + 2e^{-} \rightarrow Fe(s) \\ Cr^{3+} + 3e^{-} \rightarrow Cr(s) \\ 2H_{2}O + 2e^{-} \rightarrow 2OH^{-} + H_{2}(g) \\ Mn^{2+} + 2e^{-} \rightarrow Mn(s) \\ Al^{3+} + 3e^{-} \rightarrow Al(s) \\ Mg^{2+} + 2e^{-} \rightarrow Mg(s) \\ Mg^{2+} + 2e^{-} \rightarrow Hg(s) \\ -2.37 \\ Na^{+} + e^{-} \rightarrow Na(s) \\ -2.37 \\ Sr^{2+} + 2e^{-} \rightarrow Sr(s) \\ Ba^{2+} + 2e^{-} \rightarrow Sr(s) \\ Ba^{2+} + 2e^{-} \rightarrow Sr(s) \\ -2.89 \\ Sr^{2+} + 2e^{-} \rightarrow Sr(s) \\ -2.91 \\ Cs^{+} + e^{-} \rightarrow K(s) \\ -2.93 \\ Rb^{+} + e^{-} \rightarrow Rb(s) \\ -2.98 \\ -$		+1.22
$\begin{array}{c} Ag^{+} + e^{-} \rightarrow Ag(s) \\ Hg_{2}^{2+} + 2e^{-} \rightarrow 2Hg(\ell) \\ Fe^{3+} + e^{-} \rightarrow Fe^{2+} \\ L_{2}(s) + 2e^{-} \rightarrow 2I^{-} \\ Cu^{+} + e^{-} \rightarrow Cu(s) \\ Cu^{2+} + 2e^{-} \rightarrow Cu(s) \\ + 0.34 \\ 4H^{+} + SO_{4}^{2-} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O \\ Pb^{2+} + 2e^{-} \rightarrow H_{2}(g) \\ Pb^{2+} + 2e^{-} \rightarrow H_{2}(g) \\ + 0.17 \\ Sn^{4+} + 2e^{-} \rightarrow H_{2}(g) \\ Pb^{2+} + 2e^{-} \rightarrow H_{3}(s) \\ + 0.18 \\ Sn^{2+} + 2e^{-} \rightarrow H_{3}(s) \\ + 0.19 \\ Co^{2+} + 2e^{-} \rightarrow H_{3}(s) \\ + 0.19 \\ Co^{2+} + 2e^{-} \rightarrow H_{3}(s) \\ + 0.19 \\ Co^{2+} + 2e^{-} \rightarrow H_{3}(s) \\ + 0.19 \\ - 0.13 \\ - 0.14 \\ - 0.15 \\ - 0.13 \\ - 0.14 \\ - 0.26 \\ - 0.28 \\ Fe^{2+} + 2e^{-} \rightarrow H_{3}(s) \\ - 0.26 \\ - 0.28 \\ Fe^{2+} + 2e^{-} \rightarrow Fe(s) \\ - 0.74 \\ - 0.76 \\ - 0.83 \\ - 0.74 \\ - 0.76 \\ - 0.83 \\ - 0.76 \\ - 0.83 \\ - 0.14 \\ - 0.26 \\ - 0.28 \\ - 0.28 \\ - 0.45 \\ - 0.74 \\ - 0.76 \\ - 0.83 \\ - 0.14 \\ - 0.26 \\ - 0.28 \\ - 0.28 \\ - 0.45 \\ - 0.74 \\ - 0.76 \\ - 0.83 \\ - 0.14 \\ - 0.26 \\ - 0.28 \\ - 0.28 \\ - 0.45 \\ - 0.74 \\ - 0.76 \\ - 0.83 \\ - 0.14 \\ - 0.26 \\ - 0.28 \\ - 0.28 \\ - 0.45 \\ - 0.74 \\ - 0.76 \\ - 0.83 \\ - 0.14 \\ - 0.26 \\ - 0.28 \\ - 0.28 \\ - 0.45 \\ - 0.28 \\ - 0.28 \\ - 0.45 \\ - 0.28 \\ - 0.28 \\ - 0.45 \\ - 0.28 \\ - 0.28 \\ - 0.45 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ - 0.28 \\ $		+1.09
$\begin{array}{c} Hg_2^{2+} + 2e^ 2Hg(\ell) \\ Fe^{3+} + e^ Fe^{2+} \\ I_2(s) + 2e^ 2I^- \\ Cu^+ + e^ Cu(s) \\ Cu^{2+} + 2e^ Cu(s) \\ 4H^+ + SO_4^{2-} + 2e^ SO_2(aq) + 2H_2O \\ Fe^{3+} + 2e^ Fe^{3+} \\ 2H^+ + 2e^ Fe^{3+$		+0.85
$Fe^{3+} + e^{-} - Fe^{2+}$ $I_{2}(s) + 2e^{-} - 2I^{-}$ $Cu^{+} + e^{-} - Cu(s)$ $Cu^{2+} + 2e^{-} - Cu(s)$ $4H^{+} + SO_{4}^{2-} + 2e^{-} - SO_{2}(aq) + 2H_{2}O$ $Sn^{4+} + 2e^{-} - H_{2}(g)$ $Pb^{2+} + 2e^{-} - Pb(s)$ $Sn^{2+} + 2e^{-} - Sn(s)$ $Ni^{2+} + 2e^{-} - Sn(s)$ $Cc^{2+} + 2e^{-} - Sn(s)$ $Cr^{3+} + 3e^{-} - Cr(s)$ $2H_{2}O + 2e^{-} - 2OH^{-} + H_{2}(g)$ $Mn^{2+} + 2e^{-} - Mn(s)$ $Al^{3+} + 3e^{-} - Al(s)$ $Mg^{2+} + 2e^{-} - Mg(s)$ $Al^{3+} + 3e^{-} - Al(s)$ $Mg^{2+} + 2e^{-} - Sn(s)$ $Na^{+} + e^{-} - Na(s)$ $Ca^{2+} + 2e^{-} - Sn(s)$ $Sr^{2+} + 2e^{-} - Sn(s)$ $2H_{2}O + 2e^{-} - 2OH^{-} + H_{2}(g)$ $Mn^{2+} + 2e^{-} - Mn(s)$ $-1.66$ $Mg^{2+} + 2e^{-} - Mg(s)$ $-2.37$ $Ca^{2+} + 2e^{-} - Sn(s)$ $Sr^{2+} + 2e^{-} - Sn(s)$ $S$	$Ag^+ + e^- \rightarrow Ag(s)$	+0.80
$I_{2}(s) + 2e^{-} - 2I^{-}$ $Cu^{+} + e^{-} - Cu(s)$ $Cu^{2+} + 2e^{-} - Cu(s)$ $4H^{+} + SO_{4}^{2-} + 2e^{-} - SO_{2}(aq) + 2H_{2}O$ $Sn^{4+} + 2e^{-} - H_{2}(g)$ $Pb^{2+} + 2e^{-} - Pb(s)$ $Sn^{2+} + 2e^{-} - Ni(s)$ $Co^{2+} + 2e^{-} - Ni(s)$ $Cr^{3+} + 3e^{-} - Cr(s)$ $2H_{2}O + 2e^{-} - 2OH^{-} + H_{2}(g)$ $Mn^{2+} + 2e^{-} - Mn(s)$ $AI^{3+} + 3e^{-} - AI(s)$ $Mg^{2+} + 2e^{-} - Mn(s)$ $AI^{3+} + 3e^{-} - AI(s)$ $Mg^{2+} + 2e^{-} - Sn(s)$ $Na^{+} + e^{-} - Na(s)$ $Ca^{2+} + 2e^{-} - Ca(s)$ $Sr^{2+} + 2e^{-} - Sr(s)$ $Sr^{2+} + 2e^{-} - Sr(s)$ $Sr^{2+} + 2e^{-} - Ca(s)$ $Sr^{$		+0.80
$\begin{array}{c} \text{Cu}^{+} + \text{e}^{-} \rightarrow \text{Cu(s)} \\ \text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu(s)} \\ \text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu(s)} \\ \text{4H}^{+} + \text{SO}_{4}^{2-} + 2\text{e}^{-} \rightarrow \text{SO}_{2}(\text{aq}) + 2\text{H}_{2}\text{O} \\ \text{Sn}^{4+} + 2\text{e}^{-} \rightarrow \text{H}_{2}(\text{g}) \\ \text{Pb}^{2+} + 2\text{e}^{-} \rightarrow \text{Pb(s)} \\ \text{Sn}^{2+} + 2\text{e}^{-} \rightarrow \text{Sn(s)} \\ \text{Ni}^{2+} + 2\text{e}^{-} \rightarrow \text{Ni(s)} \\ \text{Co}^{2+} + 2\text{e}^{-} \rightarrow \text{Ni(s)} \\ \text{Co}^{2+} + 2\text{e}^{-} \rightarrow \text{Co(s)} \\ \text{Fe}^{2+} + 2\text{e}^{-} \rightarrow \text{Fe(s)} \\ \text{Cr}^{3+} + 3\text{e}^{-} \rightarrow \text{Cr(s)} \\ \text{2H}_{2}\text{O} + 2\text{e}^{-} \rightarrow \text{2DH}^{-} + \text{H}_{2}(\text{g}) \\ \text{Mn}^{2+} + 2\text{e}^{-} \rightarrow \text{Mn(s)} \\ \text{Al}^{3+} + 3\text{e}^{-} \rightarrow \text{Al(s)} \\ \text{Mg}^{2+} + 2\text{e}^{-} \rightarrow \text{Mg(s)} \\ \text{Na}^{+} + \text{e}^{-} \rightarrow \text{Na(s)} \\ \text{Ca}^{2+} + 2\text{e}^{-} \rightarrow \text{Sr(s)} \\ \text{Ba}^{2+} + 2\text{e}^{-} \rightarrow \text{Ba(s)} \\ \text{Cs}^{+} + \text{e}^{-} \rightarrow \text{Cs(s)} \\ \text{Rb}^{+} + \text{e}^{-} \rightarrow \text{Rb(s)} \\ \end{array} \begin{array}{c} +0.52 \\ +0.34 \\ +0.17 \\ +0.15 \\ 0.00 \\ -0.13 \\ -0.14 \\ -0.26 \\ -0.28 \\ -0.28 \\ -0.28 \\ -0.28 \\ -0.28 \\ -0.28 \\ -0.28 \\ -0.28 \\ -0.37 \\ -0.74 \\ -0.76 \\ -0.74 \\ -0.76 \\ -0.83 \\ -0.76 \\ -0.83 \\ -1.19 \\ -1.66 \\ -0.23 \\ -2.37 \\ -2.37 \\ -2.37 \\ -2.37 \\ -2.37 \\ -2.87 \\ -2.89 \\ -2.91 \\ -2.92 \\ -2.93 \\ -2.93 \\ -2.93 \\ -2.93 \\ -2.98 \\ \end{array}$	· -	+0.77
$Cu^{2+} + 2e^{-} \rightarrow Cu(s)$ $4H^{+} + SO_{4}^{2-} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O$ $Sn^{4+} + 2e^{-} \rightarrow Sn^{2+}$ $2H^{+} + 2e^{-} \rightarrow H_{2}(g)$ $Pb^{2+} + 2e^{-} \rightarrow Pb(s)$ $Sn^{2+} + 2e^{-} \rightarrow Sn(s)$ $Ni^{2+} + 2e^{-} \rightarrow Ni(s)$ $Co^{2+} + 2e^{-} \rightarrow Co(s)$ $Fe^{2+} + 2e^{-} \rightarrow Fe(s)$ $Cr^{3+} + 3e^{-} \rightarrow Cr(s)$ $2H_{2}O + 2e^{-} \rightarrow 2OH^{-} + H_{2}(g)$ $Mn^{2+} + 2e^{-} \rightarrow Mn(s)$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $Mg^{2+} + 2e^{-} \rightarrow Mg(s)$ $Na^{+} + e^{-} \rightarrow Na(s)$ $Ca^{2+} + 2e^{-} \rightarrow Ca(s)$ $Sr^{2+} + 2e^{-} \rightarrow Sr(s)$ $Ba^{2+} + 2e^{-} \rightarrow Ba(s)$ $Cs^{+} + e^{-} \rightarrow Cs(s)$ $Rb^{+} + e^{-} \rightarrow Rb(s)$ $-2.98$ $-2.91$ $-2.98$ $-2.98$		+0.54
$4H^{+} + SO_{4}^{2-} + 2e^{-} \rightarrow SO_{2}(aq) + 2H_{2}O$ $Sn^{4+} + 2e^{-} \rightarrow Sn^{2+}$ $2H^{+} + 2e^{-} \rightarrow H_{2}(g)$ $Pb^{2+} + 2e^{-} \rightarrow Pb(s)$ $Sn^{2+} + 2e^{-} \rightarrow Sn(s)$ $Ni^{2+} + 2e^{-} \rightarrow Ni(s)$ $Co^{2+} + 2e^{-} \rightarrow Fe(s)$ $Cr^{3+} + 3e^{-} \rightarrow Cr(s)$ $2H_{2}O + 2e^{-} \rightarrow Zn(s)$ $2H_{2}O + 2e^{-} \rightarrow Al(s)$ $Mn^{2+} + 2e^{-} \rightarrow Mg(s)$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $Mg^{2+} + 2e^{-} \rightarrow Mg(s)$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $Mg^{2+} + 2e^{-} \rightarrow Sn(s)$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $-1.19$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $-1.66$ $Mg^{2+} + 2e^{-} \rightarrow Mg(s)$ $-2.37$ $Na^{+} + e^{-} \rightarrow Na(s)$ $Ca^{2+} + 2e^{-} \rightarrow Sr(s)$ $Ba^{2+} + 2e^{-} \rightarrow Sr(s)$ $Ba^{2+} + 2e^{-} \rightarrow Sr(s)$ $-2.89$ $Ba^{2+} + 2e^{-} \rightarrow Cs(s)$ $-2.91$ $Cs^{+} + e^{-} \rightarrow Cs(s)$ $-2.93$ $Rb^{+} + e^{-} \rightarrow Rb(s)$		+0.52
$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$ +0.15 $2H^+ + 2e^- \rightarrow H_2(g)$ 0.00 $Pb^{2+} + 2e^- \rightarrow Pb(s)$ -0.13 $Sn^{2+} + 2e^- \rightarrow Sn(s)$ -0.14 $Ni^{2+} + 2e^- \rightarrow Ni(s)$ -0.26 $Co^{2+} + 2e^- \rightarrow Co(s)$ -0.28 $Fe^{2+} + 2e^- \rightarrow Fe(s)$ -0.45 $Cr^{3+} + 3e^- \rightarrow Cr(s)$ -0.74 $Zn^{2+} + 2e^- \rightarrow Zn(s)$ -0.76 $2H_2O + 2e^- \rightarrow 2OH^- + H_2(g)$ -0.83 $Mn^{2+} + 2e^- \rightarrow Mn(s)$ -1.19 $Al^{3+} + 3e^- \rightarrow Al(s)$ -1.66 $Mg^{2+} + 2e^- \rightarrow Mg(s)$ -2.37 $Na^+ + e^- \rightarrow Na(s)$ -2.37 $Ca^{2+} + 2e^- \rightarrow Ca(s)$ -2.87 $Sr^{2+} + 2e^- \rightarrow Sr(s)$ -2.89 $Ba^{2+} + 2e^- \rightarrow Ba(s)$ -2.91 $Cs^+ + e^- \rightarrow Cs(s)$ -2.92 $K^+ + e^- \rightarrow K(s)$ -2.98 $Rb^+ + e^- \rightarrow Rb(s)$ -2.98	$Cu^{2+} + 2e^{-} \rightarrow Cu(s)$	+0.34
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$4H^{+} + SO_{4}^{2-} + 2e^{-} + SO_{2}(aq) + 2H_{2}O$	+0.17
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		+0.15
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$2H^+ + 2e^- \rightarrow H_2(g)$	0.00
$Ni^{2+} + 2e^{-} \rightarrow Ni(s)$ $-0.26$ $Co^{2+} + 2e^{-} \rightarrow Co(s)$ $-0.28$ $Fe^{2+} + 2e^{-} \rightarrow Fe(s)$ $-0.45$ $Cr^{3+} + 3e^{-} \rightarrow Cr(s)$ $-0.74$ $Zn^{2+} + 2e^{-} \rightarrow Zn(s)$ $-0.76$ $2H_2O + 2e^{-} \rightarrow 2OH^{-} + H_2(g)$ $-0.83$ $Mn^{2+} + 2e^{-} \rightarrow Mn(s)$ $-1.19$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $-1.66$ $Mg^{2+} + 2e^{-} \rightarrow Mg(s)$ $-2.37$ $Na^{+} + e^{-} \rightarrow Na(s)$ $-2.71$ $Ca^{2+} + 2e^{-} \rightarrow Ca(s)$ $-2.87$ $Sr^{2+} + 2e^{-} \rightarrow Sr(s)$ $-2.89$ $Ba^{2+} + 2e^{-} \rightarrow Ba(s)$ $-2.91$ $Cs^{+} + e^{-} \rightarrow Cs(s)$ $-2.92$ $K^{+} + e^{-} \rightarrow K(s)$ $-2.93$ $Rb^{+} + e^{-} \rightarrow Rb(s)$ $-2.98$	$Pb^{2+} + 2e^{-} \rightarrow Pb(s)$	-0.13
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\operatorname{Sn}^{2+} + 2e^{-} \rightarrow \operatorname{Sn}(s)$	-0.14
$Fe^{2+} + 2e^{-} \rightarrow Fe(s)$ $Cr^{3+} + 3e^{-} \rightarrow Cr(s)$ $Zn^{2+} + 2e^{-} \rightarrow Zn(s)$ $2H_2O + 2e^{-} \rightarrow 2OH^{-} + H_2(g)$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $Mg^{2+} + 2e^{-} \rightarrow Mg(s)$ $Na^{+} + e^{-} \rightarrow Na(s)$ $Ca^{2+} + 2e^{-} \rightarrow Ca(s)$ $Sr^{2+} + 2e^{-} \rightarrow Sr(s)$ $Ba^{2+} + 2e^{-} \rightarrow Ba(s)$ $Cs^{+} + e^{-} \rightarrow Cs(s)$ $Cs^{+} + e^{-} \rightarrow K(s)$ $Rb^{+} + e^{-} \rightarrow Rb(s)$ $-0.45$ $-0.74$ $-0.83$ $-1.19$ $-1.66$ $-1.66$ $-2.37$ $-2.37$ $-2.87$ $-2.89$ $-2.91$ $-2.92$ $-2.93$ $-2.93$	$Ni^{2+} + 2e^{-} \rightarrow Ni(s)$	-0.26
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$Co^{2+} + 2e^{-} \rightarrow Co(s)$	-0.28
$Zn^{2+} + 2e^{-} \rightarrow Zn(s)$ -0.76 $2H_2O + 2e^{-} \rightarrow 2OH^{-} + H_2(g)$ -0.83 $Mn^{2+} + 2e^{-} \rightarrow Mn(s)$ -1.19 $Al^{3+} + 3e^{-} \rightarrow Al(s)$ -1.66 $Mg^{2+} + 2e^{-} \rightarrow Mg(s)$ -2.37 $Na^{+} + e^{-} \rightarrow Na(s)$ -2.71 $Ca^{2+} + 2e^{-} \rightarrow Ca(s)$ -2.87 $Sr^{2+} + 2e^{-} \rightarrow Sr(s)$ -2.89 $Ba^{2+} + 2e^{-} \rightarrow Ba(s)$ -2.91 $Cs^{+} + e^{-} \rightarrow Cs(s)$ -2.92 $K^{+} + e^{-} \rightarrow K(s)$ -2.93 $Rb^{+} + e^{-} \rightarrow Rb(s)$ -2.98	$Fe^{2+} + 2e^{-} \rightarrow Fe(s)$	-0.45
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$Cr^{3+} + 3e^{-} \rightarrow Cr(s)$	-0.74
$Mn^{2+} + 2e^{-} \rightarrow Mn(s)$ $Al^{3+} + 3e^{-} \rightarrow Al(s)$ $-1.66$ $Mg^{2+} + 2e^{-} \rightarrow Mg(s)$ $-2.37$ $Na^{+} + e^{-} \rightarrow Na(s)$ $-2.71$ $Ca^{2+} + 2e^{-} \rightarrow Ca(s)$ $Sr^{2+} + 2e^{-} \rightarrow Sr(s)$ $-2.89$ $-2.89$ $-2.89$ $-2.91$ $-2.92$ $-2.92$ $-2.93$ $-2.93$ $-2.98$	$Zn^{2+} + 2e^{-} \rightarrow Zn(s)$	-0.76
$Al^{3^{+}} + 3e^{-} \rightarrow Al(s)$ $Mg^{2^{+}} + 2e^{-} \rightarrow Mg(s)$ $Na^{+} + e^{-} \rightarrow Na(s)$ $Ca^{2^{+}} + 2e^{-} \rightarrow Ca(s)$ $Sr^{2^{+}} + 2e^{-} \rightarrow Sr(s)$ $Ba^{2^{+}} + 2e^{-} \rightarrow Ba(s)$ $Cs^{+} + e^{-} \rightarrow Cs(s)$ $K^{+} + e^{-} \rightarrow K(s)$ $Rb^{+} + e^{-} \rightarrow Rb(s)$ $-1.66$ $-2.37$ $-2.87$ $-2.89$ $-2.91$ $-2.92$ $-2.92$ $-2.93$ $-2.98$	$2H_2O + 2e^- \rightarrow 2OH^- + H_2(g)$	-0.83
$Mg^{2+} + 2e^{-} - Mg(s)$ -2.37 $Na^{+} + e^{-} - Na(s)$ -2.71 $Ca^{2+} + 2e^{-} - Ca(s)$ -2.87 $Sr^{2+} + 2e^{-} - Sr(s)$ -2.89 $Ba^{2+} + 2e^{-} - Ba(s)$ -2.91 $Cs^{+} + e^{-} - Cs(s)$ -2.92 $K^{+} + e^{-} - K(s)$ -2.93 $Rb^{+} + e^{-} - Rb(s)$ -2.98	$Mn^{2+} + 2e^{-} \rightarrow Mn(s)$	-1.19
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$Al^3 + 3e^- \rightarrow Al(s)$	-1.66
$Ca^{2+} + 2e^{-} \rightarrow Ca(s)$ $Sr^{2+} + 2e^{-} \rightarrow Sr(s)$ $Ba^{2+} + 2e^{-} \rightarrow Ba(s)$ $Cs^{+} + e^{-} \rightarrow Cs(s)$ $K^{+} + e^{-} \rightarrow K(s)$ $Rb^{+} + e^{-} \rightarrow Rb(s)$ $-2.93$ $-2.98$	$Mg^{2+} + 2e^{-} \rightarrow Mg(s)$	-2.37
$Sr^{2+} + 2e^{-} \rightarrow Sr(s)$ -2.89 $Ba^{2+} + 2e^{-} \rightarrow Ba(s)$ -2.91 $Cs^{+} + e^{-} \rightarrow Cs(s)$ -2.92 $K^{+} + e^{-} \rightarrow K(s)$ -2.93 $Rb^{+} + e^{-} \rightarrow Rb(s)$ -2.98	$Na' + e^- \rightarrow Na(s)$	-2.71
$Ba^{2+} + 2e^{-} \rightarrow Ba(s) \qquad -2.91$ $Cs^{+} + e^{-} \rightarrow Cs(s) \qquad -2.92$ $K^{+} + e^{-} \rightarrow K(s) \qquad -2.93$ $Rb^{+} + e^{-} \rightarrow Rb(s) \qquad -2.98$	$Ca^{2+} + 2e^{-} \rightarrow Ca(s)$	-2.87
$Cs^{+} + e^{-} - Cs(s)$ -2.92 $K^{+} + e^{-} - K(s)$ -2.93 $Rb^{+} + e^{-} - Rb(s)$ -2.98	$Sr^2 + 2e^- \rightarrow Sr(s)$	-2.89
$K^{+} + e^{-} \rightarrow K(s)$ -2.93 $Rb^{+} + e^{-} \rightarrow Rb(s)$ -2.98	$Ba^2 + 2e^- \rightarrow Ba(s)$	-2.91
$Rb^+ + e^- \rightarrow Rb(s)$ -2.98		
	$K' + e^{-} \rightarrow K(s)$	
• • • • • • • • • • • • • • • • • • •		
$Li^+ + e^- \rightarrow Li(s)$ -3.04	$L_1 + e \rightarrow Li(s)$	-3.04

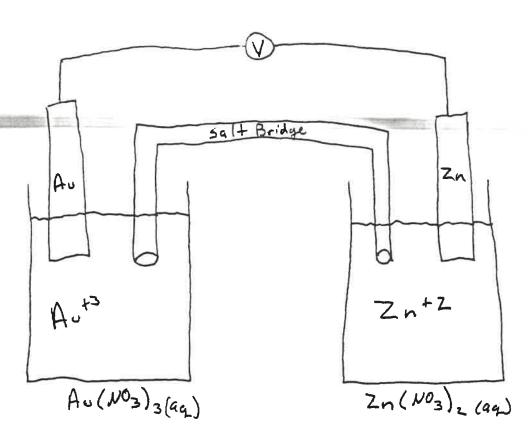


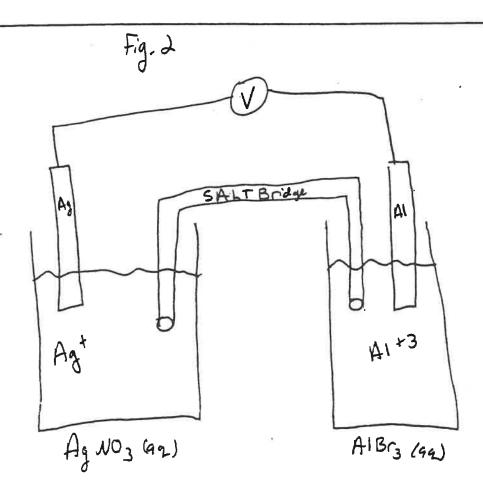
VAI	POR PRESSU	RE OF W	VATER
°C	torr (mmHg)	°C	torr (mmHg)
0	4.6	26	25.2
5	6.5	27	26.7
10	9.2	28	28.3
15	12.8	29	30.0
16	13.6	30	31.8
17	14.5	40	55.3
18	15.5	50	92.5
19	16.5	60	149.4
20	17.5	70	233.7
21	18.7	80	355.1
22	19.8	90	525.8
23	21.1	100	760.0
24	22.4	105	906.1
25	23.8	110	1074.6

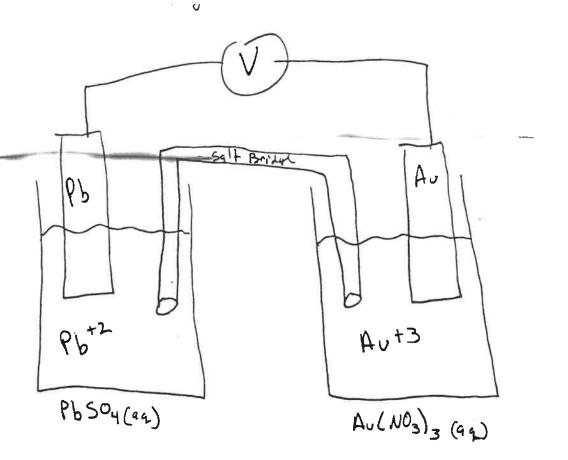
Name:	Period:
Date: Answer the following eight questions for each ce	Electrochemical Cells
Fig. 1	Fig. 2
1. What gets oxidized?	1. What gets oxidized?
2. What gets reduced?	2. What gets reduced?
3. Which electrode is the anode?	3. Which electrode is the anode?
4. Which electrode is the cathode?	4. Which electrode is the cathode?
5. Which electrode gains mass?	5. Which electrode gains mass?
6. Which electrode loses mass?	6. Which electrode loses mass?
7. Which direction do the e's flow?	7. Which direction do the e-'s flow?
8. Which direction do the ions flow?	8. Which direction do the ions flow?
9. What is the voltage of the cell?	9. What is the voltage of the cell?
fig. 3	fig. 4
1. What gets oxidized?	1. What gets oxidized?
2. What gets reduced?	2. What gets reduced?
3. Which electrode is the anode?	3. Which electrode is the anode?
4. Which electrode is the cathode?	4. Which electrode is the cathode?
5. Which electrode gains mass?	5. Which electrode gains mass?
6. Which electrode loses mass?	6. Which electrode loses mass?
7. Which direction do e <sup>-</sup> 's the flow?	7. Which direction do e <sup>-</sup> 's the flow?
8. Which direction do the ions flow?	Which direction do the ions flow?

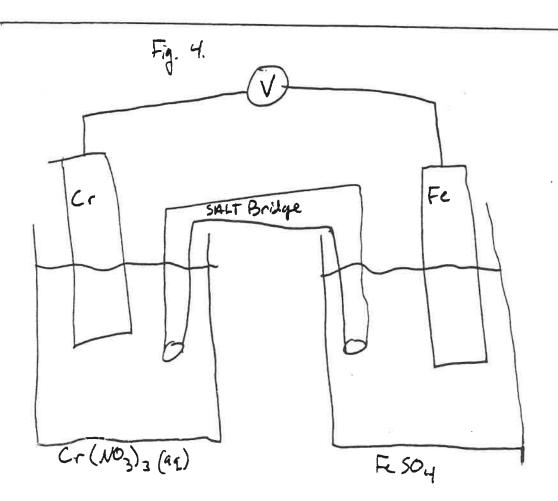
9. What is the voltage of the cell?

9. What is the voltage of the cell?







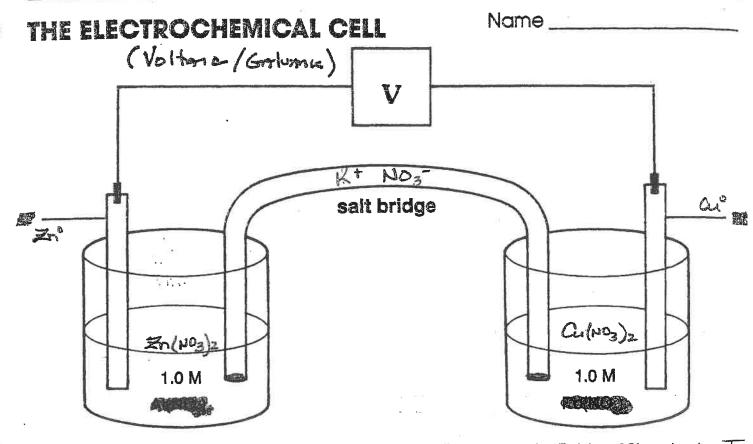


Electrode Potentials.

- 1. Which is more easily oxidized, metal, aluminum or lead?\_\_\_\_\_
- 2. What is the balanced equation showing the spontaneous reaction that occurs?

What is the maximum voltage that the above cell can produce?\_\_\_\_\_

- 4. What is the direction of electron flow in the wire?
- What is the direction of positive ion flow in the sait bridge?
- 6. Which electrode is decreasing in size?\_\_\_\_\_
- 7. Which electrode is increasing in size? \_\_\_\_\_
- 8. What is happening to the concentration of aluminum lons?
- 9. What is happening to the concentration of lead ions?\_\_\_\_\_
- What is the voltage in this cell when the reaction reaches equilibrium?
- 11. Which is the anode?\_\_\_\_\_
- Which is the cathode?\_\_\_\_\_
- 13. What is the positive electrode?\_\_\_\_\_
- 14. What is the negative electrode?



Answer the questions below referring to the above diagram and a Table of Standard  $\mathcal{T}$  Electrode Potentials.

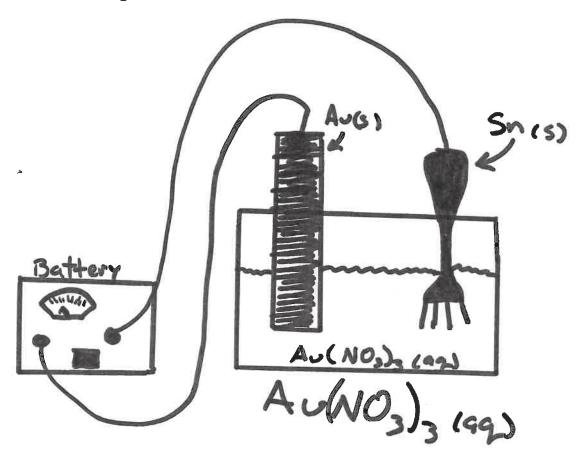
2. What is the balanced equation showing the spontaneous reaction that occurs?

$\nabla^{\!$	What is the maximum voltage that the above cell can produce?
4,	What is the direction of electron flow in the wire?
5.	What is the direction of positive ion flow in the salt bridge?
6.	Which electrode is decreasing in size?
· 7.	Which electrode is increasing in size?
8.	What is happening to the concentration of ions?
9.	What is happening to the concentration of ions?
DO W.	What is the voltage in this cell when the reaction reaches equilibrium?
11.	Which is the anode?
12.	Which is the cathode?
13.	What is the positive electrode?

14. What is the negative electrode?

## Electrolytic cells

- 1. Which electrode does oxidation occur?
- 2. Which electrode does reduction occur?
- 3. Write the oxidation ½ reaction.
- 4. Write the reduction ½ reaction.
- 5. The object to be plated will be which electrode?
- 6. Is this a spontaneous reaction?
- 7. Which is the positive electrode?
- 8. Which is the negative electrode?



- between particles for (1) neutrons (2) electrons (3) protons (4) positrons
- 3. Given the chemical cell reaction:

$$2Ag^{2} - Zn^{3} \rightarrow 2Ag^{3} + Zn^{2}$$

What is the net potential  $(E^b)$  for the cell?

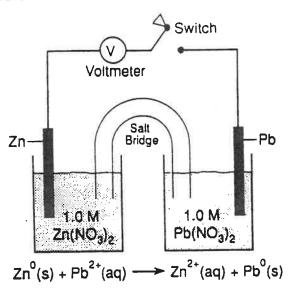
(1) 1.56 V

(2) 2.36 V

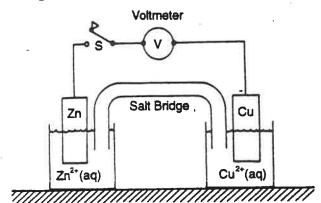
(3) 0.84 V

(4) 0.04 V

Base your answers to questions 14 and 15 on the diagram of the chemical cell shown below. The reaction occurs at 1 atmosphere and 298 K.



- 14. When the switch is closed, what occurs?
  - (1) Pb is oxidized and electrons flow to the Zn electrode.
  - (2) Pb is reduced and electrons flow to the Zn electrode.
  - (3) Zn is oxidized and electrons flow to the Pb electrode.
  - (4) Zn is reduced and electrons flow to the Pb electrode.
- 15. When the switch is closed, the cell voltage  $(E^0)$  is
  - (1) +0.63 V (2) +0.89 V (3) -0.63 V (4) -0.89 V
- 16. The diagram below represents an electrochemical cell



When switch S is closed, which particles undergo reduction? (1)  $Zn^{2+}$  ions (2) Zn atoms (3)  $Cu^{2+}$  ions (4) Cu atom

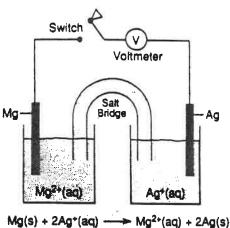
- 17. A chemical cell is made up of two half-cells connected by a salt bridge and an external conductor. What is the function of the salt bridge? (1) to permit the migration of ions (2) to prevent the migration of ions (3) to permit the mixing of solutions (4) to prevent the flow of electrons
- 7. How many moles of electrons would be required to completely reduce 1.5 moles of A1<sup>3+</sup> to A1? (1) 0.50 (2) 1.5 (3) 3.0 (4) 4.5
  - 19. In the reaction  $Zn(s) + Cu^{2*}(aq) \rightarrow Zn^{2*}(aq) + Cu(s)$ , the reducing agent is (1) Zn(s) (2) Cu(s) (3)  $Cu^{2*}(aq)$  (4)  $Zn^{2*}(aq)$

equation below?

$$2NaCl + 2H_2O + electricity \rightarrow Cl_2 + H_2 + 2NaOH$$

- (1) The reaction occurs in a chemical cell and releases energy.
- (2) The reaction occurs in a chemical cell and absorbs energy.
- (3) The reaction occurs in an electrolytic cell and releases energy.
- (4) The reaction occurs in an electrolytic cell and absorbs energy.
- 19. During the electrolysis of fused KBr, which reaction occurs at the positive electrode? (1) Br<sup>-</sup> ions are oxidized. (2) Br<sup>-</sup> ions are reduced. (3) K<sup>+</sup> ions are reduced. (4) K<sup>+</sup> ions are oxidized.
- 20. In an electrolytic cell, a Cl<sup>-</sup> ion would be attracted to the (1) positive electrode and oxidized (2) positive electrode and reduced (3) negative electrode and oxidized (4) negative electrode and reduced
- What occurs when an electrolytic cell is used for silverplating a spoon? (1) A chemical reaction produces an electrical current.
   (2) An electric current produces a chemical reaction. (3) An oxidation reaction takes place at the cathode. (4) A reduction reaction takes place at the anode.
- 22. The type of reaction in an electrochemical cell is best described as a (1) spontaneous oxidation reaction, only (2) nonspontaneous oxidation reaction, only (3) spontaneous oxidation-reduction reaction (4) nonspontaneous oxidation-reduction reaction

Base your answers to questions 23 and 24 on the equation and diagram below which represents an electrochemical cell at 298 K and 1 atmosphere.



- 23. Which species is oxidized when the switch is closed? (1) Mg(s) (2) Mg<sup>2+</sup> (aq) (3) Ag(s) (4) Ag<sup>+</sup>(aq)
- 24. When the switch is closed, electrons flow from
  - (1) Mg(s) to Ag(s)
- (2) Ag (s) to Mg(s)
- (3)  $Mg^{2+}$  (aq) to  $Ag^{+}$  (aq)
- (4)  $Ag^{+}$  (aq) to  $Mg^{2+}$  (aq)
- 25. Given the reaction:

$$Fe + Sn^{2+} \rightarrow Fe^{2+} + Sn$$

What is the potential difference  $(E^0)$  of this cell? (1) 0.14 V (2) 0.31 V (3) 0.45 V (4) 0.59 V

- 26. In both the electrochemical cell and the electrolytic cell, the anode is the electrode at which (1) reduction occurs and electrons are lost (2) reduction occurs and protons are lost (3) oxidation occur and electrons are lost (4) oxidation occurs and protons are lost
- 27. Based on Reference Table N, which reaction will take place spontaneously?
  - (1)  $Mg(s) + Ca^{2+}(aq) \rightarrow Mg^{2+}(aq) + Ca(s)$
  - (2)  $Ba(s) + 2Na^{+}(aq) \rightarrow Ba^{2+}(aq) + 2Na(s)$
  - (3)  $Cl_2(g) + 2F^-(aq) \rightarrow 2Cl^-(aq) + F_2(g)$
  - (4)  $I_2(g) + 2Br^-(aq) \rightarrow 2I^-(aq) + Br_2(g)$

2. In the reaction Mg + Cl<sub>2</sub> → MgCl<sub>2</sub>, the correct nair-reaction for the oxidation that occurs is

(1)  $Mg + 2e^- \rightarrow Mg^{2+}$ 

- (2)  $Cl_2 + 2e^- \rightarrow 2Cl^-$
- (3)  $Mg \rightarrow Mg^{2+} + 2e^{-}$
- $(4) Cl_1 \rightarrow 2Cl^- + 2e^-$
- 3. Based on Reference Table N, which of the following ions is most easily oxidized? (1)  $F^-$  (2)  $Cl^-$  (3)  $Br^-$  (4)  $I^-$
- 4. Based on Reference Table N, which half-cell has a greater reduction potential than the standard hydrogen half-cell?
  - (1)  $Na^+ + e^- \rightarrow Na(s)$
- (2)  $Ni^{2+} + 2e^- \rightarrow Ni(s)$
- (3)  $Pb^{2+} + 2e^{-} \rightarrow Pb(s)$  (4)  $Sn^{4+} + 2e^{-} \rightarrow Sn^{2+}$
- 5. According to Reference Table N, which will reduce Mg<sup>2+</sup> to Mg(s)? (1) Fe(s) (2) Ba(s) (3) Pb(s) (4) Ag(s)
- 6. Which ion will oxidize Fe?
  - (1)  $Zn^{2+}$  (2)  $Ca^{2+}$
- (3)  $Mg^{2+}$  (4)  $Cu^{2+}$
- 7. Which ion can be both an oxidizing agent and a reducing agent? (2)  $Cu^{2+}$  (3)  $Al^{3+}$  $(4) \text{ Fe}^{3+}$  $(1) Sn^{2+}$
- 8. Which reaction will take place spontaneously?

  - (1)  $Cu + 2H^+ \rightarrow Cu^{2+} + H_2$  (2)  $2Au + 6H^+ \rightarrow 2Au^{3+} + 3H_2$

  - (3)  $Pb + 2H^+ \rightarrow Pb^{2+} + H_2$  (4)  $2Ag + 2H^+ \rightarrow 2Ag^+ + H_2$
- 9. Which overall reaction in a chemical cell has the highest net potential  $(E^0)$ ?
  - (1)  $Zn(s) + 2H^+ \rightarrow Zn^{2+} + H_2(g)$  (2)  $Ni(s) + 2H^+ \rightarrow Ni^{2+} + H_2(g)$
  - (3)  $Mg(s) + 2H^+ \rightarrow Mg^{2+} + H_2(g)$  (4)  $Sn(s) + 2H^+ \rightarrow Sn^{2+} + H_2(g)$
- 10. Given the reaction:

$$2Al(s) + 3Pb^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Pb(s)$$

The potential for  $(E^0)$  for the overall reaction is (1) 1.53 V (2) 1.79 V (3) 2.93 V (4) 3.71 V

Base your answers to questions 11 and 12 on the following reaction:

$$Mg(s) + 2Ag^{*}(aq) \rightarrow Mg^{2*}(aq) + 2Ag(s)$$

- 11. Which species undergoes a loss of electrons?
  - (1) Mg(s) (2)  $Ag^{-}(aq)$  (3)  $Mg^{2+}(aq)$  (4) Ag(s)
- 12. What is the cell voltage  $(E^0)$  for the overall reaction?
- (1) + 1.57 V (2) + 2.37 V (3) + 3.17 V (4) + 3.97 V
- 21. Given the redox reaction: Ni + Sn<sup>4+</sup>  $\rightarrow$  Ni<sup>2+</sup> + Sn<sup>2+</sup> Which species has been oxidized? (1) Ni (2) Sn<sup>4+</sup> (3) Ni<sup>2+</sup>  $(4) Sn^{2+}$
- 22. In which substance is the oxidation number of nitrogen zero?  $(1) N_2 (2) NH_3 (3) NO_2 (4) N_2O$
- 23. What is the oxidation number of Pt in  $K_2$ PtCl<sub>6</sub>? (1) -2 (2) +2 (3) -4 (4) +4
- 24. In the reaction  $2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$ , the oxidizing agent is (1) oxygen (2) water (3) sulfur dioxide (4) hydrogen sulfide
- 25. In the reaction  $2Na + 2H_2O \rightarrow 2Na^+ + 2OH^- + H_2$ , the substance oxidized is (1) H<sub>2</sub> (2) H<sup>+</sup> (3) Na (4) Na<sup>+</sup>
- 26. Given the reaction:  $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$ The reducing agent is (1)  $Cu^0$  (2)  $N^{*5}$  (3)  $Cu^{*2}$  (4)  $N^{*2}$
- 27. Given the reaction:  $Sn^{2+}(aq) + 2Fe^{3+}(aq) \rightarrow Sn^{4+}(aq) + 2Fe^{2+}(aq)$ The oxidizing agent in this reaction is (1) Sn<sup>2+</sup> (2) Fe<sup>3+</sup> (3) Sn<sup>4+</sup> (4) Fe<sup>2+</sup>

In 1-19, refer to Reference Table N on page 110.

1. Given the reaction:

$$2Cr(s) + 3Cu^{2-}(aq) \rightarrow 2Cr^{3-}(aq) + 3Cu(s)$$

The potential difference (E°) of the cell is (1) 0.40 v (2) 1.08 v (3) 1.25 v (4) 2.50 v

2. Given the reaction:

$$2Na(s) + Cl_2(g) \rightarrow 2Na^- + 2Cl^-$$

What is the potential  $(E^0)$  for the overall reaction? (1) -1.35 v (2) +1.35 v (3) -4.07 v (4) +4.07 v

3. Given the reaction:

$$2Au^{3+}(aq) + 3Ni^{0} \rightarrow 2Au^{0} + 3Ni^{2+}(aq)$$

The cell potential  $(E^0)$  for the overall reaction is (1)3.75 v (2) 2.25 v (3) 1.76 v (4) 1.25 v

4. What is the potential (E<sup>0</sup>) for the reaction

$$Mg(s) + Br_2(\ell) \rightarrow Mg^{2+}(aq) + 2Br^{-}(aq)$$

- (1) 1.06 v (2) 1.31 v (3) 2.37 v (4) 3.46 v
- 5. Which species can act either as an oxidizing agent or a reducing agent? (1)  $Na^0$  (2)  $Fe^{2+}$  (3)  $Sn^0$  (4)  $Zn^{2+}$
- 6. Given the reaction:

$$\begin{array}{c} Zn(s) + \ 2H^+(aq) \ + \ 2Cl^-(aq) \to \\ & Zn^{2+}(aq) \ + \ 2Cl^-(aq) \ + \ H_2(g) \end{array}$$

Which species is oxidized?

- (1) Zn(s) (2)  $H^+$  (aq) (3)  $Cl^-$  (aq) (4)  $H_2(g)$
- 7. Which pair will react spontaneously at 298 K? (1)  $Cl_2 + F^-$  (2)  $I_2 + Br^-$  (3)  $F_2 + I^-$  (4)  $Br_2 + Cl^-$
- 8. Which pair will react spontaneously at 298 K? (1)  $Cu + H_2O$  (2)  $Ag + H_2O$  (3)  $Ca + H_2O$  (4) Au + $H_2O$
- 9. What is the standard reduction potential for the  $Cu^{2+}(aq)/Cu \text{ half-cell?}$  (1) + 0.52 v (2) + 0.34 v (3) -0.52 v (4) -0.34 v
- 10. Which species can oxidize  $Sn^{2+}$  to  $Sn^{4+}$ ? (1)  $Ag^{+}$  (2)  $Fe^{0}$  (3)  $Al^{3+}$  (4)  $H_{2}O$
- 11. Which of the following Group 17 elements is the strongest oxidizing agent? (1)  $I_2$  (2)  $Br_2$  (3)
- Cl<sub>2</sub> (4) F<sub>2</sub>
  Which of the following alkaline earth elements is the strongest reducing agent? (1) Mg (2) Sr (3) Ca (4) Ba
- 13. Which species can be reduced by Zn? (1)  $Na^{+}$  (2)  $H^{+}$  (3)  $Ca^{2+}$  (4)  $Mg^{2+}$
- 14. What is the E<sup>0</sup> for the chemical cell whose net reaction is

$$Sn(s) + 2Ag^{+}(aq) \rightarrow Sn^{2-}(aq) + 2Ag(s)$$

(1) 0.66 volt (2) 0.79 volt (3) 0.94 volt (4) 1.09 volt 15. Given the reaction:

$$\frac{?}{?} + Ni^{2-}(aq) \rightarrow \frac{?}{?} + Ni$$

If this reaction is spontaneous, the missing reactant could be (1)  $Zn^0$  (2)  $Pb^0$  (3)  $Cu^0$  (4)  $Sn^0$ 

- 10. In the decomposition reaction 2LiH → 2Li +  $H_2$  (1) Li<sup>+</sup> is oxidized. (2) Li<sup>0</sup> is oxidized. (3)  $H_2^0$ is reduced. (4) H<sup>-</sup> is oxidized.
- 11. In the double replacement reaction

$$AgNO_3 + NaCl \rightarrow AgCl(s) + NaNO_3$$

(1) AgNO<sub>3</sub> is reduced. (2) AgNO<sub>3</sub> is oxidized. (3) NaCl is reduced. (4) AgNO<sub>3</sub> is neither reduced nor oxidized.