MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) __________ is reduced in the following reaction:
   \[ \text{Cr}_2\text{O}_7^{2-} + 6\text{S}_2\text{O}_3^{2-} + 14\text{H}^+ \rightarrow 2\text{Cr}^{3+} + 3\text{S}_4\text{O}_6^{2-} + 7\text{H}_2\text{O} \]
   A) \( \text{S}_4\text{O}_6^{2-} \)  B) \( \text{Cr}^{3+} \)  C) \( \text{S}_2\text{O}_3^{2-} \)  D) \( \text{H}^+ \)  E) \( \text{Cr}_2\text{O}_7^{2-} \)

2) __________ is the oxidizing agent in the reaction below.
   \[ \text{Cr}_2\text{O}_7^{2-} + 6\text{S}_2\text{O}_3^{2-} + 14\text{H}^+ \rightarrow 2\text{Cr}^{3+} + 3\text{S}_4\text{O}_6^{2-} + 7\text{H}_2\text{O} \]
   A) \( \text{Cr}^{3+} \)  B) \( \text{S}_2\text{O}_3^{2-} \)  C) \( \text{H}^+ \)  D) \( \text{Cr}_2\text{O}_7^{2-} \)  E) \( \text{S}_4\text{O}_6^{2-} \)

3) Which substance is serving as the reducing agent in the following reaction?
   \[ 14\text{H}^+ + \text{Cr}_2\text{O}_7^{2-} + 3\text{Ni} \rightarrow 3\text{Ni}^{2+} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O} \]
   A) \( \text{Ni}^{2+} \)  B) \( \text{H}^+ \)  C) \( \text{H}_2\text{O} \)  D) \( \text{Cr}_2\text{O}_7^{2-} \)  E) \( \text{Ni} \)

4) Which substance is the reducing agent in the reaction below?
   \[ \text{Pb} + \text{PbO}_2 + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O} \]
   A) \( \text{Pb} \)  B) \( \text{PbO}_2 \)  C) \( \text{PbSO}_4 \)  D) \( \text{H}_2\text{SO}_4 \)  E) \( \text{H}_2\text{O} \)

5) What is the oxidation number of chromium in \( \text{Cr}_2\text{O}_7^{2-} \) ion?
   A) \(+14\)  B) \(+7\)  C) \(+3\)  D) \(+12\)  E) \(+6\)

6) The balanced half-reaction in which chlorine gas is reduced to the aqueous chloride ion is a __________ process.
   A) one-electron  B) four-electron  C) six-electron  D) two-electron  E) three-electron
7) The electrode at which oxidation occurs is called the ________.  
   A) oxidizing agent  
   B) anode  
   C) reducing agent  
   D) cathode  
   E) voltaic cell

8) In a voltaic cell, electrons flow from the ________ to the ________.
   A) anode, salt bridge  
   B) anode, cathode  
   C) salt bridge, anode  
   D) cathode, anode  
   E) salt bridge, cathode

9) The balanced half-reaction in which dichromate ion is reduced to chromium(III) ion is a ________ process.
   A) four-electron  
   B) twelve-electron  
   C) three-electron  
   D) two-electron  
   E) six-electron

10) The more ________ the value of \( E^\circ_{\text{red}} \) the greater the driving force for reduction.
   A) exothermic  
   B) extensive  
   C) positive  
   D) endothermic  
   E) negative

Table 20.2

<table>
<thead>
<tr>
<th>Half-reaction</th>
<th>( E^\circ ) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Cr}^{3+} ) (aq) + 3e(^-) \rightarrow \text{Cr} ) (s)</td>
<td>-0.74</td>
</tr>
<tr>
<td>( \text{Fe}^{2+} ) (aq) + 2e(^-) \rightarrow \text{Fe} ) (s)</td>
<td>-0.440</td>
</tr>
<tr>
<td>( \text{Fe}^{3+} ) (aq) + e(^-) \rightarrow \text{Fe}^{2+} ) (s)</td>
<td>+0.771</td>
</tr>
<tr>
<td>( \text{Sn}^{4+} ) (aq) + 2e(^-) \rightarrow \text{Sn}^{2+} ) (aq)</td>
<td>+0.154</td>
</tr>
</tbody>
</table>

11) The standard cell potential (\( E^\circ_{\text{cell}} \)) for the voltaic cell based on the reaction below is ________ V.

   \( \text{Sn}^{2+} \) (aq) + 2\( \text{Fe}^{3+} \) (aq) \rightarrow 2\( \text{Fe}^{2+} \) (aq) + \( \text{Sn}^{4+} \) (aq)

   A) +1.39  
   B) +0.46  
   C) +1.21  
   D) +0.617  
   E) -0.46
12) The standard cell potential ($E_{\text{cell}}^\circ$) for the voltaic cell based on the reaction below is ________ V.

$$2\text{Cr} (s) + 3\text{Fe}^{2+} (aq) \rightarrow 3\text{Fe} (s) + 2\text{Cr}^{3+} (aq)$$

A) +0.30  B) −0.16  C) +3.10  D) +2.80  E) +0.83

13) The standard cell potential ($E_{\text{cell}}^\circ$) of the reaction below is +0.126 V. The value of $\Delta G^\circ$ for the reaction is ________ kJ/mol.

$$\text{Pb} (s) + 2\text{H}^+ (aq) \rightarrow \text{Pb}^{2+} (aq) + \text{H}_2 (g)$$

A) −24  B) +24  C) −12  D) +12  E) −50

14) The standard cell potential ($E_{\text{cell}}^\circ$) for the reaction below is +0.63 V. The cell potential for this reaction is ________ V when $[\text{Zn}^{2+}] = 1.0$ M and $[\text{Pb}^{2+}] = 2.0 \times 10^{-4}$ M.

$$\text{Pb}^{2+} (aq) + \text{Zn} (s) \rightarrow \text{Zn}^{2+} (aq) + \text{Pb} (s)$$

A) 0.85  B) 0.41  C) 0.52  D) 0.63  E) 0.74

15) The standard cell potential ($E_{\text{cell}}^\circ$) for the reaction below is +1.10 V. The cell potential for this reaction is ________ V when the concentration of $[\text{Cu}^{2+}] = 1.0 \times 10^{-5}$ M and $[\text{Zn}^{2+}] = 1.0$ M.

$$\text{Zn} (s) + \text{Cu}^{2+} (aq) \rightarrow \text{Cu} (s) + \text{Zn}^{2+} (aq)$$

A) 1.10  B) 1.25  C) 0.95  D) 1.40  E) 0.80

16) Galvanized iron is iron coated with ________.


17) How many minutes will it take to plate out 2.19 g of chromium metal from a solution of Cr$^{3+}$ using a current of 35.2 amps in an electrolyte cell ________?

A) 17.3  B) 5.77  C) 115  D) 346  E) 1.92

18) What current (in A) is required to plate out 1.22 g of nickel from a solution of Ni$^{2+}$ in 1.0 hour ________?

A) $4.01 \times 10^3$  B) 1.11  C) 12.9  D) 2.34  E) 65.4
19) Which element is oxidized in the reaction below?

\[ \text{Fe(CO)}_5 (l) + 2\text{HI} (g) \rightarrow \text{Fe(CO)}_4\text{I}_2 (s) + \text{CO} (g) + \text{H}_2 (g) \]

A) Fe  B) I  C) C  D) H  E) O

20) Which of the following reactions is a redox reaction?

(a) \( \text{K}_2\text{CrO}_4 + \text{BaCl}_2 \rightarrow \text{BaCrO}_4 + 2\text{KCl} \)
(b) \( \text{Pb}^{2+} + 2\text{Br}^- \rightarrow \text{PbBr}_2 \)
(c) \( \text{Cu} + \text{S} \rightarrow \text{CuS} \)

A) (a) only  B) (b) only  C) (c) only  D) (b) and (c)  E) (a) and (c)

21) Which one of the following reactions is a redox reaction?

A) \( \text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} \)
B) \( \text{AgNO}_3 + \text{HCl} \rightarrow \text{HNO}_3 + \text{AgCl} \)
C) \( \text{H}_2\text{O} + \text{NaCl} \rightarrow \text{NaOH} + \text{HCl} \)
D) \( \text{Pb}^{2+} + 2\text{Cl}^- \rightarrow \text{PbCl}_2 \)
E) None of the above is a redox reaction.

22) Which substance is the reducing agent in the following reaction?

\[ \text{Fe}_2\text{S}_3 + 12\text{HNO}_3 \rightarrow 2\text{Fe(NO)}_3\text{S}_3 + 3\text{S} + 6\text{NO}_2 + 6\text{H}_2\text{O} \]

A) \( \text{HNO}_3 \)  B) \( \text{H}_2\text{O} \)  C) \( \text{Fe}_2\text{S}_3 \)  D) \( \text{S} \)  E) \( \text{NO}_2 \)

23) What is the coefficient of the permanganate ion when the following equation is balanced?

\[ \text{MnO}_4^- + \text{Br}^- \rightarrow \text{Mn}^{2+} + \text{Br}_2 \quad \text{(acidic solution)} \]

A) 5  B) 2  C) 4  D) 3  E) 1

24) The purpose of the salt bridge in an electrochemical cell is to __________.

A) provide a source of ions to react at the anode and cathode.
B) provide a means for electrons to travel from the cathode to the anode.
C) provide oxygen to facilitate oxidation at the anode.
D) provide a means for electrons to travel from the anode to the cathode.
E) maintain electrical neutrality in the half-cells via migration of ions.
### Table 20.1 NOT ALL ARE IN ORDER!

<table>
<thead>
<tr>
<th>Half Reaction</th>
<th>E°(V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₂ (g) + 2e⁻ → 2F⁻ (aq)</td>
<td>+2.87</td>
</tr>
<tr>
<td>Cl₂ (g) + 2e⁻ → 2Cl⁻ (aq)</td>
<td>+1.359</td>
</tr>
<tr>
<td>Br₂ (l) + 2e⁻ → 2Br⁻ (aq)</td>
<td>+1.065</td>
</tr>
<tr>
<td>O₂ (g) + 4H⁺ (aq) + 4e⁻ → 2H₂O (l)</td>
<td>+1.23</td>
</tr>
<tr>
<td>Ag⁺ + e⁻ → Ag (s)</td>
<td>+0.799</td>
</tr>
<tr>
<td>Fe³⁺ (aq) + e⁻ → Fe²⁺ (aq)</td>
<td>+0.771</td>
</tr>
<tr>
<td>I₂ (s) + 2e⁻ → 2I⁻ (aq)</td>
<td>+0.536</td>
</tr>
<tr>
<td>Cu²⁺ + 2e⁻ → Cu (s)</td>
<td>+0.34</td>
</tr>
<tr>
<td>2H⁺ + 2e⁻ → H₂ (g)</td>
<td>0</td>
</tr>
<tr>
<td>Pb²⁺ + 2e⁻ → Pb (s)</td>
<td>−0.126</td>
</tr>
<tr>
<td>Ni²⁺ + 2e⁻ → Ni (s)</td>
<td>−0.28</td>
</tr>
<tr>
<td>Li⁺ + e⁻ → Li (s)</td>
<td>−3.05</td>
</tr>
</tbody>
</table>

25) Which of the halogens in Table 20.1 is the strongest oxidizing agent?  
A) I₂  
B) Br₂  
C) Cl₂  
D) F₂  
E) All of the halogens have equal strength as oxidizing agents.

26) Which one of the following types of elements is most likely to be a good oxidizing agent?  
A) alkali metals  
B) transition elements  
C) lanthanides  
D) alkaline earth elements  
E) halogens

27) Which one of the following is the best oxidizing agent?  
A) Na  
B) Li  
C) H₂  
D) Ca  
E) O₂ (in acidic solution)
Table 20.1  NOT ALL ARE IN ORDER!

<table>
<thead>
<tr>
<th>Half Reaction</th>
<th>E°(V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₂ (g) + 2e⁻ → 2F⁻ (aq)</td>
<td>+2.87</td>
</tr>
<tr>
<td>Cl₂ (g) + 2e⁻ → 2Cl⁻ (aq)</td>
<td>+1.359</td>
</tr>
<tr>
<td>Br₂ (l) + 2e⁻ → 2Br⁻ (aq)</td>
<td>+1.065</td>
</tr>
<tr>
<td>O₂ (g) + 4H⁺ (aq) + 4e⁻ → 2H₂O (l)</td>
<td>+1.23</td>
</tr>
<tr>
<td>Ag⁺ + e⁻ → Ag (s)</td>
<td>+0.799</td>
</tr>
<tr>
<td>Fe³⁺ (aq) + e⁻ → Fe²⁺ (aq)</td>
<td>+0.771</td>
</tr>
<tr>
<td>I₂ (s) + 2e⁻ → 2I⁻ (aq)</td>
<td>+0.536</td>
</tr>
<tr>
<td>Cu²⁺ + 2e⁻ → Cu (s)</td>
<td>+0.34</td>
</tr>
<tr>
<td>2H⁺ + 2e⁻ → H₂ (g)</td>
<td>0</td>
</tr>
<tr>
<td>Pb²⁺ + 2e⁻ → Pb (s)</td>
<td>−0.126</td>
</tr>
<tr>
<td>Ni²⁺ + 2e⁻ → Ni (s)</td>
<td>−0.28</td>
</tr>
<tr>
<td>Li⁺ + e⁻ → Li (s)</td>
<td>−3.05</td>
</tr>
</tbody>
</table>

28) Using Table 20.1, which substance can be oxidized by O₂ (g) in acidic aqueous solution?
   A) Cu²⁺ (aq)  B) Ni²⁺ (aq)  C) Ag (s)  D) Br₂ (l)  E) F⁻ (aq)

29) Using Table 20.1, which substance can oxidize I⁻ (aq) to I₂ (s) ?
   A) Ni²⁺ (aq)  B) Br₂ (l)  C) Br⁻ (aq)  D) Ag (s)  E) Cu²⁺ (aq)

Table 20.2

<table>
<thead>
<tr>
<th>Half-reaction</th>
<th>E° (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr³⁺ (aq) + 3e⁻ → Cr (s)</td>
<td>−0.74</td>
</tr>
<tr>
<td>Fe²⁺ (aq) + 2e⁻ → Fe (s)</td>
<td>−0.440</td>
</tr>
<tr>
<td>Fe³⁺ (aq) + e⁻ → Fe²⁺ (s)</td>
<td>+0.771</td>
</tr>
<tr>
<td>Sn⁴⁺ (aq) + 2e⁻ → Sn²⁺ (aq)</td>
<td>+0.154</td>
</tr>
</tbody>
</table>

30) Which of the following reactions will occur spontaneously as written? Dr. B suggests writing half reactions first.
   A) 3Fe (s) + 2Cr³⁺ (aq) → 2Cr (s) + 3Fe²⁺ (aq)
   B) 3Fe²⁺ (aq) → Fe (s) + 2Fe³⁺ (aq)
   C) 3Sn⁴⁺ (aq) + 2Cr (s) → 2Cr³⁺ (aq) + 3Sn²⁺ (aq)
   D) Sn⁴⁺ (aq) + Fe²⁺ (aq) → Sn²⁺ (aq) + Fe (s)
   E) Sn⁴⁺ (aq) + Fe³⁺ (aq) → Sn²⁺ (aq) + Fe²⁺ (aq)
31) Which of the following reactions will occur spontaneously as written? Dr. B suggests writing half reactions!

A) \(2\text{Cr}^{3+} (aq) + 3\text{Sn}^{2+} (aq) \rightarrow 3\text{Sn}^{4+} (aq) + 2\text{Cr} (s)\)
B) \(\text{Sn}^{4+} (aq) + \text{Fe}^{2+} (s) \rightarrow \text{Sn}^{2+} (aq) + \text{Fe} (s)\)
C) \(3\text{Fe}^{2+} (aq) + \text{Cr}^{3+} (aq) \rightarrow \text{Cr} (s) + 3\text{Fe}^{3+} (aq)\)
D) \(\text{Sn}^{2+} (aq) + \text{Fe}^{2+} (s) \rightarrow \text{Sn}^{4+} (aq) + \text{Fe}^{3+} (aq)\)
E) \(2\text{Cr} (s) + 3\text{Fe}^{2+} (s) \rightarrow 3\text{Fe} (s) + 2\text{Cr}^{3+} (aq)\)

32) Consider an electrochemical cell based on the reaction:

\(2\text{H}^+ (aq) + \text{Sn} (s) \rightarrow \text{Sn}^{2+} (aq) + \text{H}_2 (g)\)

Which of the following actions would change the measured cell potential?

A) increasing the pressure of hydrogen gas in the cathode compartment
B) increasing the pH in the cathode compartment
C) lowering the pH in the cathode compartment
D) increasing the \([\text{Sn}^{2+}]\) in the anode compartment
E) Any of the above will change the measured cell potential.

33) One of the differences between a voltaic cell and an electrolytic cell is that in an electrolytic cell.

A) \(\text{O}_2\) gas is produced at the cathode
B) oxidation occurs at the cathode
C) electrons flow toward the anode
D) a nonspontaneous reaction is forced to occur
E) an electric current is produced by a chemical reaction

34) Of the metals below, only ________ will not dissolve in an aqueous solution containing nickel ions.

aluminum  chromium  barium  tin  potassium

A) potassium  B) barium  C) tin  D) chromium  E) aluminum
35) Which of these metals is the least easily oxidized? 

- Na
- Au
- Fe
- Ca
- Ag

A) Fe  B) Ag  C) Au  D) Na  E) Ca

36) Of the following elements, __________ is the only one that cannot be found in nature in its elemental form.

- Cu
- Hg
- Au
- Ag
- Na

A) Ag  B) Na  C) Cu  D) Hg  E) Au

37) Of the following elements, __________ is the most easily oxidized.

- oxygen
- fluorine
- nitrogen
- aluminum
- gold

A) oxygen  B) aluminum  C) nitrogen  D) gold  E) fluorine

38) Based on the equations below, which metal is the most active?

\[
\begin{align*}
\text{Pb(NO}_3\text{)}_2 (aq) + \text{Ni} (s) & \rightarrow \text{Ni(NO}_2\text{)}_2 (aq) + \text{Pb} (s) \\
\text{Pb(NO}_3\text{)}_2 (aq) + \text{Ag} (s) & \rightarrow \text{No reaction} \\
\text{Cu(NO}_3\text{)}_2 (aq) + \text{Ag} (s) & \rightarrow \text{No reaction}
\end{align*}
\]

A) Ag  B) Cu  C) N  D) Pb  E) Ni

39) Zinc is more active than cobalt and iron but less active than aluminum. Cobalt is more active than nickel but less active than iron. Which of the following correctly lists the elements in order of increasing activity?

A) Ni < Co < Fe < Zn < Al
B) Fe < Ni < Co < Al < Zn
C) Ni < Fe < Co < Zn < Al
D) Co < Ni < Fe < Zn < Al
E) Zn < Al < Co < Ni < Fe
40) Which of the following reactions will not occur as written?

A) Mg (s) + Ca(OH)₂ (aq) → Ca (s) + Mg(OH)₂ (aq)
B) Co (s) + 2HI (aq) → H₂ (g) + CoI₂ (aq)
C) Zn (s) + Pb(NO₃)₂ (aq) → Pb (s) + Zn(NO₃)₂ (aq)
D) Sn (s) + 2AgNO₃ (aq) → 2Ag (s) + Sn(NO₃)₂ (aq)
E) Co (s) + 2AgCl (aq) → 2Ag (s) + CoCl₂ (aq)
1) E
2) B
3) E
4) A
5) E
6) D
7) B
8) B
9) E
10) C
11) D
12) A
13) A
14) C
15) C
16) D
17) B
18) B
19) A
20) C
21) E
22) C
23) B
24) E
25) D
26) E
27) E
28) C
29) B
30) C
31) E
32) E
33) D
34) C
35) C
36) B
37) B
38) E
39) A
40) A