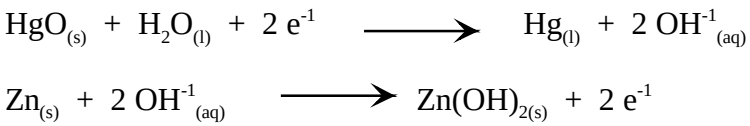
CHEM 2
Chapter 19

Key Begins on Page 3.

1. A mercury battery, used for hearing aids and electric watches, delivers a constant voltage of 1.35 V for long periods. The half-reactions are



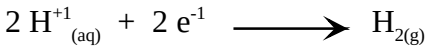
$$HgO_{(s)} + H_2O_{(l)} + 2\,e^{-1} \longrightarrow Hg_{(l)} + 2\,OH^{-1}_{(aq)}$$

$$Zn_{(s)} + 2\,OH^{-1}_{(aq)} \longrightarrow Zn(OH)_{2(s)} + 2\,e^{-1}$$

   Which half-reaction occurs at the anode and which occurs at the cathode. What is the overall cell reaction?

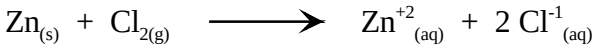
2. Write the cell notation for a voltaic cell with the following half-reactions.

$$Al_{(s)} \longrightarrow Al^{+3}_{(aq)} + 3\,e^{-1}$$



$$2\,H^{+1}_{(aq)} + 2\,e^{-1} \longrightarrow H_{2(g)}$$

3. A particular voltaic cell operates on the reaction

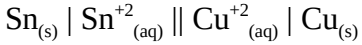


$$Zn_{(s)} + Cl_{2(g)} \longrightarrow Zn^{+2}_{(aq)} + 2\,Cl^{-1}_{(aq)}$$

   giving an emf of 0.853 V. Calculate the maximum electrical work generated when 20.0 grams of zinc metal is consumed.

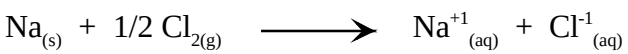
4. Dichromate ion, $Cr_2O_7^{-2}$, is added to an acidic solution containing Br^{-1} and Mn^{+2}. Write a balanced equation for any reaction that occurs. Assume standard conditions at 25°C.

5. Calculate the standard emf of the following cell at 25°C.



$$Sn_{(s)} \mid Sn^{+2}_{(aq)} \parallel Cu^{+2}_{(aq)} \mid Cu_{(s)}$$

6. Using electrode potentials, calculate the standard free energy change for the following reaction.



$$Na_{(s)} + 1/2\,Cl_{2(g)} \longrightarrow Na^{+1}_{(aq)} + Cl^{-1}_{(aq)}$$

7. Calculate the standard emf at 25°C for the following cell reaction from standard free energies of formation (see Appendix C)

$$2\ Al_{(s)} + 3\ Cu^{+2}_{(aq)} \longrightarrow 2\ Al^{+3}_{(aq)} + 3\ Cu_{(s)}$$

8. Use electrode potentials to calculate the equilibrium constant at 25°C for the reaction

$$2\ ClO_3^{-1}{}_{(aq)} \rightleftharpoons ClO_4^{-1}{}_{(aq)} + ClO2^{-1}{}_{(aq)}$$ (see Appendix I for data)

9. Calculate the emf of a cell operating with the following reaction at 25°C, in which $[Cr_2O_7^{-1}] = 0.020$ M, $[I^{-1}] = 0.015$ M, $[Cr^{+3}] = 0.20$ M, and $[H^{+1}] = 1.0$ M.

$$Cr_2O_7^{-2}{}_{(aq)} + 6\ I^{-1}_{(aq)} + 14\ H^{+}_{(aq)} \longrightarrow 2\ Cr^{+3}_{(aq)} + 3\ I_{2(s)} + 7\ H_2O_{(l)}$$

10. The emf of the following cell at 25°C is 0.475 V.

$$Zn \mid Zn^{+2}\ (1\ M) \parallel H^{+1}(\text{test solution}) \mid H_2\ (1\ atm) \mid Pt$$

What is the pH of the test solution?

11. Chlorine, Cl_2, is produced commercially by the electrolysis of aqueous sodium chloride. The anode reaction is

$$2\ Cl^{-1}_{(aq)} \longrightarrow Cl_{2(g)} + 2\ e^{-1}$$

How long will it take to produce 1.18 kg of chlorine if the current is 5.00×10^2 amps?

KEY

CHEM 132
Problem Set Ch.19

1. A mercury battery, used for hearing aids and electric watches, delivers a constant voltage of 1.35 V for long periods. The half-reactions are

(1) $HgO_{(s)} + H_2O_{(l)} + 2\,e^{-1} \longrightarrow Hg_{(l)} + 2\,OH^{-1}_{(aq)}$ – REDUCTION

(2) $Zn_{(s)} + 2\,OH^{-1}_{(aq)} \longrightarrow Zn(OH)_{2(s)} + 2\,e^{-1}$ — OXIDATION

Which half-reaction occurs at the anode and which occurs at the cathode. What is the overall cell reaction?

REACTION (1) IS A REDUCTION - CATHODE
REACTION(2) IS AN OXIDATION - ANODE

$HgO + H_2O + 2e^- \rightarrow Hg + 2OH^-$
$Zn + 2OH^- \rightarrow Zn(OH)_2 + 2e^-$

OVERALL $Zn + HgO + H_2O \rightarrow Zn(OH)_2 + Hg$

2. Write the cell notation for a voltaic cell with the following half-reactions.

$Al_{(s)} \longrightarrow Al^{+3}_{(aq)} + 3\,e^{-1}$

$2\,H^{+1}_{(aq)} + 2\,e^{-1} \longrightarrow H_{2(g)}$

$Al_{(s)} \,|\, Al^{+3}_{(aq)} \,||\, H^{+}_{(aq)} \,|\, H_2 \,|\, Pt$

3. A particular voltaic cell operates on the reaction

$Zn_{(s)} + Cl_{2(g)} \longrightarrow Zn^{+2}_{(aq)} + 2\,Cl^{-1}_{(aq)}$ — $2e^-$ TRANSFER.... $n = 2$

giving an emf of 0.853 V. Calculate the maximum electrical work generated when 20.0 grams of zinc metal is consumed. $20g\,Zn\left(\frac{1\,mole}{65.4}\right)\left(\frac{2\,mole\,e^-}{1\,mol\,Zn}\right) = 0.612\,mol\,e^- = n$.

$\mathcal{E}$ "volt"

$w_{max} = \Delta G^\circ = -nF\mathcal{E} = -(0.612\,mole)(96{,}500\,C/mole)(0.853\,J/C) = 50395\,J$

OR 50.3 kJ

4. Dichromate ion, $Cr_2O_7^{-2}$, is added to an acidic solution containing Br^{-1} and Mn^{+2}. Write a balanced equation for any reaction that occurs. Assume standard conditions at 25°C. THE OXIDATION OF Br^-

THE POTENTIAL RXN FOR $Cr_2O_7^{-2}$ IN ACID WOULD BE

$2Br^{-1} \rightarrow Br_2 + 2e^-$ $\mathcal{E} = -1.07\,V$

$Cr_2O_7^{-2} + 14H^+ + 6e^- \rightarrow 2Cr^{+3} + 7H_2O$ $\mathcal{E} = 1.33\,V$

SO $Cr_2O_7 + 14H^+ + 6Br^{-1} \rightarrow 3Br_2 + 2Cr^{+3} + 7H_2O$ WOULD OCCUR

$Mn^{+2} + 4H_2O \rightarrow MnO_4^{-1} + 8H^+ + 5e^-$ $\mathcal{E} = -1.49\,V$ } NEG $\mathcal{E}$ WON'T GO

5. Calculate the standard emf of the following cell at 25°C.

$Sn_{(s)} \,|\, Sn^{+2}_{(aq)} \,||\, Cu^{+2}_{(aq)} \,|\, Cu_{(s)}$

$Sn \rightarrow Sn^{+2} + 2e^-$ $\mathcal{E} = +0.14\,V$

$Cu^{+2} + 2e^- \rightarrow Cu$ $\mathcal{E} = +0.34\,V$

$\mathcal{E}_{cell} = +0.48\,V$

6. Using electrode potentials, calculate the standard free energy change for the following reaction.

$Na_{(s)} + 1/2\,Cl_{2(g)} \longrightarrow Na^{+1}_{(aq)} + Cl^{-1}_{(aq)}$

$Na \rightarrow Na^+ + 1e^-$ $\mathcal{E}^\circ = +2.71\,V$

$\frac{1}{2}Cl_2 + 1e^- \rightarrow Cl^-$ $\mathcal{E}^\circ = 1.36\,V$

$\mathcal{E}^\circ_{cell} = 4.07\,V$

$\Delta G^\circ = -nF\mathcal{E}^\circ$

$= -(1)(96{,}500)(4.07\,V)$

$= 392{,}755\,J \cong 393\,kJ$

7. Calculate the standard emf at 25°C for the following cell reaction from standard free energies of formation (see Appendix C)

ΔG_f°: 0 kJ, 64.98 kJ, −481.2 kJ, 0

$$2\,Al_{(s)} + 3\,Cu^{+2}_{(aq)} \longrightarrow 2\,Al^{+3}_{(aq)} + 3\,Cu_{(s)}$$

$\Delta G^\circ = 2(-481.2) - 3(64.98) = -1157.3$ kJ

6 e⁻ CHANGE, $n = 6$

$\mathcal{E}^\circ = \dfrac{\Delta G^\circ}{-nF} = \dfrac{1{,}157{,}300\ J}{-(6)(96500)} = 2.00\ V.$

8. Use electrode potentials to calculate the equilibrium constant at 25°C for the reaction

$$2\,ClO_3^{-1}{}_{(aq)} \rightleftharpoons ClO_4^{-1}{}_{(aq)} + ClO2^{-1}{}_{(aq)}$$ (see Appendix I for data)

HALF REACTIONS

$ClO_3^{-1} + 2H_2O + 2e^- \longrightarrow ClO_2^{-1} + 2OH^-$ $\quad \mathcal{E} = +0.33\ V.$

$ClO_3^{-1} + 2OH^- \longrightarrow ClO_4^{-1} + 2H_2O + 2e^-$ $\quad \mathcal{E} = -0.17\ V$

$2\,ClO_3^{-1} \longrightarrow ClO_4^{-1} + ClO_2^{-1}$ $\quad \mathcal{E}_{cell} = +0.18\ V$

$\mathcal{E}^\circ_{cell} = \dfrac{0.0592}{n} \log K$

$+0.18\ V = \dfrac{0.0592}{2} \log K$

$\log K = \dfrac{(+0.18\ V)(2)}{0.0592} = 6.081$

$K = 1.20 \times 10^6$

9. Calculate the emf of a cell operating with the following reaction at 25°C, in which $[Cr_2O_7^{-1}] = 0.020$ M, $[I^{-1}] = 0.015$ M, $[Cr^{+3}] = 0.20$ M, and $[H^{+1}] = 1.0$ M.

$$Cr_2O_7^{-2}{}_{(aq)} + 6\,I^{-1}{}_{(aq)} + 14\,H^+_{(aq)} \longrightarrow 2\,Cr^{+3}_{(aq)} + 3\,I_{2(s)} + 7\,H_2O_{(l)}$$

(+6 → +3; 6 e⁻ TRANSF, $n = 6$)

$Q = \dfrac{[Cr^{+3}]^2}{[Cr_2O_7^{-1}][I^{-1}]^6[H^+]^{14}} = \dfrac{(0.20)^2}{(0.020)(0.015)^6(1.0)^{14}} = 1.756 \times 10^{11}$

$Cr_2O_7^{-2} + 14H^+ + 6e^- \longrightarrow 2Cr^{+3} + 7H_2O$ $\quad \mathcal{E} = 1.33\ V$

$6\,I^- \rightleftharpoons 3\,I_2 + 6e^-$ $\quad \mathcal{E} = -0.54\ V$

$\mathcal{E}^\circ_{cell} = +0.79\ V$

$\mathcal{E}_{cell} = +0.79\ V - \dfrac{0.0592}{6} \log(1.756 \times 10^{11}) = +0.68\ V$

10. The emf of the following cell at 25°C is 0.475 V.

$$Zn \mid Zn^{+2}\ (1\ M) \parallel H^{+1}(\text{test solution}) \mid H_2\ (1\ atm) \mid Pt$$

$\mathcal{E}^\circ = +0.76\ V$

What is the pH of the test solution?

$pH = \dfrac{(+0.76\ V) - (0.475\ V)}{0.0592} = 4.81$

11. Chlorine, Cl_2, is produced commercially by the electrolysis of aqueous sodium chloride. The anode reaction is

$$2\,Cl^{-1}{}_{(aq)} \longrightarrow Cl_{2(g)} + 2\,e^{-1}$$

How long will it take to produce 1.18 kg of chlorine if the current is 5.00×10^2 amps?

$(1{,}180\ g)\left(\dfrac{1\ mole\ Cl_2}{70.9\ g}\right)\left(\dfrac{2\ mole\ e^-}{1\ mol\ Cl_2}\right)\left(\dfrac{96{,}500\ coul.}{mole\ e^-}\right) = 3.212 \times 10^6$ coulombs required

AT 500 A or 500 coul/sec THIS WOULD TAKE

$\dfrac{3.212 \times 10^6\ C}{500\ C/s} = 6424$ sec OR 107 MINUTES