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

E° (V)	*Half-Cell Reaction*
+0.799	$Ag^+(aq) + e^- \rightarrow Ag(s)$
+0.095	$AgBr(s) + e^- \rightarrow Ag(s) + Br^-(aq)$
–1.66	$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$
+1.42	$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$
–2.90	$Ba^{2+}(aq) + 2e^- \rightarrow Ba(s)$
+1.065	$Br_2(l) + 2e^- \rightarrow 2\ Br^-(aq)$
+1.52	$2\ BrO_3^-(aq) + 12\ H^+(aq) + 10e^- \rightarrow Br_2(l) + 6\ H_2O(l)$
–0.403	$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$
+1.359	$Cl_2(g) + 2e^- \rightarrow 2\ Cl^-(aq)$
–0.277	$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$
+1.842	$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$
–0.74	$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$
+1.33	$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O$
+0.337	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
+0.153	$Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$
+2.87	$F_2(g) + 2e^- \rightarrow 2\ F^-(aq)$
–0.440	$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$
+0.771	$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$
0.000	$2\ H^+(aq) + 2e^- \rightarrow H_2(g)$
–0.83	$2\ H_2O(l) + 2e^- \rightarrow H_2(g) + 2\ OH^-(aq)$
+0.88	$HO_2^-(aq) + H_2O(l) + 2e^- \rightarrow 3\ OH^-(aq)$
+1.776	$H_2O_2(aq) + 2\ H^+(aq) + 2e^- \rightarrow 2\ H_2O(l)$
+0.536	$I_2(s) + 2e^- \rightarrow 2\ I^-(aq)$

E° (V)	*Half-Cell Reaction*
–3.05	$Li^+(aq) + e^- \rightarrow Li(s)$
–2.37	$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$
–1.18	$Mn^{2+}(aq) + 2e^- \rightarrow Mn(s)$
+1.51	$Mn^{3+}(aq) + e^- \rightarrow Mn^{2+}(aq)$
+1.23	$MnO_2(s) + 4\ H^+(aq) + 2e^- \rightarrow Mn^{2+}(aq) + 2\ H_2O(l)$
+1.695	$MnO_4^-(aq) + 4\ H^+(aq) + 3e^- \rightarrow MnO_2(s) + 2\ H_2O(l)$
+1.51	$MnO_4^-(aq) + 8\ H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4\ H_2O(l)$
–1.16	$N_2(g) + 4\ H_2O(l) + 4e^- \rightarrow N_2H_4(aq) + 4\ OH^-(aq)$
+0.96	$NO_3^-(aq) + 4\ H^+(aq) + 3e^- \rightarrow NO(g) + 2\ H_2O(l)$
–0.28	$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$
+0.49	$NiO_2(s) + 2H_2O(l) + 2e^- \rightarrow Ni(OH)_2(s) + 2OH^-(aq)$
+1.23	$O_2(g) + 4\ H^+(aq) + 4e^- \rightarrow 2\ H_2O(l)$
+2.07	$O_3(g) + 2H^+(aq) + 2e^- \rightarrow O_2(g) + H_2O(l)$
–0.126	$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$
+1.46	$PbO_2(s) + 4\ H^+(aq) + 2e^- \rightarrow Pb^{2+}(aq) + 2\ H_2O(l)$
+0.25	$PbO_2(s) + H_2O(l) + 2e^- \rightarrow PbO(s) + 2\ OH^-(aq)$
+1.685	$PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O$
–0.356	$PbSO_4(s) + H^+(aq) + 2e^- \rightarrow Pb(s) + HSO_4^-(aq)$
+1.20	$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s)$
–0.136	$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$
+0.45	$SO_2(aq) + 4\ H^+(aq) + 4e^- \rightarrow S(s) + 2\ H_2O(l)$
–1.18	$V^{2+}(aq) + 2e^- \rightarrow V(s)$
–0.763	$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$

Questions

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

a. Write the half-reaction that occurs at the anode.

b. Write the half-reaction that occurs at the cathode.

c. Calculate $E°_{cell}$.

1. $2\ MnO_4^-(aq) + 3\ V(s) + 8\ H^+(aq) \rightarrow 2\ MnO_2(s) + 3\ V^{2+}(aq) + 4\ H_2O(l)$

2. $2\ Br^-(aq) + 2\ Mn^{3+}(aq) \rightarrow Br_2(l) + 2\ Mn^{2+}(aq)$

3. $2\ Zn^{2+}(aq) + 4\ OH^-(aq) + N_2H_4(aq) \rightarrow 2\ Zn(s) + N_2(g) + 4\ H_2O(l)$

4. $3\ Cu(s) + 2\ NO_3^-(aq) + 8\ H^+(aq) \rightarrow 3\ Cu^{2+}(aq) + 2\ NO(g) + 4\ H_2O(l)$

5. $Pb(s) + PbO_2(s) + 2\ HSO_4^-(aq) + 2\ H^+(aq) \rightarrow 2\ PbSO_4(s) + 2\ H_2O(l)$

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

6. $Co^{3+}(aq)$ $Sn^{2+}(aq)$ $I_2(s)$

7. $O_3(g)$ $H_2O_2(aq)$ $NO_3^-(aq)$

8. $Br_2(l)$ $Cl_2(g)$ $I_2(s)$

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

9. $Br^-(aq)$ $Cl^-(aq)$ $I^-(aq)$

10. $Cu(s)$ $Cd(s)$ $Mg(s)$

11. $N_2H_4(aq)$ $H_2(g)$ $Ni(s)$

Calculate $\Delta G°$ for the following voltaic cell reactions at 25 °C.

12. $3\ Ni^{2+}(aq) + 2\ Al(s) \rightarrow 3\ Ni(s) + 2\ Al^{3+}(aq)$

13. $5\ Mg(s) + 2\ BrO_3^-(aq) + 12\ H^+(aq) \rightarrow 5\ Mg^{2+}(aq) + Br_2(l) + 6\ H_2O(l)$

14. $2\ AgBr(s) + Fe(s) \rightarrow 2\ Ag(s) + 2\ Br^-(aq) + Fe^{2+}(aq)$

15. $S(s) + 2\ H_2O(l) + 2\ Cl_2(g) \rightarrow SO_2(aq) + 4\ H^+(aq) + 4\ Cl^-(aq)$

16. $6\ MnO_4^-(aq) + 10\ Cr^{3+}(aq) + 11\ H_2O(l) \rightarrow 6\ Mn^{2+}(aq) + 5\ Cr_2O_7^{2-}(aq) + 22\ H^+(aq)$

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

17. $Ni^{2+}(aq) + Fe(s) \rightarrow Ni(s) + Fe^{2+}(aq)$

18. $4\ Fe^{2+}(aq) + O_2(g) + 4\ H^+(aq) \rightarrow 4\ Fe^{3+}(aq) + 2\ H_2O(l)$

19. $Cu^+(aq) + Fe^{3+}(aq) \rightarrow Cu^{2+}(aq) + Fe^{2+}(aq)$

Answer the following questions.

20. A voltaic cell operating at 25 °C uses this reaction: $Co(s) + 2\ H^+(aq) \rightarrow Co^{2+}(aq) + H_2(g)$

    Calculate the cell voltage when P_{H2} = 1.50 atm, $[Co^{2+}]$ = 0.750 M and pH = 4.21.

21. A voltaic cell operating at 25 °C uses this reaction:

    $$5\ Fe^{2+}(aq) + MnO_4^-(aq) + 8\ H^+(aq) \rightarrow 5\ Fe^{3+}(aq) + Mn^{2+}(aq) + 4\ H_2O(l)$$

    Calculate the cell voltage when $[Fe^{2+}]$ = 0.0500 M, $[MnO_4^-]$ = 0.0700 M, $[H^+]$ = 0.0250 M, $[Fe^{3+}]$ = 0.100 M and $[Mn^{2+}]$ = 0.0880 M.

22. A voltaic cell operating at 25 °C uses this reaction: $3\ F_2(g) + 2\ Cr(s) \rightarrow 2\ Cr^{3+}(aq) + 6\ F^-(aq)$

    Calculate the cell voltage when P_{F2} = 825 torr, $[Cr^{3+}]$ = 1.50 M and $[F^-]$ = 1.25 M.

23. The pH of a solution was found by measuring the cell voltage of a voltaic cell composed of a silver electrode in a 0.0500 M Ag^+ solution and a hydrogen electrode. If the measured emf is 1.08 V at 25 °C when the hydrogen gas pressure is 0.975 atm, then what is the pH?

24. At 25 °C, $E°_{red} = -0.29$ V for this half-reaction: $CuO(s) + H_2O(l) + 2\,e^- \rightarrow Cu(s) + 2\,OH^-(aq)$

    a. What is the value of E_{red} in pure water at 25 °C when $[OH^-] = 1.00\times10^{-7}$ M?

    b. At what pH is $E_{red} = 0$?

25. A voltaic cell operating at 25 °C uses this reaction: $2\,Ag^+(aq) + Pb(s) \rightarrow 2\,Ag(s) + Pb^{2+}(aq)$

    a. If $[Ag^+] = 0.85$ M in the cathode compartment, and the cell generates an emf of +1.08 V, then what is $[Pb^{2+}]$ in the anode compartment?

    b. If the anode compartment contains $[SO_4^{2-}] = 0.0043$ M in equilibrium with $PbSO_4(s)$ 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 9.65×10^4 C/mol.

1. a. $V(s) \rightarrow V^{2+}(aq) + 2e^-$ b. $MnO_4^-(aq) + 4H^+(aq) + 3e^- \rightarrow MnO_2(s) + 2H_2O(l)$ c. +2.88 V

2. a. $2\,Br^-(aq) \rightarrow Br_2(l) + 2\,e^-$ b. $Mn^{3+}(aq) + e^- \rightarrow Mn^{2+}(aq)$ c. +0.45 V

3. a. $4\,OH^-(aq) + N_2H_4(aq) \rightarrow N_2(g) + 4\,H_2O(l) + 4\,e^-$ b. $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ c. +0.40 V

4. a. $Cu(s) \rightarrow Cu^{2+}(aq) + 2\,e^-$ b. $NO_3^-(aq) + 4\,H^+(aq) + 3\,e^- \rightarrow NO(g) + 2\,H_2O(l)$ c. +0.62 V

5. a. $Pb(s) + HSO_4^-(aq) \rightarrow PbSO_4(s) + H^+(aq) + 2\,e^-$

   b. $PbO_2(s) + HSO_4^-(aq) + 3\,H^+(aq) + 2\,e^- \rightarrow PbSO_4(s) + 2\,H_2O(l)$

   c. +2.041 V

6. $Sn^{2+}(aq) < I_2(s) < Co^{3+}(aq)$

7. $NO_3^-(aq) < H_2O_2(aq) < O_3(g)$

8. $I_2(s) < Br_2(l) < Cl_2(g)$

9. $Cl^-(aq) < Br^-(aq) < I^-(aq)$

10. $Cu(s) < Cd(s) < Mg(s)$

11. $H_2(g) < Ni(s) < N_2H_4(aq)$

12. –799 kJ

13. -3.75×10^3 kJ

14. –103 kJ

15. -3.5×10^2 kJ

16. -5.2×10^2 kJ

17. 3×10^5

18. 1×10^{31}

19. 3×10^{10}

20. +0.027 V

21. +0.57 V

22. +3.60 V

23. 6.0

24. a. 0.12 V b. 9.0

25. a. 3×10^{-6} M b. 1×10^{-8}

26. 3