

# 21 • Electron Transfer Reactions

## PRACTICE TEST

*"ox" anode || cathode "red"*

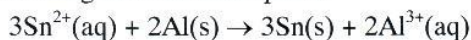
1. Which of the following is the correct cell notation for the reaction



- a)  $\text{Cd}^{2+} | \text{Cd} || \text{Hg}_2^{2+} | \text{Hg}$
- b)  $\text{Cd}^{2+} | \text{Hg}_2^{2+} || \text{Cd} | \text{Hg}$
- c)  $\text{Cd} | \text{Cd}^{2+} || \text{Hg}_2^{2+} | \text{Hg}$**
- d)  $\text{Cd}^{2+} | \text{Hg} || \text{Hg}_2^{2+} | \text{Cd}$
- e)  $\text{Hg} | \text{Cd} || \text{Hg}_2^{2+} | \text{Cd}^{2+}$

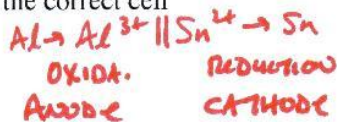


2. Consider an electrochemical cell where the following reaction takes place:



Which of the following is the correct cell notation for this cell?

- a)  $\text{Al} | \text{Al}^{3+} || \text{Sn}^{2+} | \text{Sn}$**
- b)  $\text{Al}^{3+} | \text{Al} || \text{Sn} | \text{Sn}^{2+}$
- c)  $\text{Sn} | \text{Sn}^{2+} || \text{Al}^{3+} | \text{Al}$
- d)  $\text{Sn} | \text{Al}^{3+} || \text{Al} | \text{Sn}^{2+}$
- e)  $\text{Al} | \text{Sn}^{2+} || \text{Sn} | \text{Al}^{3+}$



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

$\text{F}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{F}^-(\text{aq})$	+2.87
$\text{Au}^{3+} + 3\text{e}^- \rightarrow \text{Au(s)}$	+1.50
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2(\text{g}) + 4\text{H}_3\text{O}^+(\text{aq}) + 4\text{e}^- \rightarrow 6\text{H}_2\text{O(l)}$	+1.23
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightarrow 2\text{Br}^-(\text{aq})$	+1.08
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag(s)}$	+0.80
$\text{Hg}_2^{2+}(\text{aq}) + 2\text{e}^- \rightarrow 2\text{Hg(l)}$	+0.79
$\text{I}_2(\text{s}) + 2\text{e}^- \rightarrow 2\text{I}^-(\text{aq})$	+0.535
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu(s)}$	+0.337
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}^{2+}(\text{aq})$	+0.15
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn(s)}$	-0.14
$\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cd(s)}$	-0.40
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn(s)}$	-0.763
$2\text{H}_2\text{O(l)} + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.828
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Al(s)}$	-1.66
$\text{K}^+(\text{aq}) + \text{e}^- \rightarrow \text{K(s)}$	-2.93
$\text{Li}^+(\text{aq}) + \text{e}^- \rightarrow \text{Li(s)}$	-3.045

3. Given the two half reactions and their potentials, which net reaction is spontaneous?

- $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni(s)}$   $E^\circ = -0.25 \text{ V}$  *reactants HIGHER*
- $\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mg(s)}$   $E^\circ = -2.37 \text{ V}$  *LOWER*
- a)  $\text{Ni(s)} + \text{Mg}^{2+}(\text{aq}) \rightarrow \text{Mg(s)} + \text{Ni}^{2+}(\text{aq})$
- b)  $\text{Ni}^{2+}(\text{aq}) + \text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Ni(s)}$**
- c)  $\text{Ni(s)} + \text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Ni}^{2+}(\text{aq})$
- d)  $\text{Mg}^{2+}(\text{aq}) + \text{Ni}^{2+}(\text{aq}) \rightarrow \text{Mg(s)} + \text{Ni(s)}$
- e)  $\text{Mg}^{2+}(\text{aq}) + \text{Mg(s)} \rightarrow \text{Ni(s)} + \text{Ni}^{2+}(\text{aq})$

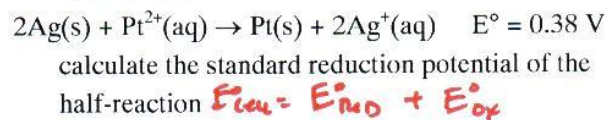
4. Calculate E° for the following reaction:  $\text{Sn}^{4+} \rightarrow \text{Sn}^{2+} + 1.5$   
 $\text{Sn}^{4+}(\text{aq}) + 2\text{K(s)} \rightarrow \text{Sn}^{2+}(\text{aq}) + 2\text{K}^+(\text{aq})$   $\text{K}^+ \rightarrow \text{K} -2.93$

- a) +6.00 V
- b) -3.08 V
- c) +3.08 V**  $E^\circ_{\text{cell}} = (+1.5) + (+2.93)$
- d) +2.78 V
- e) -2.78 V

5. Calculate E° for the following reaction:  $2\text{Al}^{3+}(\text{aq}) + 3\text{Cd(s)} \rightarrow 2\text{Al(s)} + 3\text{Cd}^{2+}(\text{aq})$  *NOT A SPONTANEOUS REACTION*

- a) -2.06 V
- b) +4.52 V
- c) +2.06 V**  $E^\circ_{\text{cell}} = -1.66 + (+4.0)$
- d) -4.52 V
- e) -1.26 V

6. Using data from the reduction potential table and the reaction



- a) -1.18 V
  - b) -0.40 V
  - c) 0.40 V
  - d) 1.18 V**
  - e) 2.00 V
- $0.38\text{V} = 1 + (-0.80)$*

7. Using data from the reduction potential table, predict which of the following is the best oxidizing agent.

- a)  $\text{F}_2$**  *most likely reduced*
  - b) Ag
  - c)  $\text{Sn}^{4+}$
  - d)  $\text{Ag}^+$
  - e)  $\text{Al}^{3+}$
- Top of chart*

$$E^{\circ}_{\text{cell}} = E^{\circ}_{\text{red}} + E^{\circ}_{\text{ox}}$$

$$-0.65 = 0.34 + x$$

8. An electrochemical cell of notation  $\text{Pd} | \text{Pd}^{2+} || \text{Cu}^{2+} | \text{Cu}$  has an  $E^{\circ} = -0.65 \text{ V}$ . If we know that the standard reduction potential of  $\text{Cu}^{2+}/\text{Cu}$  is  $E^{\circ} = 0.34 \text{ V}$ , what is the standard reduction potential for  $\text{Pd}^{2+}/\text{Pd}$ ?

- a)  $-0.99 \text{ V}$                       d)  $0.62 \text{ V}$   
 b)  $-0.31 \text{ V}$                       e)  $+0.99 \text{ V}$   
 c)  $+0.31 \text{ V}$

$x = -0.99 \text{ V} = E^{\circ}_{\text{ox}}$   
 CHANGE SIGN FOR  $E^{\circ}_{\text{red}}$

9. The standard cell potential for  $3\text{Sn}^{4+}(\text{aq}) + 2\text{Al}(\text{s}) \rightarrow 3\text{Sn}^{2+}(\text{aq}) + 2\text{Al}^{3+}(\text{aq})$  is  $E^{\circ} = 1.81 \text{ V}$ . What is  $E_{\text{cell}}$  when

use NERNST EQUATION

$[\text{Sn}^{4+}] = 1.0$ ,  
 $[\text{Sn}^{2+}] = 1.0 \times 10^{-2}$ , and  
 $[\text{Al}^{3+}] = 1.5 \times 10^{-3}$  at  $298 \text{ K}$ .  $= 25^{\circ}\text{C}$

- a)  $1.70 \text{ V}$                       d)  $1.86 \text{ V}$   
 b)  $1.76 \text{ V}$                       e)  $1.93 \text{ V}$   
 c)  $1.81 \text{ V}$

10. Predict the product at the anode when electric current is passed through a solution of KI.

- a)  $\text{I}_2(\text{l})$                       d)  $\text{K}(\text{s})$   
 b)  $\text{K}^{+}(\text{aq})$                       e)  $\text{O}_2(\text{g})$   
 c)  $\text{H}_2(\text{g})$

OXIDATION "LEO"  
 $e^{-}$ 's are lost at  $\oplus$  electrode  
 Higher  $E^{\circ}_{\text{ox}} \rightarrow 2\text{I}^{-} \rightarrow \text{I}_2 + 2e^{-}$   
 $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^{+} + 4e^{-}$

11. If electric current is passed through aqueous LiBr, the product at the cathode would be

- $\text{H}_2$  and the product at the anode would be  $\text{Br}_2$ .  
 See "Scratch paper"  
 a)  $\text{H}_2\text{O}(\text{l}), \text{Li}^{+}(\text{aq})$                       d)  $\text{Br}_2(\text{l}), \text{H}_2(\text{g})$   
 b)  $\text{Br}_2(\text{l}), \text{Li}(\text{s})$                       e)  $\text{H}_2(\text{g}), \text{Br}_2(\text{l})$   
 c)  $\text{Li}(\text{s}), \text{Br}_2(\text{l})$

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?

- a)  $2070 \text{ sec}$                       d)  $736 \text{ sec}$   
 b)  $1.11 \times 10^{-5} \text{ sec}$                       e)  $1030 \text{ sec}$   
 c)  $2570 \text{ sec}$

13. If a current of 6.0 amps is passed through a solution of  $\text{Ag}^{+}$  for 1.5 hours, how many grams of silver are produced?

- a)  $0.60 \text{ g}$                       d)  $3.0 \text{ g}$   
 b)  $36 \text{ g}$                       e)  $1.0 \text{ g}$   
 c)  $0.34 \text{ g}$

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

14. How is aluminum currently produced in industry?

- a) by reduction of  $\text{Al}^{3+}$  in  $\text{Al}_2\text{O}_3$  with  $\text{Na}(\text{s})$   
 b) electrochemical reduction of pure  $\text{Al}_2\text{O}_3$  to give Al and  $\text{O}_2$   
 c) electrolysis of  $\text{AlF}_3$  to give Al and  $\text{F}_2$   
 d) electrolysis of a mixture of  $\text{Al}_2\text{O}_3$  and  $\text{Na}_3\text{AlF}_6$  to give Al and  $\text{O}_2$   
 e) by reduction of  $\text{Al}^{3+}$  in  $\text{Al}_2\text{O}_3$  with  $\text{CO}(\text{g})$

15. How was aluminum originally made?

- a) the Hall-Heroult process  
 b)  $\text{Al}_2\text{O}_3$  mixed with cryolite is electrolyzed  
 c) electrolysis of molten  $\text{Al}_2\text{O}_3$   
 d) mining and purifying directly  
 e) reducing  $\text{AlCl}_3$  with sodium

16. Under acidic conditions the bromate ion is reduced to the bromide ion. Write the balanced half-reaction for this process.

- a)  $\text{BrO}_3^{-} + 6\text{H}^{+} + 6e^{-} \rightarrow \text{Br}^{-} + 3\text{H}_2\text{O}$   
 b)  $2\text{BrO}_3^{-} + 6\text{H}^{+} \rightarrow \text{Br}_2 + 6\text{H}_2\text{O} + 3e^{-}$   
 c)  $\text{BrO}_3^{-} + 6\text{H}_2\text{O} + 10e^{-} \rightarrow \text{Br}_2 + 12\text{H}^{+} + 3\text{O}_2$   
 d)  $2\text{BrO}_3^{-} + 6\text{H}_2\text{O} \rightarrow 2\text{Br}^{-} + 12\text{H}^{+} + 6\text{O}_2 + 8e^{-}$   
 e)  $2\text{BrO}_3^{-} + 6\text{H}^{+} \rightarrow \text{Br}_2 + 3\text{H}_2\text{O} + 3e^{-}$

17. Balance the following redox equation which occurs in acidic solution.

- $\text{N}_2\text{H}_4(\text{g}) + \text{BrO}_3^{-}(\text{aq}) \rightarrow \text{Br}^{-}(\text{aq}) + \text{N}_2(\text{g})$   
 a)  $3\text{N}_2\text{H}_4 + \text{BrO}_3^{-} \rightarrow 3\text{N}_2 + \text{Br}^{-} + 3\text{H}_2\text{O} + 6\text{H}^{+}$   
 b)  $\text{N}_2\text{H}_4 + \text{BrO}_3^{-} + 2\text{H}^{+} \rightarrow 2\text{Br}^{-} + \text{N}_2 + 3\text{H}_2\text{O}$   
 c)  $3\text{N}_2\text{H}_4 + 2\text{BrO}_3^{-} + 12\text{H}^{+} \rightarrow 3\text{N}_2 + 2\text{Br}^{-} + 6\text{H}_2\text{O} + 12\text{H}^{+}$   
 d)  $\text{N}_2\text{H}_4 + 2\text{BrO}_3^{-} + 8\text{H}^{+} \rightarrow 2\text{Br}^{-} + \text{N}_2 + 6\text{H}_2\text{O}$   
 e)  $3\text{N}_2\text{H}_4 + 2\text{BrO}_3^{-} \rightarrow 3\text{N}_2 + 2\text{Br}^{-} + 6\text{H}_2\text{O}$

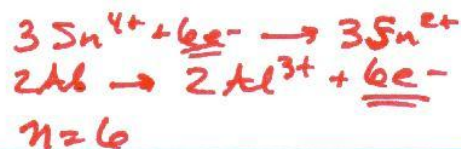
18. Which of the following reactions is NOT a redox reaction?

- a)  $2\text{HgO}(\text{s}) \rightarrow 2\text{Hg}(\text{l}) + \text{O}_2(\text{g})$   
 b)  $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \rightarrow 2\text{HBr}(\text{g})$   
 c)  $2\text{HCl}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{H}_2(\text{g}) + \text{ZnCl}_2(\text{aq})$   
 d)  $\text{H}_2\text{CO}_3(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$   
 e)  $2\text{KClO}_3 \rightarrow 2\text{KCl}(\text{s}) + 3\text{O}_2(\text{g})$

- 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

#9

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{0.0592}{n} \log Q$$



$$Q = \frac{[\text{Sn}^{2+}]^3 [\text{Al}^{3+}]^2}{[\text{Sn}^{4+}]^3} = \frac{(1 \times 10^{-2})^3 (1.5 \times 10^{-3})^2}{(1.0)^3} = 2.25 \times 10^{-12}$$

$$E_{\text{cell}} = 1.81 - \frac{0.0592}{6} \log 2.25 \times 10^{-12}$$

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

closest answer

#11

OXIDATION = ANODE

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



higher  $E^{\circ}_{\text{ox}}$

REDUCTION = CATHODE

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



HIGHER  $E^{\circ}_{\text{red}}$

#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



#17

