Name_____Date_____ Period_____

Topic: Electrochemistry (Oxidation-Reduction Reactions)

Outline

1. **In all chemical reactions there is a conservation of mass, energy, and charge.**
2. **An oxidation-reduction (redox) reaction involves the transfer of electrons (e-).**
3. **Reduction is the gain of electrons.**
   - ✓ A half-reaction can be written to represent reduction.

     For example: $Cl_2 + 2\ e^- \rightarrow 2\ Cl^{1-}$
4. **Oxidation is the loss of electrons.**
   - ✓ A half-reaction can be written to represent oxidation.

     For example: $Na \rightarrow Na^+ + 1\ e^-$
5. **Oxidation numbers (states) can be assigned to atoms and ions. Changes in oxidation numbers indicate that oxidation and reduction have occurred.**
   - ✓ Be able to use an activity series (Reference Table J) to determine whether a redox reaction is spontaneous.
6. **In a redox reaction the number of electrons lost is equal to the number of electrons gained.**
   - ✓ This supports the fact that charge is always conserved!
7. **An electrochemical cell can be either voltaic or electrolytic. In an electrochemical cell, oxidation occurs at the anode and reduction at the cathode.**
   - ✓ Be able to compare and contrast voltaic and electrolytic cells.
8. **A voltaic cell spontaneously converts chemical energy to electrical energy.**
   - ✓ Identify and label the parts of a voltaic cell (cathode, anode, salt bridge) and direction of electron flow, given the reaction equation.
   - ✓ Since this reaction is spontaneous, use Ref. Table J to help you determine what is the anode (oxidation) and the cathode (reduction). The most reactive metal will oxidize, the most reactive non-metal will reduce.
9. **An electrolytic cell requires electrical energy to produce a chemical change. This process is known as electrolysis.**
   - ✓ Identify and label the parts of an electrolytic cell (cathode, anode) and direction of electron flow, given the reaction equation
   - ✓ Since this reaction is non-spontaneous, use Ref. Table J to help you determine what is the anode (oxidation) and the cathode (reduction). The most reactive metal will reduce, the most reactive non-metal will oxidize. (NOTE: This is the opposite of what metals/non-metals want to do!)

Electrochemistry Practice Questions

1. Given the equation:

__$Ca^{2+}(aq)$ + $PO_4^{3-}(aq)$ → $Ca_3(PO_4)_2(s)$

When the equation is correctly balanced, the sum of the total charge of the reactants is

(1) 0 (3) -3
(2) +2 (4) +6

2. The net ionic equation:
$Fe(s) + Pb^{2+}(aq) \rightarrow Fe^{2+}(aq) + Pb(s)$
illustrates conservation of

(1) mass and charge
(2) charge but not mass
(3) mass but not charge
(4) neither mass nor charge

3. As an atom of nitrogen gains electrons, its oxidation number

(1) decreases
(2) increases
(3) remains the same

4. When a neutral atom undergoes oxidation, the atom's oxidation state

(1) decreases as it gains electrons
(2) decreases as it loses electrons
(3) increases as it gains electrons
(4) increases as it loses electrons

5. In which substance does hydrogen have an oxidation number of zero?

(1) LiH (3) H_2S
(2) H_2O (4) H_2

6. What is the oxidation number of chlorine in $HClO_4$?

(1) +1 (3) +3
(2) +5 (4) +7

7. In which substance is the oxidation number of Cl equal to +1?

(1) Cl_2 (3) $AlCl_3$
(2) Cl_2O (4) $HClO_2$

8. What is the oxidation number of chromium in $K_2Cr_2O_7$?

(1) +12 (3) +3
(2) +2 (4) +6

9. Oxygen has an oxidation number of -2 in

(1) O_2 (3) Na_2O_2
(2) NO_2 (4) OF_2

10. In which compound does chlorine have the highest oxidation number?

(1) NaClO (3) $NaClO_3$
(2) $NaClO_2$ (4) $NaClO_4$

11. In which compound does carbon have an oxidation state of -4?

(1) CO (3) CCl_4
(2) CO_2 (4) CH_4

12. What is the oxidation number of carbon in $NaHCO_3$?

(1) +6 (3) -4
(2) +2 (4) +4

13. Given the reaction:

$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_3(g) + 2H_2O(l)$

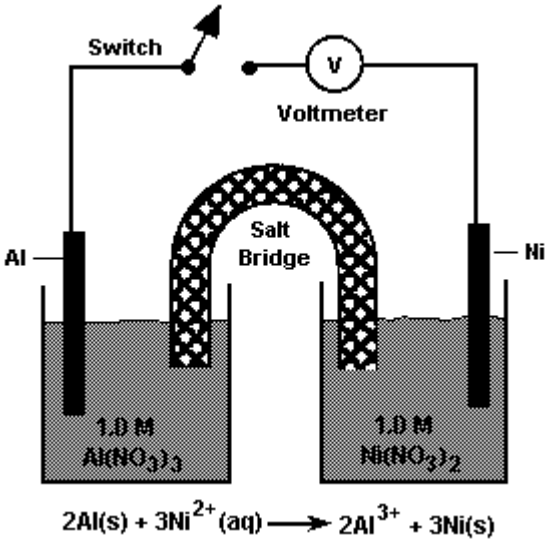
As the reaction occurs, what happens to copper?

(1) It undergoes reduction and its oxidation number decreases.
(2) It undergoes reduction and its oxidation number increases.
(3) It undergoes oxidation and its oxidation number decreases.
(4) It undergoes oxidation and its oxidation number increases.

14. Which component of a voltaic cell is correctly paired with its function?

(1) external conductor — allows the solutions to mix
(2) external conductor — permits the migration of ions
(3) salt bridge — allows the solutions to mix
(4) salt bridge — permits the migration of ions

15. The diagram represents a chemical cell at 298 K.



When the switch is closed, electrons flow from
(1) Al(*s*) to Ni(*s*)
(2) Ni(*s*) to Al(*s*)
(3) $Al^{3+}(aq)$ to $Ni^{2+}(aq)$
(4) $Ni^{2+}(aq)$ to $Al^{3+}(aq)$

16. Which redox equation is correctly balanced?
(1) $Cr^{3+} + Mg \rightarrow Cr + Mg^{2+}$
(2) $Al^{3+} + K \rightarrow Al + K^{+}$
(3) $Sn^{4+} + H_2 \rightarrow Sn + 2H^{+}$
(4) $Br_2 + Hg \rightarrow Hg^{2+} + 2Br^{-}$

17. Which statement best describes how a salt bridge maintains electrical neutrality in the half-cells of a voltaic cell?

(1) It prevents the migration of electrons.
(2) It permits the migration of ions.
(3) It permits the two solutions to mix completely.
(4) It prevents the reaction from occuring spontaneously.

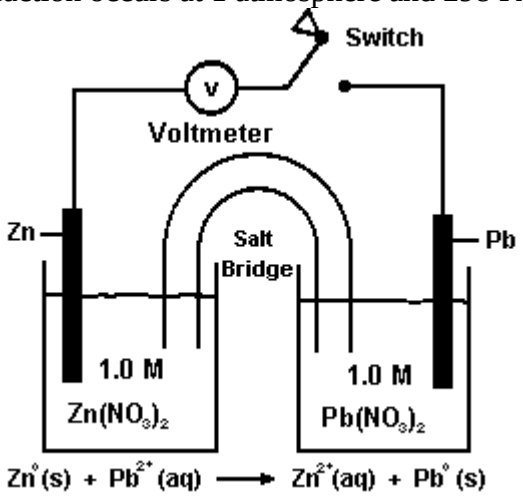
18. Given the reaction:

$$\_\_Hg^{2+} + Ag^{0} \rightarrow Hg^{0} + Ag^{1+}$$

When the equation is completely balanced using the smallest whole-number coefficients, the coefficient of Hg will be

(1) 1 (3) 3
(2) 2 (4) 4

19. The diagram shows a voltaic cell. The reaction occurs at 1 atmosphere and 298 K.



When the switch is closed, what occurs?

(1) Pb is oxidized and electrons flow to the Zn electrode.
(2) Pb is reduced and electrons flow to the Zn electrode.
(3) Zn is oxidized and electrons flow to the Pb electrode.
(4) Zn is reduced and electrons flow to the Pb electrode.

20. Which metal can replace Cr in Cr_2O_3?

(1) nickel (3) copper
(2) lead (4) aluminum

21. Given the reaction:

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

When the reaction is correctly balanced using the smallest whole numbers, the coefficient of $Sn^{2+}(aq)$ is

(1) 1 (3) 3
(2) 2 (4) 4

22. An electrochemical cell that generates electricity contains half-cells that produce

(1) oxidation half-reactions, only
(2) reduction half-reactions, only
(3) spontaneous redox reactions
(4) nonspontaneous redox reactions

23. Given the reaction:

$2Li(s) + Cl_2(g) \rightarrow 2LiCl(s)$

As the reaction takes place, the $Cl_2(g)$ will

(1) gain electrons (3) gain protons
(2) lose electrons (4) lose protons

24. In the reaction $Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$, the oxidizing agent is

(1) Cu (3) Ag^+
(2) Cu^{2+} (4) Ag

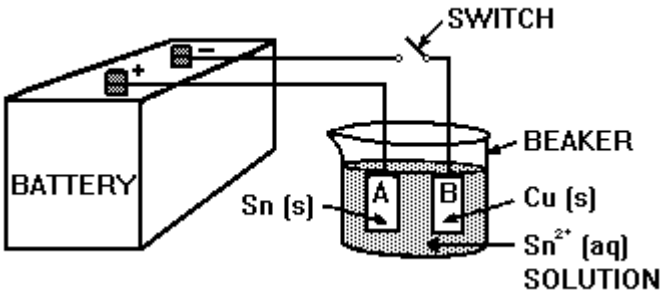
25. Which procedure requires the use of an external electric current to force a redox reaction to occur?

(1) polymerization
(2) distillation
(3) electrolysis
(4) saponification

26. An electrolytic cell is different from a voltaic cell because in an electrolytic cell

(1) a redox reaction occurs
(2) a spontaneous reaction occurs
(3) an electric current is produced
(4) an electric current causes a chemical reaction

27. The diagram shows an electrolytic cell in which the electrodes are tin and copper.



When the switch is closed, what will happen to the two electrodes?

(1) *B* will dissolve and *A* will become coated with tin.
(2) *A* will dissolve and *B* will become coated with tin.
(3) *B* will dissolve and *A* will become coated with copper.
(4) *A* will dissolve and *B* will become coated with copper.

28. Which statement best describes the reaction represented by the equation below?

$2NaCl + 2H_2O + \text{electricity} \rightarrow Cl_2 + H_2 + 2NaOH$

(1) The reaction occurs in a voltaic cell and releases energy.
(2) The reaction occurs in a voltaic cell and absorbs energy.
(3) The reaction occurs in an electrolytic cell and releases energy.
(4) The reaction occurs in an electrolytic cell and absorbs energy.

29. What is the oxidation state of nitrogen in the compound NH_4Br?

(1) –1 (3) –3
(2) +2 (4) +4

30. Given the unbalanced ionic equation:

$3Mg + \_\_\_\_ Fe^{3+} \rightarrow 3Mg^{2+} + \_\_\_\_ Fe$

When this equation is balanced, both Fe^{3+} and Fe have a coefficient of

(1) 1, because a total of 6 electrons is transferred
(2) 2, because a total of 6 electrons is transferred
(3) 1, because a total of 3 electrons is transferred
(4) 2, because a total of 3 electrons is transferred

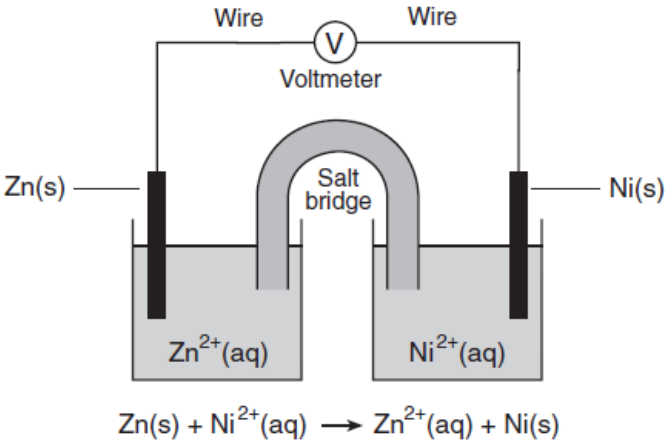
31. A student collects the materials and equipment below to construct a voltaic cell.

- two 250-mL beakers
- wire and a switch
- one strip of magnesium
- one strip of copper
- 125 mL of 0.20 M $Mg(NO_3)_2(aq)$
- 125 mL of 0.20 M $Cu(NO_3)_2(aq)$

Which additional item is required for the construction of the voltaic cell?

(1) an anode (3) a cathode
(2) a battery (4) a salt bridge

32. The diagram below represents an operating electrochemical cell and the balanced ionic equation for the reaction occurring in the cell.



Which statement identifies the part of the cell that conducts electrons and describes the direction of electron flow as the cell operates?

(1) Electrons flow through the salt bridge from the Ni(s) to the Zn(s).
(2) Electrons flow through the salt bridge from the Zn(s) to the Ni(s).
(3) Electrons flow through the wire from the Ni(s) to the Zn(s).
(4) Electrons flow through the wire from the Zn(s) to the Ni(s).

Base your answers to questions 33 through 35 on the information below.

In a laboratory investigation, magnesium reacts with hydrochloric acid to produce hydrogen gas and magnesium chloride. This reaction is represented by the unbalanced equation below.

____ Mg(s) + ____ HCl(aq) → ____ H_2(g) + $MgCl_2$(aq)

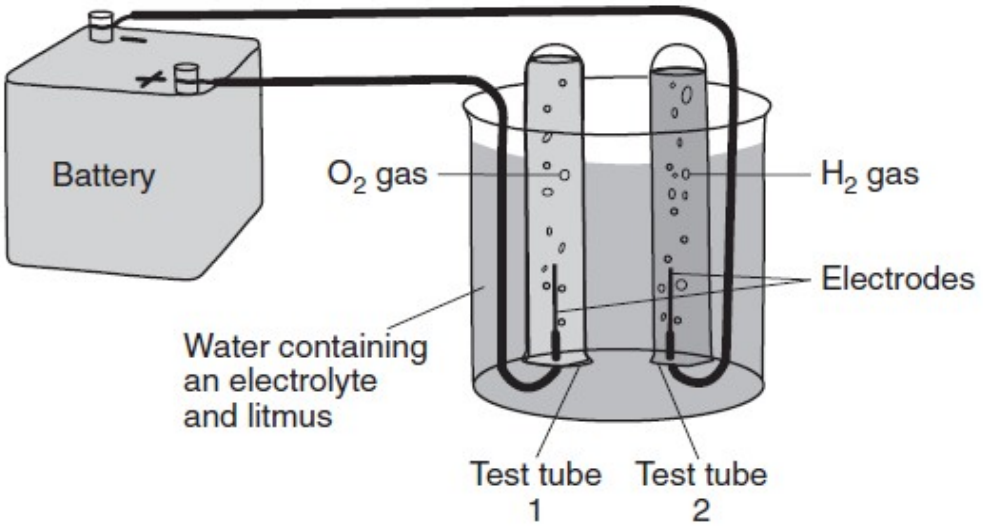
33. State, in terms of the relative activity of elements, why this reaction is spontaneous. [1]

34. Balance the equation above, using the smallest whole-number coefficients. [1]

35. Write a balanced half-reaction equation for the oxidation that occurs. [1]

Base your answers to questions 36 through 37 on the information below.

The diagram below shows a system in which water is being decomposed into oxygen gas and hydrogen gas. Litmus is used as an indicator in the water. The litmus turns red in test tube 1 and blue in test tube 2.



The oxidation and reduction occurring in the test tubes are represented by the balanced equations below.

Test tube 1: $2H_2O(\ell) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

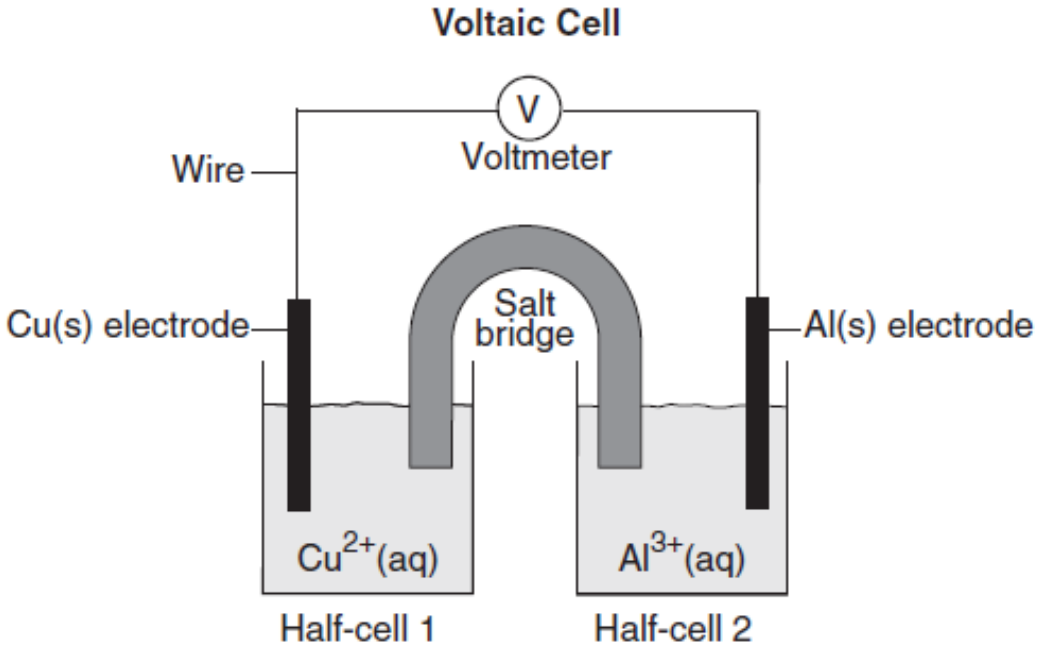
Test tube 2: $4H_2O(\ell) + 4e^- \rightarrow 2H_2(g) + 4OH^-(aq)$

36. Identify the information in the diagram that indicates this system is an electrolytic cell. [1]

37. Determine the change in oxidation number of oxygen during the reaction in test tube 1. [1]

Base your answers to questions 38 through 40 on the diagram below.

The diagram shows a voltaic cell with copper and aluminum electrodes immediately after the external circuit is completed.



38. Balance the redox equation below using the smallest whole-number coefficients. [1]

$$\_\_\_\_\_\ Cu^{2+}(aq) + \_\_\_\_\_\ Al(s) \rightarrow \_\_\_\_\_\ Cu(s) + \_\_\_\_\_\ Al^{3+}(aq)$$

39. As this voltaic cell operates, the mass of the Al(s) electrode decreases. Explain, in terms of particles, why this decrease in mass occurs. [1]

40. Explain the function of the salt bridge. [1]

Base your answers to questions 41 through 44 on the information below.

In a laboratory investigation, a student constructs a voltaic cell with iron and copper electrodes. Another student constructs a voltaic cell with zinc and iron electrodes. Testing the cells during operation enables the students to write the balanced ionic equations below.

Cell with iron and copper electrodes: $Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$

Cell with zinc and iron electrodes: $Fe^{2+}(aq) + Zn(s) \rightarrow Fe(s) + Zn^{2+}(aq)$

41. State evidence from the balanced equation for the cell with iron and copper electrodes that indicates the reaction in the cell is an oxidation-reduction reaction. [1]

42. Identify the particles transferred between Fe^{2+} and Zn during the reaction in the cell with zinc and iron electrodes. [1]

43. Write a balanced half-reaction equation for the reduction that takes place in the cell with zinc and iron electrodes. [1]

44. State the relative activity of the three metals used in these two voltaic cells. [1]