Science Olympiad Event: Chemistry Lab

Team name:_____

Team number:_____

Lab score:_____

Multiple Choice Test score:_____

Total Score: _____

Tiebreaker points: _____

Team rank:_____

Part I: Oxidation-Reduction Lab

Purpose:

*To study some simple redox reactions and observe their results qualitatively,
*determine the relative strengths of the oxidizing and reducing agents,
*correctly identify those agents,
*correctly write balanced equations for whole and half reactions

Equipment:

Well plate
Microspatula or forceps
droppers or pipettes
safety goggles
lab apron or coat

Materials:

0.1 M solutions of:
- $AgNO_3$
- $Pb(NO_3)_2$
- $Zn(NO_3)_2$
- $Cu(NO_3)_2$

Also:
bits of unknown metals A, B, C, D

Safety: **handle all chemicals with care. Avoid spills on your skin or clothing. Flush any spills with cool water and report them to the event leaders. Keep your goggles and aprons on at all times; removal will result in immediate disqualification; this includes propping the goggles on top of your head. They belong in front of your eyes.**

Procedure:

1. Add a piece of each metal to four separate wells in the well plate, so that 4 wells have metal A, 4 wells have metal B, etc.

2. Cover 1 sample of each metal with $AgNO_3$ solution, 1 sample of each metal with $Pb(NO_3)_2$ solution, 1 sample of each metal with $Zn(NO_3)_2$ solution and 1 sample of each metal with $Cu(NO_3)_2$ solution.
3. Record observation in Data Table. Dispose of all used solutions and metal pieces in waste container.

Data Table: (16 points) describe any color changes, precipitates, gases or other changes you see in each tube.

Metal	+ $AgNO_3$	+ $Pb(NO_3)_2$	+ $Zn(NO_3)_2$	$Cu(NO_3)_2$
A				
B				
C				
D				

Short Answer questions: (36 points) refer to the Table of Standard Electrode Potentials where necessary to help you answer the following questions.

1. **(2 points)** List the order of activity of the metals A, B, C, D from **most active to least active** as determined by your experimental results.

2. **(4 points)** Metals A, B, C, and D are Ag, Cu, Pb, and Zn (but not necessarily in that order). Use the Table of Standard Electrode Potentials to determine which letter corresponds to which metal.

   A =

   B =

   C =

   D =

3. **(4 points)**Define the following: **oxidation; reduction; oxidizing agent; reducing agent.**

Points = _____ / 26

4. **(6 points)**Write a balanced chemical equation for the reaction between **Cu and $AgNO_3$.**

Balanced equation:

a. Write the half reaction for the oxidation reaction that occurs.

Oxidation half-reaction:

b. Write the half reaction for the reduction reaction that occurs.

Reduction half-reaction:

5. **(6 points)** Write the balanced **net ionic** equation that occurs when **Zn reacts with $AgNO_3$.**

Net ionic equation:

a. Which species in the above reaction is the oxidizing agent? _____

b. Which species is the reducing agent? _____

6. **(2 points)**Which metal listed in the Table of Standard Electrode Potentials will replace Fe^{2+} but will not replace Zn^{2+}? Explain using the table.

_____

_____

_____

7. **(4 points)** In an electrolytic cell, a current of 0.250 amperes is passed through a solution of $CuCl_2$, producing Cu(s) and Cl_2 (g)

a. Write the equation for the half reaction that occurs at the anode.

Half-reaction equation:

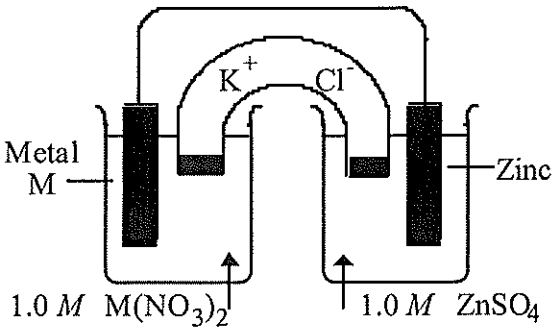
b. When the cell operates for 2.00 hours, how much Cu(s) will be deposited in grams? (Use 96485 c/mol electrons as Faraday's constant.)

Answer: _____

Points = _____ / 12

Tiebreaker = _____ / 6

8. **(8 points)**Use the diagram below to answer the following questions.



a. If metal "M" in the above diagram is Pb, what is the potential, E°, of this galvanic cell?

b. Which electrode in the cell is the anode? Which is the cathode?

Anode:

Cathode:

c. What is the name of the structure containing "K^{+}" and "Cl^{-}"? What is its function?

Structure:

Function:

d. Which way will electrons flow through the wire?

Points = _____ / 8

Science Olympiad Chemistry Lab Event, Part 2: Multiple Choice Test

Team name and number: _____

Score = _____

Tiebreaker points = _____

____ 1. Which one of the following is an alkaline earth metal?

a. potassium, K
b. magnesium, Mg
c. iron, Fe
d. tin, Sn
e. bismuth, Bi

____ 2. Which element and group are **not** correctly matched?

	Element	Periodic Group or Classification
a.	Sb	metalloid
b.	Kr	noble gas
c.	Al	alkali metal
d.	F	halogen
e.	Ca	alkaline earth metal

____ 3. Determine the oxidation number of the underlined element in $H_2\underline{P}O_2^-$.

a. +1
b. +2
c. +3
d. +4
e. +5

____ 4. What are the oxidation numbers (oxidation states) of the elements in HCO_3^-?

a. H = +1, C = +5, O = -2
b. H = +1, C = +3, O = -2
c. H = +1, C = +2, O = -2
d. H = +2, C = +2, O = -2
e. H = +1, C = +4, O = -2

____ 5. Which of the following is both a decomposition reaction and a reduction-oxidation reaction?

a. $H_2CO_3(aq) \rightarrow CO_2(g) + H_2O(l)$
b. $Zn(s) + CuNO_3(aq) \rightarrow Cu(s) + ZnNO_3(aq)$
c. $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$
d. $2NH_4NO_3(s) \rightarrow 2N_2(g) + O_2(g) + 4H_2O(g)$
e. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

____ 6. Accordingly to the periodic law the properties of elements repeat at regular intervals when the elements are arranged in order of
   a. their increasing atomic mass.
   b. their increasing atomic size.
   c. their increasing number of neutrons in the nucleus.
   d. their increasing number of isotopes.
   e. their increasing number of protons in the nucleus.

____ 7. Of the following, which periodic group(s) do not match their designation?

a.	*d*-transition metals	IIIB → IIB
b.	representative metals	IA, IIA
c.	noble gases	VIIIB
d.	alkaline earth metals	IIA
e.	halogens	VIIA

____ 8. _____ is a d-transition metal.
   a. Cr
   b. Ga
   c. Al
   d. Sb
   e. Na

____ 9. Choose the response that includes all of the listed elements that are *d*-transition elements, and no others.

   I. $_{22}$Ti
   II. $_{42}$Mo
   III. $_{81}$Tl
   IV. $_{36}$Kr
   V. $_{92}$U

   a. I and II
   b. II and III
   c. III and IV
   d. IV and V
   e. I, III, and V

____ 10. What would be the outer electron configuration of group VIA (O, S, Se, . . .)?
   a. ns^2np^6
   b. ns^2np^2
   c. ns^2np^4
   d. np^6
   e. ns^0np^6

____ 11. What would be the outer electron configuration of alkaline earth metals?
   a. ns^2np^2
   b. np^2
   c. ns^0np^2
   d. nd^2
   e. ns^2

____ 12. Choose the term that best describes **all** members of this series of elements:

Xe, Rn, He, Ne, Kr

a. metalloids
b. noble gases
c. alkaline earth metals
d. alkali metals
e. representative elements

____ 13. Choose the term that best describes **all** members of this series of elements:

K, Ca, Ba, Cl, N

a. metalloids
b. *d*-transition elements
c. alkaline earth metals
d. alkali metals
e. representative elements

____ 14. Which of the following statements is **false**?

a. The effective nuclear charge experienced by an electron in an outer shell is less than the actual nuclear charge.
b. Within a family (vertical group in the periodic table) of representative elements atomic radii increase from top to bottom.
c. Electrons in inner shells screen, or shield, electrons in outer shells from the full effect of the nuclear charge.
d. The atomic radii of representative elements decrease from left to right across a period (horizontal row in the periodic table).
e. Transition elements have larger atomic radii than the preceding IA and IIA elements in the same period because transition elements have electrons in their *d* orbitals.

____ 15. Which element has the **largest** atomic radius?

a. Ga
b. In
c. Ge
d. P
e. O

____ 16. Arrange the following elements in order of **increasing** atomic radii.

Sr, Rb, Sb, I, In

a. Rb < Sr < In < Sb < I
b. I < Sb < In < Rb < Sr
c. In < Sb < I < Sr < Rb
d. Sb < I < In < Sr < Rb
e. I < Sb < In < Sr < Rb

____ 17. The minimum energy required to remove the most loosely held electron is
a. first ionization energy.
b. electron affinity
c. potential energy
d. kinetic energy
e. electronegativity.

____ 18. The first ionization energy of sulfur is less than that of phosphorus. A reasonable explanation for this fact involves
a. the stability of the half-filled subshell in atomic sulfur.
b. pairing of two electrons in one 3*p* orbital in sulfur atoms.
c. the smaller size of sulfur atoms relative to phosphorus atoms.
d. the ease with which phosphorus attains a noble gas electronic configuration.
e. the higher electronegativity of sulfur relative to phosphorus.

____ 19. Which element has the **highest** first ionization energy?
a. B
b. Al
c. Ga
d. In
e. Tl

____ 20. Arrange the following elements in order of **decreasing** first ionization energy.

Be, Ca, Cs, Mg, K

a. Mg > Be > Ca > K > Cs
b. Be > Mg > Ca > K > Cs
c. Cs > K > Ca > Be > Mg
d. Ca > Mg > Be > Cs > K
e. Ca > Mg > Be > K > Cs

____ 21. The general electron configuration for the element group that would have the largest negative value for the electron affinity for its atoms is _____?
a. ns^2np^6
b. ns^2np^4
c. ns^1
d. ns^2np^5
e. ns^2np^3

____ 22. Arrange the following elements in order of **increasing** values of electron affinity, i.e., from most negative to least negative. (Note: None of these elements is an exception to the general trends of electron affinities.)

Cl, Se, S, Cs, Rb, Te

a. Cl < S < Se < Rb < Te < Cs
b. Cl > Te > Se > S > Rb > Cs
c. Cl > Se > S > Te > Rb > Cs
d. Cl < S < Se < Te < Cs < Rb
e. Cl < S < Se < Te < Rb < Cs

____ 23. A property that measures the ability of an atom to attract electrons in a chemical bond is
a. binding energy.
b. mass defect.
c. electron affinity.
d. ionization energy.
e. electronegativity.

____ 24. Arrange the following elements in order of **increasing** electronegativities.

At, Bi, Cl, F, I

a. At < Bi < Cl < F < I
b. F < Cl < Bi < I < At
c. Bi < At < I < Cl < F
d. F < Cl < I < At < Bi
e. At < Bi < I < Cl < F

____ 25. Which of the these elements has the greatest attraction for electrons in a covalent bond?
a. Ge
b. As
c. Se
d. Br
e. Kr

____ 26. Arrange the following in order of increasing ionic character (most ionic at right).

BaO, SiO_2, SO_2

a. $BaO < SiO_2 < SO_2$
b. $SO_2 < BaO < SiO_2$
c. $SiO_2 < SO_2 < BaO$
d. $BaO < SO_2 < SiO_2$
e. $SO_2 < SiO_2 < BaO$

____ 27. The electrolysis of **molten** lithium hydride, LiH, using inert electrodes produces metallic lithium and gaseous hydrogen. The hydrogen is produced by the (I) half-reaction, (II).

	(I)	(II)
a.	reduction	$2H^+ + 2e^- \rightarrow H_2(g)$
b.	oxidation	$2H^- \rightarrow H_2(g) + 2e^-$
c.	reduction	$2e^- + H_2O \rightarrow H_2(g) + O^{2-}$
d.	oxidation	$2e^- + 2OH^- \rightarrow H_2(g) + 2O^{2-}$
e.	auto-oxidation-reduction	$H^+ + H^- \rightarrow H_2(g)$

____ 28. Oxidation occurs at the _____ in a voltaic cell and oxidation occurs at the _____ in an electrolytic cell.
a. anode, anode
b. cathode, cathode
c. anode, cathode
d. cathode, anode
e. anode, salt bridge

____ 29. A voltaic cell is constructed by immersing a strip of copper metal in 1.0 *M* $CuSO_4$ solution and a strip of aluminum in 0.50 *M* $Al_2(SO_4)_3$ solution. A wire and a salt bridge complete the circuit. The aluminum strip loses mass, and the concentration of aluminum ions in the solution increases. The copper electrode gains mass, and the concentration of copper ions decreases. What is the cell potential?
a. +1.28 V
b. +2.00 V
c. +2.34 V
d. +2.50 V
e. +3.66 V

____ 30. Given the following standard electrode potentials:

Half-Reaction	E^0
$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.23 V
$2CO_2(g) + 2H^+ + 2e^- \rightarrow (COOH)_2$	-0.49 V

Which response contains all the true statements and no others? (Assume all species are present under standard electrochemical conditions.)

I. H_2O will spontaneously oxidize $(COOH)_2$ to form CO_2.
II. $O_2(g)$ will spontaneously oxidize $(COOH)_2$ to form CO_2.
III. $(COOH)_2$ will spontaneously reduce $O_2(g)$ to form H_2O.
IV. H^+ will spontaneously reduce $(COOH)_2$ to form CO_2.
V. CO_2 will spontaneously oxidize H_2O to form $O_2(g)$.

a. II, IV, and V
b. I, III, and IV
c. II and III
d. I and IV
e. III and V

____ 31. A zinc bar weighing 3.0 kg is attached to a buried iron pipe to protect the pipe from corrosion. An average current of 0.020 A flows between the bar and the pipe. How many years will be required for the zinc bar to be entirely consumed? (1 yr = 3.16×10^7 s)
a. 600yr
b. 14.0 yr
c. 5.99 yr
d. 7.00 yr
e. 6.66 yr

KEY Science Olympiad Event: Chemistry Lab

Part I: Oxidation-Reduction Lab

Purpose:

*To study some simple redox reactions and observe their results qualitatively,
*determine the relative strengths of the oxidizing and reducing agents,
*correctly identify those agents,
*correctly write balanced equations for whole and half reactions

Equipment:

Well plate
Microspatula or forcepts
droppers or pipets
safety goggles
lab apron or coat

Materials:

0.1 M solutions of:
- $AgNO_3$
- $Pb(NO_3)_2$
- $Zn(NO_3)_2$
- $Cu(NO_3)_2$

Also:
unknown metals A, B, C, D

A = Pb
B = Zn
C = Cu
D = Ag

Each team will need:
4 bits of "A", 4 bits of "B", 4 bits of "C" and 4 bits of "D". You could put the bits in labeled vials or labeled baggies.
1 dropper bottle of $AgNO_3$, 1 dropper bottle of $Pb(NO_3)_2$, 1 dropper bottle of $Zn(NO_3)_2$, and 1 dropper bottle of $Cu(NO_3)_2$. Make extras of each solution to refill between sessions.
1 well plate
1 spatula or tweezers or forcepts

Safety: handle all chemicals with care. Avoid spills on your skin or clothing. Flush any spills with cool water and report them to the event leaders. Keep your goggles and aprons on at all times; removal will result in immediate disqualification; this includes propping the goggles on top of your head. They belong in front of your eyes.

Procedure:

1. Add a piece of each metal to four separate wells in the well plate, so that 4 wells have metal A, 4 wells have metal B, etc.

2. Cover 1 sample of each metal with $AgNO_3$ solution, 1 sample of each metal with $Pb(NO_3)_2$ solution, 1 sample of each metal with $Zn(NO_3)_2$ solution and 1 sample of each metal with $Cu(NO_3)_2$ solution.
3. Record observation in Data Table. Dispose of all used solutions and metal pieces in waste container.

Data Table: (16 points) describe any color changes, precipitates, gases or other changes you see in each tube.

metal	+ $AgNO_3$	+ $Pb(NO_3)_2$	+ $Zn(NO_3)_2$	$Cu(NO_3)_2$
A Pb	reaction	NR (no reaction)	NR	reaction
B Zn	reaction	reaction	NR	reaction
C Cu	reaction	NR	NR	NR
D Ag	NR	NR	NR	NR

Short Answer questions: (36 points) refer to the Table of Standard Electrode Potentials where necessary to help you answer the following questions.

1. **(2 points)** List the order of activity of the metals A, B, C, D from **most active to least active** as determined by your experimental results.

   B, A, C, D

2. **(4 points)** Metals A, B, C, and D are Ag, Cu, Pb, and Zn (but not necessarily in that order). Use the Table of Standard Electrode Potentials to determine which letter corresponds to which metal.

   A = Pb
   B = Zn
   C = Cu
   D = Ag

3. **(4 points)**Define the following: oxidation; reduction; oxidizing agent; reducing agent.

   Oxidation is a loss of electrons.

   Reduction is a gain of electrons.

   Oxidizing agent is a substance that is reduced in a reaction, that removes electrons from another substance and thus gains electrons.

   Reducing agent is a substance that is oxidized in a reaction, that gives electrons to another substance and thus loses electrons.

4. (6 points)Write a balanced chemical equation for the reaction between Cu and $AgNO_3$.

Balanced equation:

$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$ (order of reactants and order of products does not matter)

a. Write the half reaction for the oxidation reaction that occurs.

$Cu \rightarrow Cu^{2+} + 2e^-$ (Cu on left may be Cu^o)

b. Write the half reaction for the reduction reaction that occurs.

$Ag^+ + e^- \rightarrow Ag$ (Ag on right may be Ag^o, equation may be balanced with all 2s)

5. **(6 points)** Write the balanced **net ionic** equation that occurs when Zn reacts with $AgNO_3$.

Net ionic equation:

$Zn + 2Ag^+ \rightarrow 2Ag + Zn^{2+}$ (order of reactants and order of products does not matter)

a. Which species in the above reaction is the oxidizing agent? Ag^+ OR $AgNO_3$

b. Which species is the reducing agent? Cu

6. **TieBreaker(2 points)**Which metal listed in the Table of Standard Electrode Potentials will replace Fe^{2+} but will not replace Zn^{2+}? Explain using the table.

Chromium (Cr) will replace Fe^{2+} in a reaction but will not replace Zn^{2+}. Cr is below Fe in the table but is above Zn.

7. **Tie breaker(4 points)** In an electrolytic cell, a current of 0.250 amperes is passed through a solution of $CuCl_2$, producing Cu(s) and Cl_2 (g)

a. Write the equation for the half reaction that occurs at the anode.

Half-reaction equation: $2Cl^- \rightarrow Cl_2 + 2e^-$

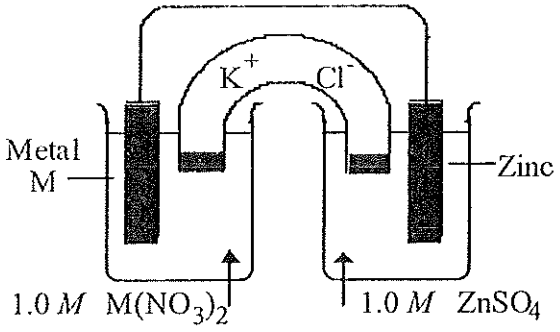
b. When the cell operates for 2.00 hours, how much Cu(s) will be deposited in grams? (Use 96485 c/mol electrons as Faraday's constant.)

2.00 hours = 7200 seconds

.250 amps * 7200 sec = 1800 C

1800 C/(96485 C/mol e^-)*(1mol Cu/2 mol e^-)*(63.55 g/mol Cu) = .593 g Cu

8. **8 points)** Use the diagram below to answer the following questions.



a. If metal "M" in the above diagram is Pb, what is the potential, E°, of this galvanic cell?

0.63 V (cannot be negative)

b. Which electrode in the cell is the anode? Which is the cathode?

Anode: Zn

Cathode: Pb

c. What is the name of the structure containing "K^+" and "Cl^-"? What is its function?

Structure: salt bridge

Function: to maintain electrical neutrality, or something equivalent

d. Which way will electrons flow through the wire?

Right to left, or Zn to Pb

Science Olympiad

Chem Lab Event

Mutliple Choice test Answer sheet

Mark you answers to the multiple choice Portion of this event on this bubble sheet.

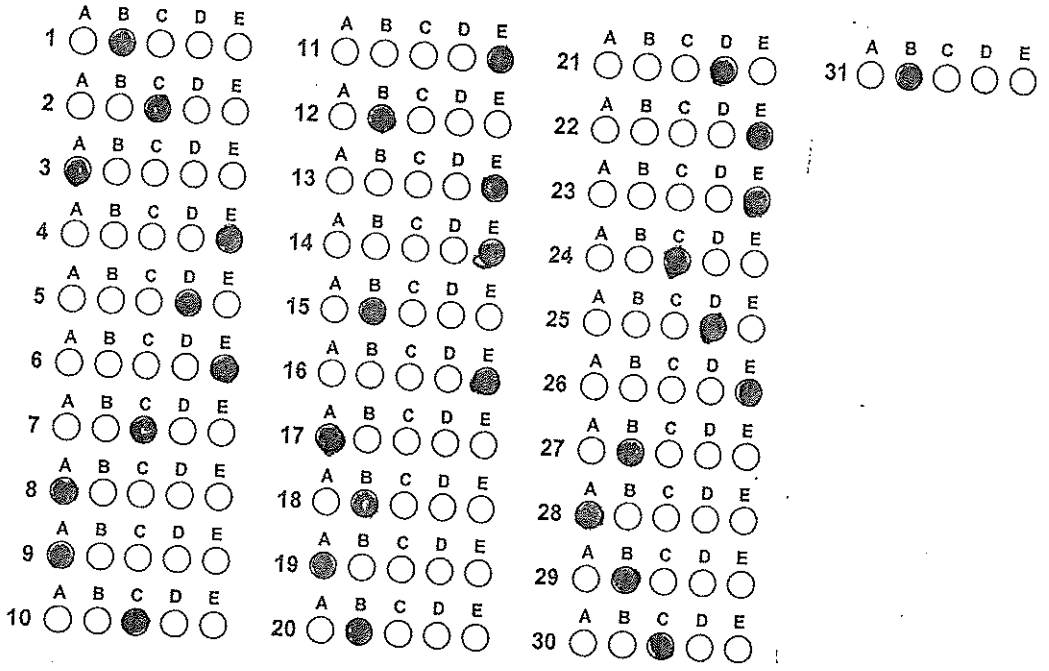
Key

Team Name:_____

Team Number:_____

Score = _____ / 30

Tiebreaker points= _____



Science Olympiad Chemistry Lab Event, Part 2: Multiple Choice Test
Answer Section

MULTIPLE CHOICE

1. ANS: B PTS: 1 TOP: The Periodic Table: Metals | Nonmetals | and Metalloids
2. ANS: C PTS: 1 TOP: The Periodic Table: Metals | Nonmetals | and Metalloids
3. ANS: A PTS: 1 TOP: Oxidation Numbers
4. ANS: E PTS: 1 TOP: Oxidation Numbers
5. ANS: D PTS: 1 TOP: Decomposition Reactions
6. ANS: E PTS: 1 TOP: More About the Periodic Table
7. ANS: C PTS: 1 TOP: More About the Periodic Table
8. ANS: A PTS: 1 TOP: More About the Periodic Table
9. ANS: A PTS: 1 TOP: More About the Periodic Table
10. ANS: C PTS: 1 TOP: More About the Periodic Table
11. ANS: E PTS: 1 TOP: More About the Periodic Table
12. ANS: B PTS: 1 TOP: More About the Periodic Table
13. ANS: E PTS: 1 TOP: More About the Periodic Table
14. ANS: E PTS: 1 TOP: Atomic Radii
15. ANS: B PTS: 1 TOP: Atomic Radii
16. ANS: E PTS: 1 TOP: Atomic Radii
17. ANS: A PTS: 1 TOP: Ionization Energy
18. ANS: B PTS: 1 TOP: Ionization Energy
19. ANS: A PTS: 1 TOP: Ionization Energy
20. ANS: B PTS: 1 TOP: Ionization Energy
21. ANS: D PTS: 1 TOP: Electron Affinity
22. ANS: E PTS: 1 TOP: Electron Affinity
23. ANS: E PTS: 1 TOP: Electronegativity
24. ANS: C PTS: 1 TOP: Electronegativity
25. ANS: D PTS: 1 TOP: Electronegativity
26. ANS: E PTS: 1 TOP: Oxygen and the Oxides
27. ANS: B PTS: 1 TOP: The Electrolysis of Molten Salts
28. ANS: A PTS: 1 TOP: Voltaic or Galvanic Cells
29. ANS: B
    A table of standard electrode potentials may be necessary for this question.

    PTS: 1 TOP: Uses of Standard Electrode Potentials
30. ANS: C
    TIEBREAKER A table of standard electrode potentials may be necessary for this question.

    PTS: 1 TOP: Standard Electrode Potentials for Other Half-Reactions
31. ANS: B
    A table of standard electrode potentials may be necessary for this question.

    PTS: 1 TOP: Corrosion Protection