Name:_____ **Period:**_____

Redox and Voltaic Cells

1. Which half-reaction equation represents the reduction of an iron(II) ion?

   1) $Fe^{2+} \rightarrow Fe^{3+} + e^-$
   3) $Fe^{3+} + e^- \rightarrow Fe^{2+}$
   2) $Fe^{2+} + 2e^- \rightarrow Fe$
   4) $Fe \rightarrow Fe^{2+} + 2e^-$

2. Which change in oxidation number indicates oxidation?

   1) –1 to +2
   3) +2 to –3
   2) –1 to –2
   4) +3 to +2

3. The overall reaction in a electrochemical cell is

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

   As the reaction in this cell takes place, the

   1) mass of the Zn(s) electrode decreases
   2) mass of the Cu(s) electrode decreases
   3) $Cu^{2+}(aq)$ concentration remains the same
   4) $Zn^{2+}(aq)$ concentration remains the same

4. Which equation represents an oxidation- reduction reaction?

   1) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
   2) $H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$
   3) $MgCrO_4 + BaCl_2 \rightarrow MgCl_2 + BaCrO_4$
   4) $Zn(NO_3)_2 + Na_2CO_3 \rightarrow 2NaNO_3 + ZnCO_3$

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

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

6. Given the balanced equation representing a reaction:

   $Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$
   During this reaction, the oxidation number of Fe changes from

   1) +2 to 0 as electrons are transferred
   2) +2 to 0 as protons are transferred
   3) +3 to 0 as electrons are transferred
   4) +3 to 0 as protons are transferred

7. When a voltaic cell operates, ions move through the

   1) anode
   3) salt bridge
   2) cathode
   4) external circuit

8. Which expression correctly represents a balanced reduction half-reaction?

   1) $Na^+ + e^- \rightarrow Na$
   3) $Cl_2 + 2e^- \rightarrow Cl^-$
   2) $Na \rightarrow Na^+ + e^-$
   4) $2\ Cl^- \rightarrow Cl_2 + 2e^-$

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

   1) –2 2) +2 3) –4 **4) +4**

10. 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

11. Given the reaction for the corrosion of aluminum:

$4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$

Which half-reaction correctly represents the oxidation that occurs?

1) $Al + 3e^- \rightarrow Al^{3+}$
3) $O_2 + 4e^- \rightarrow 2\ O^{2-}$
2) $Al \rightarrow Al^{3+} + 3e^-$
4) $O_2 \rightarrow 2\ O^{2-} + 4e^-$

12. Which balanced equation represents a redox reaction?

1) $PCl_5 \rightarrow PCl_3 + Cl_2$
2) $KOH + HCl \rightarrow KCl + H_2O$
3) $LiBr \rightarrow Li^+ + Br^-$
4) $Ca^{2+} + SO_4{}^{2-} \rightarrow CaSO_4$

13. Referring to Reference Table J, which reaction will not occur under standard conditions?

1) $Sn(s) + 2\ HCl(aq) \rightarrow SnCl_2(ag) + H_2(g)$
2) $Cu(s) + 2\ HCl(aq) \rightarrow CuCl_2(aq) + H_2(g)$
3) $Ba(s) + 2\ HCl(aq) \rightarrow BaCl_2(aq) + H_2(g)$
4) $Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

Base your answers to questions **14** through **16** 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: $Fe^{2+}(aq) + Zn(s) \rightarrow Fe(s) + Zn^{2+}(aq)$

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

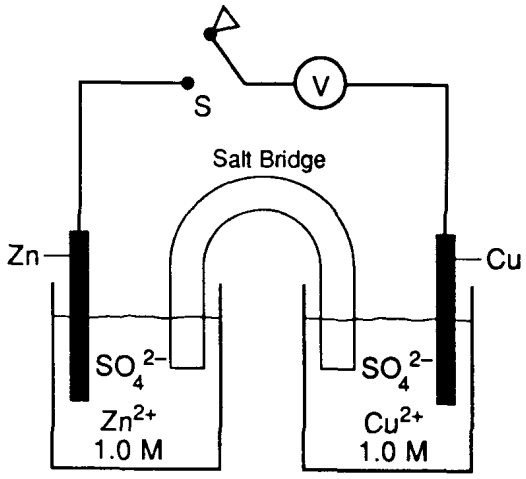
15. State the relative activity of the three metals used in these two voltaic cells.

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

17. Which energy conversion occurs in a voltaic cell?

1) chemical energy to electrical energy
2) chemical energy to nuclear energy
3) electrical energy to chemical energy
4) nuclear energy to electrical energy

18. Base your answer to the following question on the diagram below which represents a chemical cell at 298 K and 1 atmosphere.



Which species represents the cathode?

1) Zn 2) Zn^{2+} **3) Cu** 4) Cu^{2+}

19. Which ion is most easily reduced?

1) Zn^{2+} 2) Mg^{2+} **3) Co^{2+}** 4) Ca^{2+}

20. 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

21. What is the oxidation number of manganese in $KMnO_4$?

1) +7 2) +2 3) +3 4) +4

22. Given the balanced equation representing a reaction:

$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$
The oxidation state of chlorine in this reaction changes from

1) –1 to +1
2) –1 to +5
3) +1 to –1
4) +5 to –1

23. Which metal is more active than H_2?

1) Ag 2) Au 3) Cu **4) Pb**

24. Which equation represents an oxidation-reduction reaction?

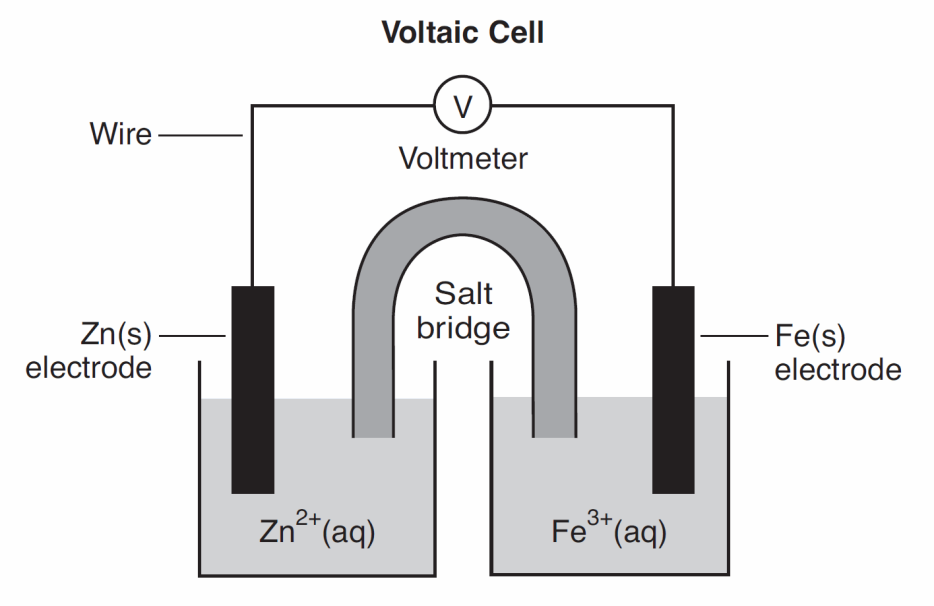
1) $H^+ + OH^- \rightarrow H_2O$
2) $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$
3) $Zn + Sn^{4+} \rightarrow Zn^{2+} + Sn^{2+}$
4) $3AgNO_3 + Li_3PO_4 \rightarrow Ag_3PO_4 + 3LiNO_3$

25. During which process does an atom gain one or more electrons?

1) transmutation
3) oxidation
2) reduction
4) neutralization

26. Base your answer to the following question on the information below and on your knowledge of chemistry.

An operating voltaic cell has zinc and iron electrodes. The cell and the unbalanced ionic equation representing the reaction that occurs in the cell are shown below.



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

Explain, in terms of Zn atoms and Zn ions, why the mass of the Zn electrode *decreases as the cell operates*.

27. Which balanced equation represents an oxidation-reduction reaction?

1) $Ba(NO_3)_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaNO_3$
2) $H_3PO_4 + 3KOH \rightarrow K_3PO_4 + 3H_2O$
3) $Fe(s) + S(s) \rightarrow FeS(s)$
4) $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

28. Given the balanced ionic equation representing the reaction in an operating voltaic cell:

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

The flow of electrons through the external circuit in this cell is from the

1) Cu anode to the Zn cathode
2) Cu cathode to the Zn anode
3) **Zn anode to the Cu cathode**
4) Zn cathode to the Cu anode

29. Given the redox reaction:

$Cr^{3+} + Al \rightarrow Cr + Al^{3+}$

As the reaction takes place, there is a transfer of

1) **electrons from Al to Cr^{3+}**
2) electrons from Cr^{3+} to Al
3) protons from Al to Cr^{3+}
4) protons from Cr^{3+} to Al

30. What is the oxidation number of sulfur in $Na_2S_2O_3$?

1) –1 **2) +2** 3) +6 4) +4

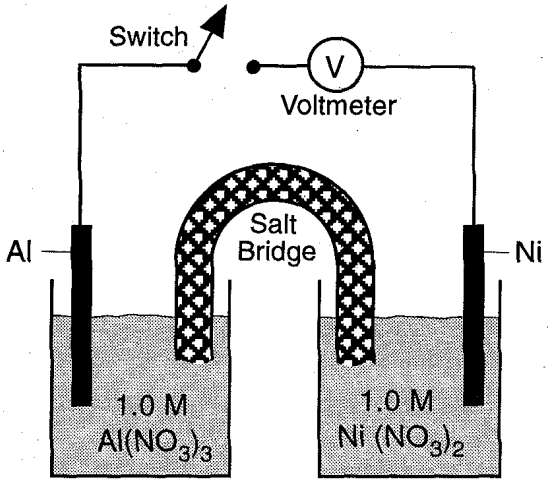
31. Reduction occurs at the cathode in

1) electrolytic cells, only
2) voltaic cells, only
3) **both electrolytic cells and voltaic cells**
4) neither electrolytic cells nor voltaic cells

32. Which half-reaction can occur at the anode in a voltaic cell?

1) $Ni^{2+} + 2e^- \rightarrow Ni$ **3) $Zn \rightarrow Zn^{2+} + 2e^-$**
2) $Sn + 2e^- \rightarrow Sn^{2+}$ 4) $Fe^{3+} \rightarrow Fe^{2+} + e^-$

33. The diagram below represents a chemical cell at 298 K.



$$2\,Al(s) + 3Ni^{2+}(aq) \longrightarrow 2Al^{3+} + 3Ni(s)$$

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 $Al^{3+}(aq)$

34. Given the overall cell reaction:

$$Zn(s) + 2\,Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2\,Ag(s)$$

Which will occur as the cell operates?

1) The amount of Zn(s) will increase.
2) The amount of Ag(s) will decrease.
3) **The concentration of $Zn^{+2}(aq)$ will increase.**
4) The concentration of $Ag^+(aq)$ will increase.

35. Given the balanced equation representing a reaction:

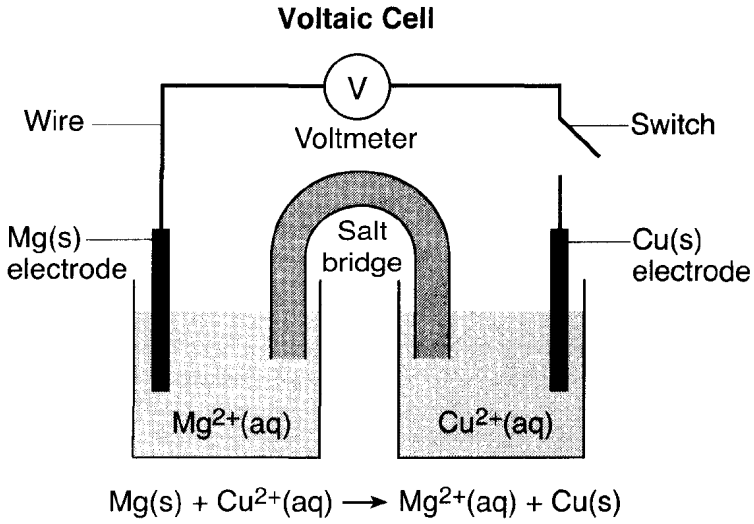
$$2Fe + 3Cu^{2+} \rightarrow 2Fe^{3+} + 3Cu$$

When the iron atoms lose six moles of electrons, how many moles of electrons are gained by the copper ions?

1) 12 moles 3) 3 moles
2) 2 moles **4) 6 moles**

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

A voltaic cell with magnesium and copper electrodes is shown in the diagram below. The copper electrode has a mass of 15.0 grams.



$Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$

When the switch is closed, the reaction in the cell begins. The balanced ionic equation for the reaction in the cell is shown below the cell diagram. After several hours, the copper electrode is removed, rinsed with water, and dried. At this time, the mass of the copper electrode is greater than 15.0 grams.

36. State the directions of electron flow through the wire between the electrodes when the switch is closed.

37. State the purpose of the salt bridge in this cell.

38. In a redox reaction, the total number of electrons lost is

    1) less than the total number of electrons gained
    2) greater than the total number of electrons gained
    3) equal to the total number of electrons gained
    4) equal to the total number of protons gained

39. A chemical cell is made up of two half-cells connected by an external conductor and a salt bridge. The function of the salt bridge is to

    1) permit the migration of ions
    2) permit the mixing of solutions
    3) prevent the migration of ions
    4) prevent the flow of electrons

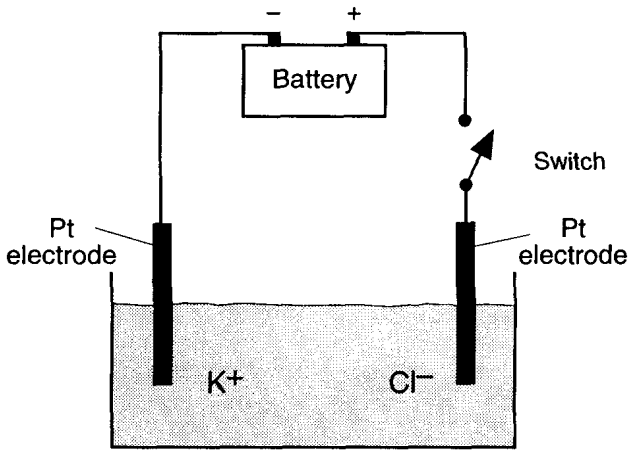
40. What is the oxidation number of chromium in $K_2Cr_2O_7$?

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

41. Compared to the amount of mass and total charge at the beginning of a redox reaction, the amount of mass and total charge upon completion of the reaction is

1) less **3) the same**
2) greater

42. The diagram below shows the electrolysis of fused KCl.

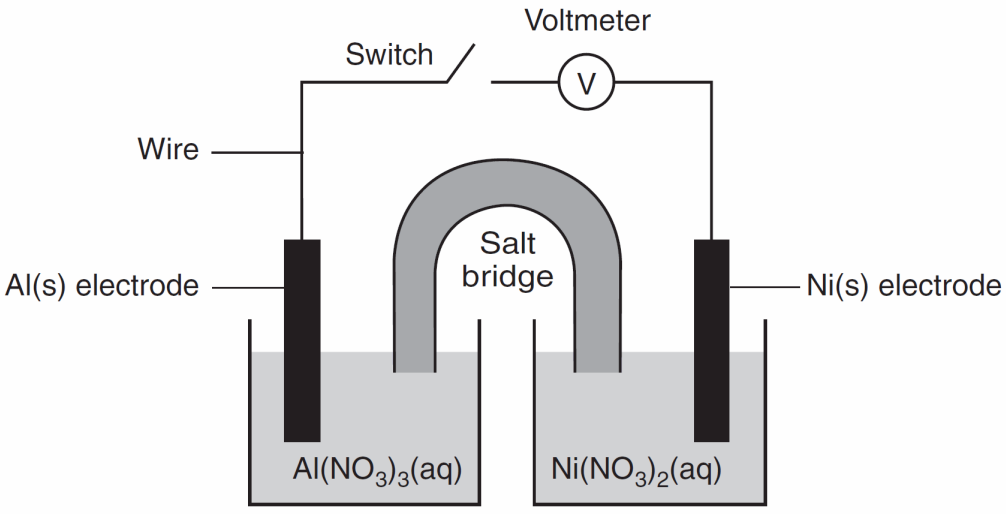


What occurs when the switch is closed?

1) Positive ions migrate toward the anode, where they lose electrons.
2) Positive ions migrate toward the anode, where they gain electrons.
3) Positive ions migrate toward the cathode, where they lose electrons.
4) Positive ions migrate toward the cathode, where they gain electrons.

43. Base your answer to the following question on the information below.

A student constructs an electrochemical cell during a laboratory investigation. When the switch is closed, electrons flow through the external circuit. The diagram and equation below represent this cell and the reaction that occurs.



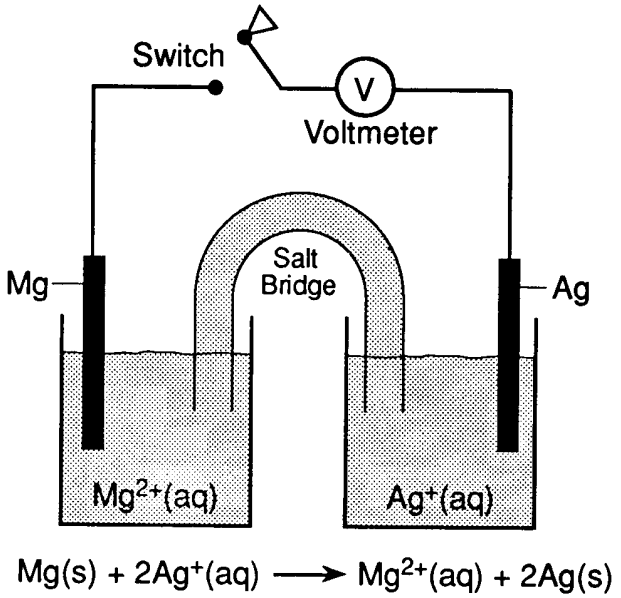
$$2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$$

State, in terms of energy, why this cell is a voltaic cell.

44. Which metal is more active than Ni and *less* active than Zn?

1) Cu **2) Cr** 3) Mg 4) Pb

45. Base your answer to the following question on the equation and diagram below represent an electrochemical cell at 298 K and 1 atmosphere.



$Mg(s) + 2Ag^{+}(aq) \longrightarrow Mg^{2+}(aq) + 2Ag(s)$

Which species is oxidized when the switch is closed?

1) Mg(s)
2) Mg^{2+} (aq)
3) Ag(s)
4) Ag^{+}(aq)

46. During the operation of a voltaic cell, the cell produces

1) electrical energy spontaneously
2) chemical energy spontaneously
3) electrical energy nonspontaneously
4) chemical energy nonspontaneously

47. Given the reaction:

$Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

Which statement correctly describes what occurs when this reaction takes place in a closed system?

1) Atoms of Zn(s) lose electrons and are oxidized.
2) Atoms of Zn(s) gain electrons and are reduced.
3) There is a net loss of mass.
4) There is a net gain of mass.

48. Which half-reaction correctly represents reduction?

1) $Mn^{4+} \rightarrow Mn^{3+} + e^{-}$
2) $Mn^{4+} \rightarrow Mn^{7+} + 3e^{-}$
3) $Mn^{4+} + e^{-} \rightarrow Mn^{3+}$
4) $Mn^{4+} + 3e^{-} \rightarrow Mn^{7+}$

49. Given the redox reaction in an electrochemical cell:

$Ni(s) + Pb^{2+}(aq) \leftrightarrow Ni^{2+}(aq) + Pb(s)$

A salt bridge is used to connect

1) Ni(s) and Pb(s)
2) $Pb^{2+}(aq)$ and $Ni^{2+}(aq)$
3) Ni(s) and $Ni^{2+}(aq)$
4) $Pb^{2+}(aq)$ and Pb(s)

50. Given the balanced ionic equation representing a reaction:

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

Which half-reaction represents the reduction that occurs?

1) $Al \rightarrow Al^{3+} + 3e^{-}$
2) $Al^{3+} + 3e^{-} \rightarrow Al$
3) $Cu \rightarrow Cu^{2+} + 2e^{-}$
4) $Cu^{2+} + 2e^{-} \rightarrow Cu$

Answer Key
Redox and Electrochemistry

1. **2**
2. **1**
3. **1**
4. **1**
5. **2**
6. **3**
7. **3**
8. **1**
9. **4**
10. **4**
11. **2**
12. **1**
13. **2**
14. Examples: electrons; e^-
15. Examples: Zinc is more reactive than iron, and iron is more reactive than copper.; The order of decreasing activity is Zn, Fe, Cu.; Copper is least active and zinc is most active.
16. Example: $Fe^{2+} + 2e^- \rightarrow Fe$
17. **1**
18. **3**
19. **3**
20. **2**
21. **1**
22. **4**
23. **4**
24. **3**
25. **2**
26. –Zinc atoms from the electrode are oxidized to zinc ions in the solution, decreasing the mass of the electrode. –Zinc atoms become $Zn^{2+}(aq)$. –The atoms become ions dissolved in the water. –Zn atoms lose electrons, producing ions in solution.
27. **3**
28. **3**
29. **1**
30. **2**
31. **3**
32. **3**
33. **1**
34. **3**
35. **4**
36. The electrons flow from the Mg electrode to the Cu electrode; From anode to cathode.
37. The salt bridge allows ions to flow between the half-cells; Preventing polarization.
38. **3**
39. **1**
40. **4**
41. **3**
42. **4**
43. —A spontaneous reaction converts chemical energy to electrical energy. —A battery is not required to provide energy for the cell to operate.
44. **2**
45. **1**
46. **1**
47. **1**
48. **3**
49. **2**
50. **4**