

12. VOLTAIC CELLS

These problems are intended to **supplement** the problems in the textbook, not **replace** them.

E° (V)	Half-Cell Reaction
+0.799	$\text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s)$
+0.095	$\text{AgBr}(s) + e^- \rightarrow \text{Ag}(s) + \text{Br}^-(aq)$
-1.66	$\text{Al}^{3+}(aq) + 3e^- \rightarrow \text{Al}(s)$
+1.42	$\text{Au}^{3+}(aq) + 3e^- \rightarrow \text{Au}(s)$
-2.90	$\text{Ba}^{2+}(aq) + 2e^- \rightarrow \text{Ba}(s)$
+1.065	$\text{Br}_2(l) + 2e^- \rightarrow 2\text{Br}^-(aq)$
+1.52	$2\text{BrO}_3^-(aq) + 12\text{H}^+(aq) + 10e^- \rightarrow \text{Br}_2(l) + 6\text{H}_2\text{O}(l)$
-0.403	$\text{Cd}^{2+}(aq) + 2e^- \rightarrow \text{Cd}(s)$
+1.359	$\text{Cl}_2(g) + 2e^- \rightarrow 2\text{Cl}^-(aq)$
-0.277	$\text{Co}^{2+}(aq) + 2e^- \rightarrow \text{Co}(s)$
+1.842	$\text{Co}^{3+}(aq) + e^- \rightarrow \text{Co}^{2+}(aq)$
-0.74	$\text{Cr}^{3+}(aq) + 3e^- \rightarrow \text{Cr}(s)$
+1.33	$\text{Cr}_2\text{O}_7^{2-}(aq) + 14\text{H}^+(aq) + 6e^- \rightarrow 2\text{Cr}^{3+}(aq) + 7\text{H}_2\text{O}$
+0.337	$\text{Cu}^{2+}(aq) + 2e^- \rightarrow \text{Cu}(s)$
+0.153	$\text{Cu}^{2+}(aq) + e^- \rightarrow \text{Cu}^+(aq)$
+2.87	$\text{F}_2(g) + 2e^- \rightarrow 2\text{F}^-(aq)$
-0.440	$\text{Fe}^{2+}(aq) + 2e^- \rightarrow \text{Fe}(s)$
+0.771	$\text{Fe}^{3+}(aq) + e^- \rightarrow \text{Fe}^{2+}(aq)$
0.000	$2\text{H}^+(aq) + 2e^- \rightarrow \text{H}_2(g)$
-0.83	$2\text{H}_2\text{O}(l) + 2e^- \rightarrow \text{H}_2(g) + 2\text{OH}^-(aq)$
+0.88	$\text{HO}_2^-(aq) + \text{H}_2\text{O}(l) + 2e^- \rightarrow 3\text{OH}^-(aq)$
+1.776	$\text{H}_2\text{O}_2(aq) + 2\text{H}^+(aq) + 2e^- \rightarrow 2\text{H}_2\text{O}(l)$
+0.536	$\text{I}_2(s) + 2e^- \rightarrow 2\text{I}^-(aq)$

E° (V)	Half-Cell Reaction
-3.05	$\text{Li}^+(aq) + e^- \rightarrow \text{Li}(s)$
-2.37	$\text{Mg}^{2+}(aq) + 2e^- \rightarrow \text{Mg}(s)$
-1.18	$\text{Mn}^{2+}(aq) + 2e^- \rightarrow \text{Mn}(s)$
+1.51	$\text{Mn}^{3+}(aq) + e^- \rightarrow \text{Mn}^{2+}(aq)$
+1.23	$\text{MnO}_2(s) + 4\text{H}^+(aq) + 2e^- \rightarrow \text{Mn}^{2+}(aq) + 2\text{H}_2\text{O}(l)$
+1.695	$\text{MnO}_4^-(aq) + 4\text{H}^+(aq) + 3e^- \rightarrow \text{MnO}_2(s) + 2\text{H}_2\text{O}(l)$
+1.51	$\text{MnO}_4^-(aq) + 8\text{H}^+(aq) + 5e^- \rightarrow \text{Mn}^{2+}(aq) + 4\text{H}_2\text{O}(l)$
-1.16	$\text{N}_2(g) + 4\text{H}_2\text{O}(l) + 4e^- \rightarrow \text{N}_2\text{H}_4(aq) + 4\text{OH}^-(aq)$
+0.96	$\text{NO}_3^-(aq) + 4\text{H}^+(aq) + 3e^- \rightarrow \text{NO}(g) + 2\text{H}_2\text{O}(l)$
-0.28	$\text{Ni}^{2+}(aq) + 2e^- \rightarrow \text{Ni}(s)$
+0.49	$\text{NiO}_2(s) + 2\text{H}_2\text{O}(l) + 2e^- \rightarrow \text{Ni}(\text{OH})_2(s) + 2\text{OH}^-(aq)$
+1.23	$\text{O}_2(g) + 4\text{H}^+(aq) + 4e^- \rightarrow 2\text{H}_2\text{O}(l)$
+2.07	$\text{O}_3(g) + 2\text{H}^+(aq) + 2e^- \rightarrow \text{O}_2(g) + \text{H}_2\text{O}(l)$
-0.126	$\text{Pb}^{2+}(aq) + 2e^- \rightarrow \text{Pb}(s)$
+1.46	$\text{PbO}_2(s) + 4\text{H}^+(aq) + 2e^- \rightarrow \text{Pb}^{2+}(aq) + 2\text{H}_2\text{O}(l)$
+0.25	$\text{PbO}_2(s) + \text{H}_2\text{O}(l) + 2e^- \rightarrow \text{PbO}(s) + 2\text{OH}^-(aq)$
+1.685	$\text{PbO}_2(s) + \text{HSO}_4^-(aq) + 3\text{H}^+(aq) + 2e^- \rightarrow \text{PbSO}_4(s) + 2\text{H}_2\text{O}$
-0.356	$\text{PbSO}_4(s) + \text{H}^+(aq) + 2e^- \rightarrow \text{Pb}(s) + \text{HSO}_4^-(aq)$
+1.20	$\text{Pt}^{2+}(aq) + 2e^- \rightarrow \text{Pt}(s)$
-0.136	$\text{Sn}^{2+}(aq) + 2e^- \rightarrow \text{Sn}(s)$
+0.45	$\text{SO}_2(aq) + 4\text{H}^+(aq) + 4e^- \rightarrow \text{S}(s) + 2\text{H}_2\text{O}(l)$
-1.18	$\text{V}^{2+}(aq) + 2e^- \rightarrow \text{V}(s)$
-0.763	$\text{Zn}^{2+}(aq) + 2e^- \rightarrow \text{Zn}(s)$

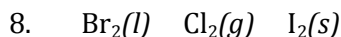
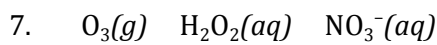
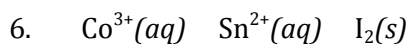
Questions

Each of the following spontaneous redox reactions occurs in a voltaic cell.

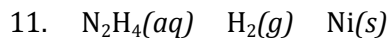
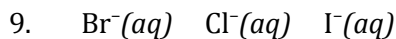
- Write the half-reaction that occurs at the anode.
- Write the half-reaction that occurs at the cathode.
- Calculate E°_{cell} .

- $2\text{MnO}_4^-(aq) + 3\text{V}(s) + 8\text{H}^+(aq) \rightarrow 2\text{MnO}_2(s) + 3\text{V}^{2+}(aq) + 4\text{H}_2\text{O}(l)$
- $2\text{Br}^-(aq) + 2\text{Mn}^{3+}(aq) \rightarrow \text{Br}_2(l) + 2\text{Mn}^{2+}(aq)$
- $2\text{Zn}^{2+}(aq) + 4\text{OH}^-(aq) + \text{N}_2\text{H}_4(aq) \rightarrow 2\text{Zn}(s) + \text{N}_2(g) + 4\text{H}_2\text{O}(l)$
- $3\text{Cu}(s) + 2\text{NO}_3^-(aq) + 8\text{H}^+(aq) \rightarrow 3\text{Cu}^{2+}(aq) + 2\text{NO}(g) + 4\text{H}_2\text{O}(l)$
- $\text{Pb}(s) + \text{PbO}_2(s) + 2\text{HSO}_4^-(aq) + 2\text{H}^+(aq) \rightarrow 2\text{PbSO}_4(s) + 2\text{H}_2\text{O}(l)$

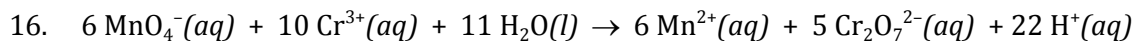
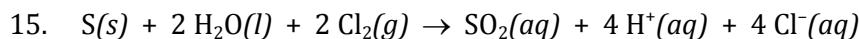
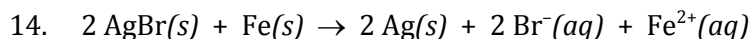
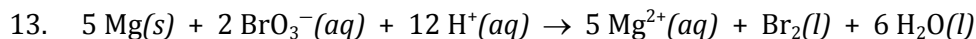
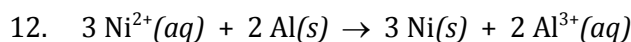
Arrange each group of three in order of increasing strength as oxidizing agents.



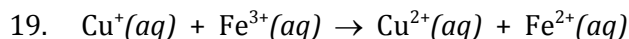
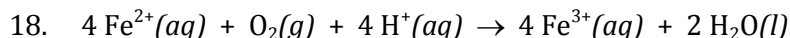
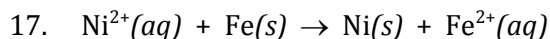
Arrange each group of three in order of increasing strength as reducing agents.



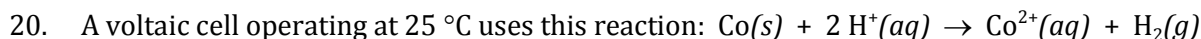
Calculate ΔG° for the following voltaic cell reactions at 25 °C.



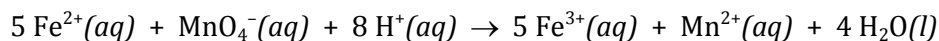
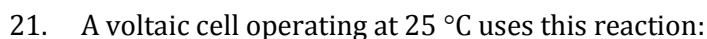
Calculate the equilibrium constant for the following voltaic cell reactions at 25 °C.



Answer the following questions.



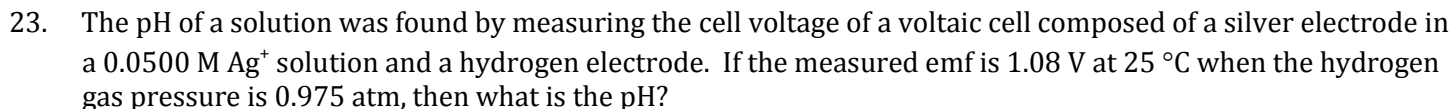
Calculate the cell voltage when $P_{\text{H}_2} = 1.50 \text{ atm}$, $[\text{Co}^{2+}] = 0.750 \text{ M}$ and $\text{pH} = 4.21$.



Calculate the cell voltage when $[\text{Fe}^{2+}] = 0.0500 \text{ M}$, $[\text{MnO}_4^-] = 0.0700 \text{ M}$, $[\text{H}^+] = 0.0250 \text{ M}$, $[\text{Fe}^{3+}] = 0.100 \text{ M}$ and $[\text{Mn}^{2+}] = 0.0880 \text{ M}$.



Calculate the cell voltage when $P_{\text{F}_2} = 825 \text{ torr}$, $[\text{Cr}^{3+}] = 1.50 \text{ M}$ and $[\text{F}^-] = 1.25 \text{ M}$.



24. At 25 °C, $E_{\text{red}}^{\circ} = -0.29 \text{ V}$ for this half-reaction: $\text{CuO}(s) + \text{H}_2\text{O}(l) + 2 e^{-} \rightarrow \text{Cu}(s) + 2 \text{OH}^{-}(aq)$
- What is the value of E_{red} in pure water at 25 °C when $[\text{OH}^{-}] = 1.00 \times 10^{-7} \text{ M}$?
 - At what pH is $E_{\text{red}} = 0$?
25. A voltaic cell operating at 25 °C uses this reaction: $2 \text{Ag}^{+}(aq) + \text{Pb}(s) \rightarrow 2 \text{Ag}(s) + \text{Pb}^{2+}(aq)$
- If $[\text{Ag}^{+}] = 0.85 \text{ M}$ in the cathode compartment, and the cell generates an emf of +1.08 V, then what is $[\text{Pb}^{2+}]$ in the anode compartment?
 - If the anode compartment contains $[\text{SO}_4^{2-}] = 0.0043 \text{ M}$ in equilibrium with $\text{PbSO}_4(s)$ then what is K_{sp} for PbSO_4 ?
26. At 25 °C a cell reaction exhibits a standard emf of +0.11 V. The equilibrium constant for the cell reaction is 5.50×10^5 . What is the value of “n” for the cell reaction?

Answers

If you cannot figure out how to get the correct answer, go to your instructor, Science Tutoring Center, etc.

The faraday constant was taken to be $9.65 \times 10^4 \text{ C/mol}$.

- $\text{V}(s) \rightarrow \text{V}^{2+}(aq) + 2 e^{-}$
 - $\text{MnO}_4^{-}(aq) + 4 \text{H}^{+}(aq) + 3 e^{-} \rightarrow \text{MnO}_2(s) + 2 \text{H}_2\text{O}(l)$
 - +2.88 V
- $2 \text{Br}^{-}(aq) \rightarrow \text{Br}_2(l) + 2 e^{-}$
 - $\text{Mn}^{3+}(aq) + e^{-} \rightarrow \text{Mn}^{2+}(aq)$
 - +0.45 V
- $4 \text{OH}^{-}(aq) + \text{N}_2\text{H}_4(aq) \rightarrow \text{N}_2(g) + 4 \text{H}_2\text{O}(l) + 4 e^{-}$
 - $\text{Zn}^{2+}(aq) + 2 e^{-} \rightarrow \text{Zn}(s)$
 - +0.40 V
- $\text{Cu}(s) \rightarrow \text{Cu}^{2+}(aq) + 2 e^{-}$
 - $\text{NO}_3^{-}(aq) + 4 \text{H}^{+}(aq) + 3 e^{-} \rightarrow \text{NO}(g) + 2 \text{H}_2\text{O}(l)$
 - +0.62 V
- $\text{Pb}(s) + \text{HSO}_4^{-}(aq) \rightarrow \text{PbSO}_4(s) + \text{H}^{+}(aq) + 2 e^{-}$
 - $\text{PbO}_2(s) + \text{HSO}_4^{-}(aq) + 3 \text{H}^{+}(aq) + 2 e^{-} \rightarrow \text{PbSO}_4(s) + 2 \text{H}_2\text{O}(l)$
 - +2.041 V
- $\text{Sn}^{2+}(aq) < \text{I}_2(s) < \text{Co}^{3+}(aq)$
 - 103 kJ
 - +0.57 V
- $\text{NO}_3^{-}(aq) < \text{H}_2\text{O}_2(aq) < \text{O}_3(g)$
 - $-3.5 \times 10^2 \text{ kJ}$
 - +3.60 V
- $\text{I}_2(s) < \text{Br}_2(l) < \text{Cl}_2(g)$
 - $-5.2 \times 10^2 \text{ kJ}$
 - 6.0
- $\text{Cl}^{-}(aq) < \text{Br}^{-}(aq) < \text{I}^{-}(aq)$
 - 3×10^5
 - a. 0.12 V b. 9.0
- $\text{Cu}(s) < \text{Cd}(s) < \text{Mg}(s)$
 - 1×10^{31}
 - a. $3 \times 10^{-6} \text{ M}$ b. 1×10^{-8}
- $\text{H}_2(g) < \text{Ni}(s) < \text{N}_2\text{H}_4(aq)$
 - 3×10^{10}
 - 3
- 799 kJ
- +0.027 V
- $-3.75 \times 10^3 \text{ kJ}$