

CH 302 Spring 2008 Worksheet 9

Half-reaction	ΔE_r^0 (V)
$\text{Li}^+(\text{aq}) + \text{e}^- \rightarrow \text{Li}(\text{s})$	-3.05
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Al}(\text{s})$	-1.68
$\text{TiO}(\text{s}) + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{Ti}(\text{s}) + \text{H}_2\text{O}$	-1.31
$\text{Ti}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Ti}(\text{s})$	-1.21
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$	-0.25
$\text{CO}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{HCOOH}(\text{aq})$	-0.11
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0
$\text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+ + 2\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{SO}_2(\text{aq})$	+0.17
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{NO}_3^-(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$	+0.80
$\text{Au}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Au}(\text{s})$	+1.52
$\text{Ag}_2\text{O}_3(\text{s}) + 6\text{H}^+ + 4\text{e}^- \rightarrow 2\text{Ag}^+(\text{aq}) + 3\text{H}_2\text{O}$	+1.67
$\text{F}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{F}^-(\text{aq})$	+2.87

For questions 1-5, determine whether, as written, the reaction is a battery (“galvanic”) or electrolytic. Balance the reaction and then indicate which species is receiving the electrons and the sign of the cell for that electrode.

Note: These problems are harder than the problems on the next page. It was just convenient to put them here.

1. $\text{TiO}(\text{s}) + \text{Au}(\text{s}) \rightarrow \text{Au}^{3+}(\text{aq}) + \text{Ti}(\text{s})$ *in acid*
Answer: Electrolytic and electrons flow to TiO at cathode which is negative

$$6\text{H}^+(\text{aq}) + 3\text{TiO}(\text{s}) + 2\text{Au}(\text{s}) \rightarrow 2\text{Au}^{3+}(\text{aq}) + 3\text{Ti}(\text{s}) + 3\text{H}_2\text{O}$$
2. $\text{TiO}(\text{s}) + \text{Au}(\text{s}) \rightarrow \text{Au}^{3+}(\text{aq}) + \text{Ti}(\text{s})$ *in base*
Answer: Electrolytic and electrons flow to TiO at cathode which is negative

$$3\text{H}_2\text{O} + 3\text{TiO}(\text{s}) + 2\text{Au}(\text{s}) \rightarrow 2\text{Au}^{3+}(\text{aq}) + 3\text{Ti}(\text{s}) + 6\text{OH}^-(\text{aq})$$
3. $\text{Ag}^+(\text{aq}) + \text{F}_2(\text{g}) \rightarrow \text{F}^-(\text{aq}) + \text{Ag}_2\text{O}_3(\text{s})$ *in base*
Answer: Battery and electrons flow to F_2 at cathode which is positive

$$6\text{OH}^-(\text{aq}) + 2\text{Ag}^+(\text{aq}) + 2\text{F}_2(\text{g}) \rightarrow 4\text{F}^-(\text{aq}) + \text{Ag}_2\text{O}_3 + 3\text{H}_2\text{O}$$
4. $\text{SO}_4^{2-}(\text{aq}) + \text{Al}(\text{s}) \rightarrow \text{Al}^{3+}(\text{aq}) + \text{SO}_2(\text{aq})$ *in acid*
Answer: Battery and electrons flow to sulfate at cathode which is positive

$$12\text{H}^+(\text{aq}) + 3\text{SO}_4^{2-}(\text{aq}) + 2\text{Al}(\text{s}) \rightarrow 2\text{Al}^{3+} + 3\text{SO}_2(\text{aq}) + 6\text{H}_2\text{O}$$
5. $\text{NO}_3^- + \text{Ag}^+(\text{aq}) \rightarrow \text{Ag}_2\text{O}_3(\text{s}) + \text{NO}_2(\text{g})$ *in acid*
Answer: Electrolytic and electrons flow to nitrate which is negative

$$2\text{H}^+(\text{aq}) + 4\text{NO}_3^-(\text{aq}) + 2\text{Ag}^+(\text{aq}) \rightarrow \text{Ag}_2\text{O}_3(\text{s}) + 4\text{NO}_2(\text{g}) + \text{H}_2\text{O}$$

For the table on the following page, fill in the requested information for a battery made from the two indicated half-reactions

Half-reaction 1	Half-reaction 2	Cathode	Anode	Balanced Reaction	ΔE	Strongest oxidizing agent	Strongest reducing agent
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Ni}(\text{s})$	$2\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g})$	2	1	$2\text{H}^{+}(\text{aq}) + \text{Ni}(\text{s}) \rightarrow \text{Ni}^{2+}(\text{aq}) + \text{H}_2(\text{g})$	+0.25	H^{+}	Ni
$\text{F}_2(\text{g}) + 2\text{e}^{-} \rightarrow 2\text{F}^{-}(\text{aq})$	$\text{Li}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Li}(\text{s})$	1	2	$\text{F}_2(\text{g}) + 2\text{Li}(\text{s}) \rightarrow 2\text{F}^{-}(\text{aq}) + 2\text{Li}^{+}(\text{aq})$	+5.86	F_2	Li
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Al}(\text{s})$	$\text{Ti}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Ti}(\text{s})$	2	1	$\text{Ti}^{3+}(\text{aq}) + \text{Al}(\text{s}) \rightarrow \text{Al}^{3+}(\text{aq}) + \text{Ti}(\text{s})$	+0.47	Ti^{3+}	Al
$\text{F}_2(\text{g}) + 2\text{e}^{-} \rightarrow 2\text{F}^{-}(\text{aq})$	$2\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g})$	1	2	$\text{F}_2(\text{g}) + \text{H}_2(\text{g}) \rightarrow 2\text{F}^{-}(\text{aq}) + 2\text{H}^{+}(\text{aq})$	+2.87	F_2	H_2
$2\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g})$	$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Fe}^{2+}(\text{aq})$	2	1	$2\text{Fe}^{3+}(\text{aq}) + \text{H}_2(\text{g}) \rightarrow 2\text{H}^{+}(\text{aq}) + 2\text{Fe}^{2+}(\text{aq})$	+0.77	Fe^{3+}	H_2
$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Fe}^{2+}(\text{aq})$	$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Ni}(\text{s})$	1	2	$2\text{Fe}^{3+}(\text{aq}) + \text{Ni}(\text{s}) \rightarrow \text{Ni}^{2+}(\text{aq}) + 2\text{Fe}^{2+}(\text{aq})$	+1.02	Fe^{3+}	Ni
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})$	$\text{Au}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Au}(\text{s})$	2	1	$2\text{Au}^{3+}(\text{aq}) + 3\text{Cu}(\text{s}) \rightarrow 3\text{Cu}^{2+}(\text{aq}) + 2\text{Au}(\text{s})$	+1.18	Au^{3+}	Cu
$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Fe}^{2+}(\text{aq})$	$\text{Li}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Li}(\text{s})$	1	2	$\text{Fe}^{3+}(\text{aq}) + \text{Li}(\text{s}) \rightarrow \text{Li}^{+}(\text{aq}) + \text{Fe}^{2+}(\text{aq})$	+3.82	Fe^{3+}	Li
$\text{Ti}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Ti}(\text{s})$	$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})$	2	1	$3\text{Cu}^{2+}(\text{aq}) + 2\text{Ti}(\text{s}) \rightarrow 2\text{Ti}^{3+}(\text{aq}) + 3\text{Cu}(\text{s})$	+1.55	Cu^{2+}	Ti
$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Fe}^{2+}(\text{aq})$	$\text{F}_2(\text{g}) + 2\text{e}^{-} \rightarrow 2\text{F}^{-}(\text{aq})$	2	1	$\text{F}_2(\text{g}) + 2\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + 2\text{F}^{-}(\text{aq})$	+2.10	F_2	Fe^{2+}