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) H^+  B) Cr^{6+}  C) S_4O_6^{2-}  D) S^2+  E) O^{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) Cr^{3+}  B) S_4O_6^{2-}  C) Cr_2O_7^{2-}  D) S_2O_3^{2-}  E) H^+

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) Ni  B) H_2O  C) Cr_2O_7^{2-}  D) Ni^{2+}  E) H^+

4) What is the oxidation number of chromium in Cr_2O_7^{2-} ion?
   A) +12  B) +7  C) +14  D) +6  E) +3

5) What is the oxidation number of potassium in KMnO_4?
   A) +2  B) -1  C) +1  D) 0  E) +3

6) ________ electrons appear in the following half-reaction when it is balanced.
\[ \text{S}_4\text{O}_6^{2-} \rightarrow 2\text{S}_2\text{O}_3^{2-} \]
   A) 2  B) 3  C) 6  D) 4  E) 1

7) The balanced half-reaction in which dichromate ion is reduced to chromium metal is a ________ process.
   A) six-electron  B) three-electron  C) twelve-electron  D) four-electron  E) two-electron
8) The half-reaction occurring at the anode in the balanced reaction shown below is \[ 3\text{MnO}_4^- \text{(aq)} + 24\text{H}^+ \text{(aq)} + 5\text{Fe} \rightarrow 3\text{Mn}^{2+} \text{(aq)} + 5\text{Fe}^{3+} \text{(aq)} + 12\text{H}_2\text{O} \text{(l)} \]

A) \[ 2\text{MnO}_4^- \text{(aq)} + 12\text{H}^+ \text{(aq)} + 6\text{e}^- \rightarrow 2\text{Mn}^{2+} \text{(aq)} + 3\text{H}_2\text{O} \text{(l)} \]
B) \[ \text{Fe}^{2+} \text{(aq)} \rightarrow \text{Fe}^{3+} \text{(aq)} + \text{e}^- \]
C) \[ \text{Fe} \text{(s)} \rightarrow \text{Fe}^{2+} \text{(aq)} + 2\text{e}^- \]
D) \[ \text{Fe} \text{(s)} \rightarrow \text{Fe}^{3+} \text{(aq)} + 3\text{e}^- \]
E) \[ \text{MnO}_4^- \text{(aq)} + 8\text{H}^+ \text{(aq)} + 5\text{e}^- \rightarrow \text{Mn}^{2+} \text{(aq)} + 4\text{H}_2\text{O} \text{(l)} \]

9) The electrode at which oxidation occurs is called the \[ \underline{\text{anode}} \]

A) oxidizing agent 
B) anode 
C) reducing agent 
D) cathode 
E) voltaic cell 

10) The reduction half reaction occurring in the standard hydrogen electrode is \[ \underline{\text{H}_2 \text{(g, 1 atm)} \rightarrow 2\text{H}^+ \text{(aq, 1 M)} + 2\text{e}^-} \]

A) \[ 2\text{H}^+ \text{(aq, 1 M)} + 2\text{e}^- \rightarrow \text{H}_2 \text{(g, 1 atm)} \]
B) \[ \text{H}_2 \text{(g, 1 atm)} \rightarrow 2\text{H}^+ \text{(aq, 1 M)} + 2\text{e}^- \]
C) \[ 2\text{H}^+ \text{(aq, 1 M)} + \text{Cl}_2 \text{(aq)} \rightarrow 2\text{HCl} \text{(aq)} \]
D) \[ 2\text{H}^+ \text{(aq)} + 2\text{OH}^- \rightarrow \text{H}_2\text{O} \text{(l)} \]
E) \[ \text{O}_2 \text{(g)} + 4\text{H}^+ \text{(aq)} + 4\text{e}^- \rightarrow 2\text{H}_2\text{O} \text{(l)} \]

11) The more \[ \underline{\text{exothermic}} \] the value of \[ E^\circ \text{red} \text{, the greater the driving force for reduction.} \]

A) positive 
B) extensive 
C) endothermic 
D) negative 
E) exothermic 

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>Half-reaction</td>
</tr>
<tr>
<td>[ \text{Cr}^{3+} \text{(aq)} + 3\text{e}^- \rightarrow \text{Cr} \text{(s)} ]</td>
</tr>
<tr>
<td>[ \text{Fe}^{2+} \text{(aq)} + 2\text{e}^- \rightarrow \text{Fe} \text{(s)} ]</td>
</tr>
<tr>
<td>[ \text{Fe}^{3+} \text{(aq)} + \text{e}^- \rightarrow \text{Fe}^{2+} \text{(s)} ]</td>
</tr>
<tr>
<td>[ \text{Sn}^{4+} \text{(aq)} + 2\text{e}^- \rightarrow \text{Sn}^{2+} \text{(aq)} ]</td>
</tr>
</tbody>
</table>

12) The standard cell potential (\[ E^\circ \text{cell} \]) for the voltaic cell based on the reaction below is \[ \underline{\text{+1.51 V}} \]

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

A) +3.05 
B) -1.45 
C) +1.57 
D) +2.99 
E) +1.51
13) The relationship between the change in Gibbs free energy and the emf of an electrochemical cell is given by

\[ A) \Delta G = \frac{-nF}{E} \]

\[ B) \Delta G = \frac{-nF}{ERT} \]

\[ C) \Delta G = -nFE \]

\[ D) \Delta G = -nRTF \]

\[ E) \Delta G = \frac{-E}{nF} \]

<table>
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<tr>
<td>Half-reaction</td>
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<tr>
<td>Cr(^{3+}) (aq) + 3e(^-) → Cr (s)</td>
</tr>
<tr>
<td>Fe(^{2+}) (aq) + 2e(^-) → Fe (s)</td>
</tr>
<tr>
<td>Fe(^{3+}) (aq) + e(^-) → Fe(^{2+}) (s)</td>
</tr>
<tr>
<td>Sn(^{4+}) (aq) + 2e(^-) → Sn(^{2+}) (aq)</td>
</tr>
</tbody>
</table>

14) The standard cell potential (\( E^o_{\text{cell}} \)) for the voltaic cell based on the reaction below is \( \ldots \) V.

\[ 2Cr (s) + 3Fe^{2+} (aq) \rightarrow 3Fe (s) + 2Cr^{3+} (aq) \]

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

15) The standard cell potential (\( E^o_{\text{cell}} \)) of the reaction below is +0.126 V. The value of \( \Delta G^o \) for the reaction is \( \ldots \) kJ/mol.

\[ Pb (s) + 2H^+ (aq) \rightarrow Pb^{2+} (aq) + H_2 (g) \]

A) -24.3 B) +24.3 C) -12.6 D) +12.6 E) -50.8

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

\[ Pb^{2+} (aq) + Zn (s) \rightarrow Zn^{2+} (aq) + Pb (s) \]

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

17) Corrosion of iron is retarded by \( \ldots \).

A) high pH conditions
B) the presence of salts
C) low pH conditions
D) both the presence of salts and high pH conditions
E) both the presence of salts and low pH conditions

18) 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) 5.77 B) 346 C) 17.3 D) 115 E) 1.92
19) The standard cell potential \( (E^\circ_{cell}) \) for the reaction below is \(+1.10\) V. The cell potential for this reaction is __________ V when the concentration of \([Cu^{2+}] = 1.0 \times 10^{-5}\) M and \([Zn^{2+}] = 1.0\) M.

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

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

20) How many grams of copper will be plated out by a current of 2.3 A applied for 25 minutes to a 0.50 M solution of copper(II) sulfate?

A) 1.1  
B) 0.036  
C) 0.019  
D) 2.2  
E) \(1.8 \times 10^{-2}\)

21) How many seconds are required to produce 1.0 g of silver metal by the electrolysis of a AgNO\(_3\) solution using a current of 30 amps?

A) \(3.7 \times 10^{-5}\)  
B) 60  
C) \(2.7 \times 10^4\)  
D) \(3.0 \times 10^1\)  
E) \(3.2 \times 10^3\)

22) How many grams of Ca metal are produced by the electrolysis of molten CaBr\(_2\) using a current of 30.0 amp for 10.0 hours?

A) 0.0622  
B) 112  
C) 448  
D) 22.4  
E) 224

Table 20.2

<table>
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<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>

23) The standard cell potential \( (E^\circ_{cell}) \) 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) +0.617  
B) +1.21  
C) -0.46  
D) +1.39  
E) +0.46

24) \(1V = \) __________.

A) 1 J/C  
B) 1 C/J  
C) 1 J/s  
D) 1 amp \cdot s  
E) 96485 C

25) In a voltaic cell, electrons flow from the __________ to the __________.

A) salt bridge, anode  
B) cathode, anode  
C) anode, cathode  
D) anode, salt bridge  
E) salt bridge, cathode

26) What is the oxidation number of bromine in the BrO\(_3^-\) ion?

A) -1  
B) +7  
C) +5  
D) +1  
E) +3
27) 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 oxygen to facilitate oxidation at the anode.
   C) provide a means for electrons to travel from the anode to the cathode.
   D) provide a means for electrons to travel from the cathode to the anode.
   E) maintain electrical neutrality in the half-cells via migration of ions.

28) One of the differences between a voltaic cell and an electrolytic cell is that in an electrolytic cell ________.
   A) oxidation occurs at the cathode
   B) electrons flow toward the anode
   C) O₂ gas is produced at the cathode
   D) an electric current is produced by a chemical reaction
   E) a nonspontaneous reaction is forced to occur

Table 20.1

<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>

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

30) How many minutes will it take to plate out 16.22 g of Al metal from a solution of Al⁺³ using a current of 12.9 amps in an electrolytic cell?
   A) 173  B) 60.1  C) 13480  D) 74.9  E) 225

31) How many minutes will it take to plate out 4.56 g of Ni metal from a solution of Ni⁺² using a current of 45.5 amps in an electrolytic cell?
   A) 155  B) 2.75  C) 330  D) 5.49  E) 4.55
32) Which element is reduced in the reaction below?

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

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

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

Table 20.2

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<thead>
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<th>Half-reaction</th>
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<td>( \text{Sn}^{4+} \text{(aq)} + 2\text{e}^- \rightarrow \text{Sn}^{2+} \text{(aq)} )</td>
<td>+0.154</td>
</tr>
</tbody>
</table>

34) The standard cell potential (\( E_{\text{cell}}^0 \)) for the voltaic cell based on the reaction below is \( \text{__________} \) V.

\[ 3\text{Sn}^{4+} \text{(aq)} + 2\text{Cr} \text{(s)} \rightarrow 2\text{Cr}^{3+} \text{(aq)} + 3\text{Sn}^{2+} \text{(aq)} \]

A) 2.53  B) -1.02  C) 0.89  D) 1.94  E) -0.59

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

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

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