South Pasadena • AP Chemistry

Name Key
Period ___ Date ___/___/___

21 • Electron Transfer Reactions

"ox" anode || cathode "red"

PRACTICE TEST

1. Which of the following is the correct cell notation for the reaction
$$Hg_2^{2+} + Cd(s) \rightarrow Cd^{2+} + 2Hg(l)$$
   a) $Cd^{2+} | Cd || Hg_2^{2+} | Hg$
   b) $Cd^{2+} | Hg_2^{2+} || Cd | Hg$
   c) $Cd | Cd^{2+} || Hg_2^{2+} | Hg$
   d) $Cd^{2+} | Hg || Hg_2^{2+} | Cd$
   e) $Hg | Cd || Hg_2^{2+} | Cd^{2+}$

$Cd \rightarrow Cd^{2+} || Hg_2^{2+} \rightarrow Hg$

2. Consider an electrochemical cell where the following reaction takes place:
$$3Sn^{2+}(aq) + 2Al(s) \rightarrow 3Sn(s) + 2Al^{3+}(aq)$$
Which of the following is the correct cell notation for this cell?
   a) $Al | Al^{3+} || Sn^{2+} | Sn$
   b) $Al^{3+} | Al || Sn | Sn^{2+}$
   c) $Sn | Sn^{2+} || Al^{3+} | Al$
   d) $Sn | Al^{3+} || Al | Sn^{2+}$
   e) $Al | Sn^{2+} || Sn | Al^{3+}$

$Al \rightarrow Al^{3+} || Sn^{2+} \rightarrow Sn$
OXIDA. REDUCTION
ANODE CATHODE

Standard Reduction Potentials at 25°C E° (volts)

$F_2(g) + 2e^- \rightarrow 2F^-(aq)$	+2.87
$Au^{3+} + 3e^- \rightarrow Au(s)$	+1.50
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2(g) + 4H_3O^+(aq) + 4e^- \rightarrow 6H_2O(l)$	+1.23
$Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$	+1.08
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Hg_2^{2+}(aq) + 2e^- \rightarrow 2Hg(l)$	+0.79
$I_2(s) + 2e^- \rightarrow 2I^-(aq)$	+0.535
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.337
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	-0.14
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	-0.40
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	-0.763
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	-0.828
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	-1.66
$K^+(aq) + e^- \rightarrow K(s)$	-2.93
$Li^+(aq) + e^- \rightarrow Li(s)$	-3.045

3. Given the two half reactions and their potentials, which net reaction is spontaneous? reactants
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ $E° = -0.25$ V HIGHER
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$ $E° = -2.37$ V LOWER
   a) $Ni(s) + Mg^{2+}(aq) \rightarrow Mg(s) + Ni^{2+}(aq)$
   b) $Ni^{2+}(aq) + Mg(s) \rightarrow Mg^{2+}(aq) + Ni(s)$
   c) $Ni(s) + Mg(s) \rightarrow Mg^{2+}(aq) + Ni^{2+}(aq)$
   d) $Mg^{2+}(aq) + Ni^{2+}(aq) \rightarrow Mg(s) + Ni(s)$
   e) $Mg^{2+}(aq) + Mg(s) \rightarrow Ni(s) + Ni^{2+}(aq)$

4. Calculate E° for the following reaction: $Sn^{4+} \rightarrow Sn^{2+}$ E° +.15
$Sn^{4+}(aq) + 2K(s) \rightarrow Sn^{2+}(aq) + 2K^+(aq)$ $K^+ \rightarrow K$ −2.93
   a) +6.00 V
   b) -3.08 V
   c) +3.08 V
   d) +2.78 V
   e) -2.78 V

$E°_{cell} = (+.15) + (+2.93)$

5. Calculate E° for the following reaction: ← NOT A SPONTANEOUS REACTION
$2Al^{3+}(aq) + 3Cd(s) \rightarrow 2Al(s) + 3Cd^{2+}(aq)$
   a) -2.06 V
   b) +4.52 V
   c) +2.06 V
   d) -4.52 V
   e) -1.26 V

RED = $Al^{3+} \rightarrow Al$ $E°_{RED}$ −1.66
OX = $Cd \rightarrow Cd^{2+}$ $E°_{OX}$ +.40
$E°_{cell} = -1.66 + (+.40)$

6. Using data from the reduction potential table and the reaction
$2Ag(s) + Pt^{2+}(aq) \rightarrow Pt(s) + 2Ag^+(aq)$ $E° = 0.38$ V
calculate the standard reduction potential of the half-reaction $E°_{cell} = E°_{RED} + E°_{OX}$
$$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s)$$
   a) -1.18 V
   b) -0.40 V
   c) 0.40 V
   d) 1.18 V
   e) 2.00 V

$.38V = x + (-.80)$

7. Using data from the reduction potential table, predict which of the following is the best *oxidizing* agent. most likely REDUCED
   a) F_2
   b) Ag
   c) Sn^{4+}
   d) Ag^+
   e) Al^{3+}

Top of CHART

$E^\circ_{cell} = E^\circ_{red} + E^\circ_{ox}$
$-.65 = .34 + x$

8. An electrochemical cell of notation $Pd \mid Pd^{2+} \mid\mid Cu^{2+} \mid Cu$ has an E° = -0.65 V. If we know that the standard reduction potential of Cu^{2+}/Cu is E° = 0.34 V, what is the standard reduction potential for Pd^{2+}/Pd? $x = -.99V = E^\circ_{ox}$
   a) -0.99 V
   b) -0.31 V
   c) +0.31 V
   d) 0.62 V
   e) +0.99 V

   CHANGE SIGN FOR E°_{red}

9. The standard cell potential for $3Sn^{4+}(aq) + 2Al(s) \rightarrow 3Sn^{2+}(aq) + 2Al^{3+}(aq)$ is E° = 1.81 V. What is E_{cell} when
   use Nernst Equation
   $[Sn^{4+}] = 1.0$,
   $[Sn^{2+}] = 1.0 \times 10^{-2}$, and
   $[Al^{3+}] = 1.5 \times 10^{-3}$ at 298 K. = 25°C
   a) 1.70 V
   b) 1.76 V
   c) 1.81 V
   d) 1.86 V
   e) 1.93 V

   OXIDATION "LEO"

10. Predict the product at the anode when electric current is passed through a solution of KI.
   a) $I_2(l)$ liquid?!
   b) $K^+(aq)$
   c) $H_2(g)$
   d) K(s)
   e) $O_2(g)$

   e-'s are lost at ⊕ electrode
   Higher E°_{ox} → $2I^- \rightarrow I_2 + 2e^-$
   $2H_2O \rightarrow \cancel{O_2} + 4H^+ + 4e^-$

11. If electric current is passed through aqueous LiBr, the product at the cathode would be __H_2__ and the product at the anode would be __Br_2__. See "Scratch paper"
   a) $H_2O(l), Li^+(aq)$
   b) $Br_2(l), Li(s)$
   c) $Li(s), Br_2(l)$
   d) $Br_2(l), H_2(g)$
   e) $H_2(g), Br_2(l)$

12. How long would it take to deposit 1.36 g of copper from an aqueous solution of copper(II) sulfate by passing a current of two amperes through the solution? See "Scratch paper"
   a) 2070 sec
   b) 1.11×10^{-5} sec
   c) 2570 sec
   d) 736 sec
   e) 1030 sec

13. If a current of 6.0 amps is passed through a solution of Ag^+ for 1.5 hours, how many grams of silver are produced?
   a) 0.60 g
   b) 36 g
   c) 0.34 g
   d) 3.0 g
   e) 1.0 g

$$6\,amp \times 1.5\,hr \times \frac{3600\,s}{1\,hr} \times \frac{1\,C}{1\,amp \cdot s} \times \frac{1\,mole\,e^-}{96500\,C} \times \frac{1\,mole\,Ag}{1\,mole\,e^-} \times \frac{107.9\,g\,Ag}{1\,mole\,Ag} = \boxed{36.2\,g\,Ag}$$

14. How is aluminum currently produced in industry? TRIVIA p 992
   a) by reduction of Al^{3+} in Al_2O_3 with Na(s)
   b) electrochemical reduction of pure Al_2O_3 to give Al and O_2
   c) electrolysis of AlF_3 to give Al and F_2
   d) electrolysis of a mixture of Al_2O_3 and Na_3AlF_6 to give Al and O_2
   e) by reduction of Al^{3+} in Al_2O_3 with CO(g)

   TRIVIA p 991

15. How was aluminum originally made?
   a) the Hall-Heroult process
   b) Al_2O_3 mixed with cryolite is electrolyzed
   c) electrolysis of molten Al_2O_3
   d) mining and purifying directly
   e) reducing $AlCl_3$ with sodium

16. Under acidic conditions the bromate ion is reduced to the bromide ion. Write the balanced half-reaction for this process.
   a) $BrO_3^- + 6H^+ + 6e \rightarrow Br^- + 3H_2O$
   b) $2BrO_3^- + 6H^+ \rightarrow Br_2^- + 6H_2O + 3e$
   c) $Bro_3^- + 6H_2O + 10e \rightarrow Br_2^- + 12H^+ + 3\,O_2$
   d) $2BrO_3^- + 6H_2O \rightarrow 2Br^- + 12H^+ + 6\,O_2 + 8e$
   e) $2BrO_3^- + 6H^+ \rightarrow Br_2^- + 3H_2O + 3e$

17. Balance the following redox equation which occurs in acidic solution.
   $N_2H_4(g) + BrO_3^-(aq) \rightarrow Br^-(aq) + N_2(g)$
   a) $3N_2H_4 + BrO_3^- \rightarrow 3N_2 + Br^- + 3H_2O + 6H^+$
   b) $N_2H_4 + BrO_3^- + 2H^+ \rightarrow 2Br^- + N_2 + 3H_2O$
   c) $3N_2H_4 + 2BrO_3^- + 12H^+ \rightarrow 3N_2 + 2Br^- + 6H_2O + 12H^+$
   d) $N_2H_4 + 2BrO_3^- + 8H^+ \rightarrow 2Br^- + N_2 + 6H_2O$
   e) $3N_2H_4 + 2BrO_3^- \rightarrow 3N_2 + 2Br^- + 6H_2O$

18. Which of the following reactions is NOT a redox reaction?
   a) $2HgO(s) \rightarrow 2\,Hg(l) + O_2(g)$
   b) $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$
   c) $2HCl(aq) + Zn(s) \rightarrow H_2(g) + ZnCl_2(aq)$
   d) $H_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g)$
   e) $2KClO_3 \rightarrow 2KCl(s) + 3\,O_2(g)$

1.C 2.A 3.B 4.C 5.E 6.D 7.A 8.E 9.E 10.A
11.E 12.A 13.B 14.D 15.E 16.A 17.E 18.D

$3Sn^{4+} + 6e^- \rightarrow 3Sn^{2+}$

$2Al \rightarrow 2Al^{3+} + 6e^-$

#9

$E_{cell} = E^\circ_{cell} - \frac{0.0592}{n} \log Q$ $\quad n = 6$

$Q = \frac{[Sn^{2+}]^3[Al^{3+}]^2}{[Sn^{4+}]^3} = \frac{(1\times10^{-2})^3(1.5\times10^{-3})^2}{(1.0)^3} = 2.25\times10^{-12}$

$E_{cell} = 1.81 - \frac{0.0592}{6} \log 2.25\times10^{-12}$

$= 1.81 - (-.11492) = 1.9249 \text{ V} = \boxed{1.92 \text{ V}}$ "E"

CLOSEST ANSWER

(11)

OXIDATION = ANODE

$\boxed{+}$ chemical lose e^-s

$2Br^- \rightarrow Br_2 + 2e^-$

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Higher E°_{ox}

REDUCTION = CATHODE

$\boxed{-}$ chemicals gain e^-'s

$Li^+ + e^- \rightarrow Li$

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

HIGHER E°_{RED}

(12) $(2\text{amp})(x) \times \frac{1\text{C}}{1\text{amp}\cdot\text{s}} \times \frac{1\text{mole } e^-}{96500\text{C}} \times \frac{1\text{mole Cu}}{2\text{mole } e^-} \times \frac{63.55\text{g Cu}}{1\text{mole Cu}} = 1.36\text{g}$

solve for x or try the answers. $\boxed{2070\text{sec}}$

(16) $BrO_3^- \rightarrow Br^-$

$+6H^+ \qquad + 3H_2O$

$+6e^-$

(17)

$(N_2H_4 \rightarrow N_2 + 4H^+ + 4e^-) \times 3$

$(BrO_3^- + 6H^+ + 6e^- \rightarrow Br^- + 3H_2O) \times 2$

$\cancel{12H^+} + 3N_2H_4 + 2BrO_3^- + \cancel{12e^-} \rightarrow 3N_2 + \cancel{12H^+} + \cancel{12e^-} + 2Br^- + 6H_2O$