1. What is the oxidation state of nitrogen in the compound NH_4Br?
   1) −1
   3) −3
   2) +2
   4) +4

2. What is the oxidation number of sulfur in $Na_2S_2O_3$?
   1) −1
   3) +6
   2) +2
   4) +4

3. 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
   3) +1 to −1
   2) −1 to +5
   4) +5 to −1

4. What is the oxidation number of chromium in the chromate ion, CrO_4^{2-} ?
   1) +6
   3) +3
   2) +2
   4) +8

5. What is the oxidation number assigned to manganese in $KMnO_4$?
   1) +7
   3) +3
   2) +2
   4) +4

6. What is the oxidation state of nitrogen in $NaNO_2$?
   1) +1
   3) +3
   2) +2
   4) +4

7. During which process does an atom gain one or more electrons?
   1) transmutation
   3) oxidation
   2) reduction
   4) neutralization

8. Which half-reaction correctly represents reduction?
   1) $Mn^{4+} \rightarrow Mn^{3+} + e^-$
   3) $Mn^{4+} + e^- \rightarrow Mn^{3+}$
   2) $Mn^{4+} \rightarrow Mn^{7+} + 3e^-$
   4) $Mn^{4+} + 3e^- \rightarrow Mn^{7+}$

9. 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

10. Which changes occur when Pt^{2+} is reduced?
    1) The Pt^{2+} gains electrons and its oxidation number increases.
    2) The Pt^{2+} gains electrons and its oxidation number decreases.
    3) The Pt^{2+} loses electrons and its oxidation number increases.
    4) The Pt^{2+} loses electrons and its oxidation number decreases.

11. Half-reactions can be written to represent all
    1) double-replacement reactions
    2) neutralization reactions
    3) fission and fusion reactions
    4) oxidation and reduction reactions

12. The oxidation number of a reducing agent can change from
    1) −1 to −3
    3) 3 to −1
    2) −2 to −1
    4) 4 to −3

13. In a redox reaction, the reducing agent will
    1) lose electrons and be reduced
    2) lose electrons and be oxidized
    3) gain electrons and be reduced
    4) gain electrons and be oxidized

14. Given the redox reaction:

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

    Which species acts as a reducing agent?
    1) $Fe(s)$
    3) $Zn(s)$
    2) $Fe^{2+}(aq)$
    4) $Zn^{2+}(aq)$

15. In a redox reaction, the species reduced
    1) gains electrons and is the oxidizing agent
    2) gains electrons and is the reducing agent
    3) loses electrons and is the oxidizing agent
    4) loses electrons and is the reducing agent

16. 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

17. Which half-reaction equation represents the reduction of a potassium ion?
    1) $K^+ + e^- \rightarrow K$
    3) $K^+ \rightarrow K + e^-$
    2) $K + e^- \rightarrow K^+$
    4) $K \rightarrow K^+ + e^-$

18. Given the balanced equation representing a redox reaction:

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

    Which statement is true about this reaction?
    1) Each Al loses $2e^-$ and each Cu^{2+} gains $3e^-$.
    2) Each Al loses $3e^-$ and each Cu^{2+} gains $2e^-$.
    3) Each Al^{3+} gains $2e^-$ and each Cu loses $3e^-$.
    4) Each Al^{3+} gains $3e^-$ and each Cu loses $2e^-$.

19. 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+}
    3) protons from Al to Cr^{3+}
    2) electrons from Cr^{3+} to Al
    4) protons from Cr^{3+} to Al

20. Which half-reaction correctly represents reduction?
    1) $Ag \rightarrow Ag^+ + e^-$
    2) $F_2 \rightarrow 2\,F^- + 2e^-$
    3) $Au^{3+} + 3e^- \rightarrow Au$
    4) $Fe^{2+} + e^- \rightarrow Fe^{3+}$

21. Given the reaction for the corrosion of aluminum:

    $$4\,Al + 3\,O_2 \rightarrow 2\,Al_2O_3$$
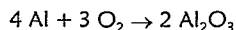
    Which half-reaction correctly represents the oxidation that occurs?
    1) $Al + 3e^- \rightarrow Al^{3+}$
    2) $Al \rightarrow Al^{3+} + 3e^-$
    3) $O_2 + 4e^- \rightarrow 2\,O^{2-}$
    4) $O_2 \rightarrow 2\,O^{2-} + 4e^-$

22. Given the equation:

    $$2\,Al + 3\,Cu^{2+} \rightarrow 2\,Al^{3+} + 3\,Cu$$
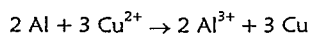
    The reduction half-reaction is
    1) $Al \rightarrow Al^{3+} + 3e^-$
    2) $Cu^{2+} + 2e^- \rightarrow Cu$
    3) $Al + 3e^- \rightarrow Al^{3+}$
    4) $Cu^{2+} \rightarrow Cu + 2e^-$

23. Given the equation:

    $$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$$
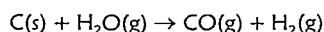
    Which species undergoes reduction?
    1) $C(s)$
    2) H^+
    3) C^{2+}
    4) $H_2(g)$

24. Given the reaction:

    $$Cu(s) + 4\,HNO_3(aq) \rightarrow$$
    $$Cu(NO_3)_2(aq) + 2\,NO_2(g) + 2\,H_2O(\ell)$$
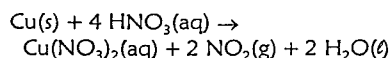
    As the reaction occurs, what happens to copper?
    1) It undergoes reduction and its oxidation number decreases.
    2) It undergoes reduction and its oxidation number increases.
    3) It undergoes oxidation and its oxidation number decreases.
    4) It undergoes oxidation and its oxidation, number increases.

25. Given the reaction:

    $$2\,Na(s) + 2\,H_2O(\ell) \rightarrow 2\,NaOH(aq) + H_2(g)$$
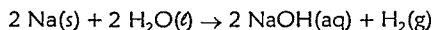
    What substance undergoes oxidation?
    1) Na
    2) $NaOH$
    3) H_2
    4) H_2O

26. Given the reaction:

    $$Mg + CuSO_4 \rightarrow MgSO_4 + Cu$$
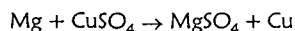
    Which equation represents the oxidation that takes place?
    1) $Mg^{2+} + 2e^- \rightarrow Mg$
    2) $Mg \rightarrow Mg^{2+} + 2e^-$
    3) $Cu^{2+} + 2e^- \rightarrow Cu$
    4) $Cu \rightarrow Cu^{2+} + 2e^-$
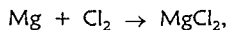
27. In the reaction
    $Mg + Cl_2 \rightarrow MgCl_2$,
    the correct half-reaction for the oxidation that occurs is
    1) $Mg + 2e^- \rightarrow Mg^{2+}$
    2) $Cl_2 + 2e^- \rightarrow 2Cl^-$
    3) $Mg \rightarrow Mg^{2+} + 2e^-$
    4) $Cl_2 \rightarrow 2Cl^- + 2e^-$

28. Given the reaction:

    $$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$
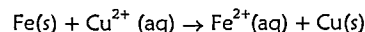
    Which half-reaction correctly shows the oxidation that occurs?
    1) $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
    2) $Fe(s) + 2e^- \rightarrow Fe^{2+}(aq)$
    3) $Cu^{2+}(aq) \rightarrow Cu(s) + 2e^-$
    4) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

29. Given the cell reaction:

    $$Sn(s) + Pb^{2+}(aq) \rightarrow Sn^{2+}(aq) + Pb(s)$$
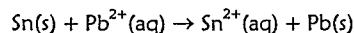
    The reduction half-reaction for this cell is
    1) $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$
    2) $Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$
    3) $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$
    4) $Sn(s) \rightarrow Sn^{2+}(aq) + 2e^-$

30. Given the reaction:

    $$2\,Al^0(s) + 3\,Ni^{2+}(aq) \rightarrow 2\,Al^{3+}(aq) + 3\,Ni^0(s)$$
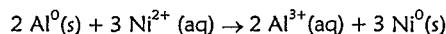
    What is the total number of moles of electrons lost by 2 moles of $Al^0(s)$?
    1) 6
    2) 2
    3) 3
    4) 8

31. Given the reaction:

    $$3\,Sn^{4+}(aq) + 2\,Cr(s) \rightarrow 3\,Sn^{2+}(aq) + 2\,Cr^{3+}(aq)$$
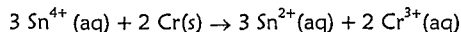
    Which half-reaction correctly represents the reduction that occurs?
    1) $Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$
    2) $Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$
    3) $Cr(s) \rightarrow Cr^{3+}(aq) + 3e^-$
    4) $Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$

32. Given the reaction:

    $$Zn(s) + 2\,HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$
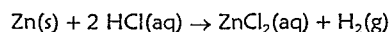
    Which equation represents the correct oxidation half-reaction?
    1) $Zn(s) \rightarrow Zn^{2+} + 2e^-$
    2) $2\,H + 2e^- \rightarrow H_2(g)$
    3) $Zn^{2+} + 2e \rightarrow Zn(s)$
    4) $2\,Cl^- \rightarrow Cl_2(g) + 2e^-$

33. Given the reaction:

    $$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$$
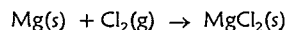
    Which half-reaction correctly represents the reduction that occurs?
    1) $Mg(s) + 2e^- \rightarrow Mg^{2+}$
    2) $Cl_2(g) + 2e^- \rightarrow 2\,Cl^-$
    3) $Mg^{2+} \rightarrow Mg(s) + 2e^-$
    4) $2\,Cl^- \rightarrow Cl_2 + 2e^-$

34. Given the reaction:

    $$2\,NaCl + 2\,H_2O \rightarrow 2\,NaOH + H_2 + Cl_2$$
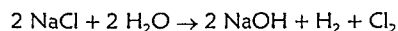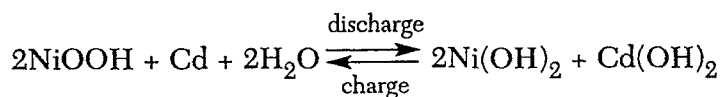
    Which electronic equation correctly represents the oxidation that occurs in this reaction?
    1) $2\,Na^0 \rightarrow 2\,Na^+ + 2e^-$
    2) $2\,Cl^- \rightarrow Cl_2^0 + 2e^-$
    3) $2\,H^+ + 2e^- \rightarrow H_2^0$
    4) $O_2^0 + 2e^- \rightarrow 2\,O^{-2}$

35. Given the nickel-cadmium battery reaction:

$$2NiOOH + Cd + 2H_2O \underset{charge}{\overset{discharge}{\rightleftharpoons}} 2Ni(OH)_2 + Cd(OH)_2$$

During the discharge of the battery, Ni^{3+} ions are
1) reduced, and cadmium metal is reduced
2) reduced, and cadmium metal is oxidized
3) oxidized, and cadmium metal is reduced
4) oxidized, and cadmium metal is oxidized
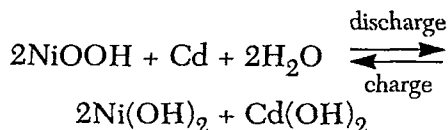
36. Given the reaction:

$$Ca(s) + Cu_{2+}(aq) \rightarrow Ca_{2+}(aq) + Cu(s)$$
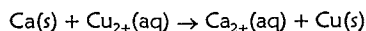
What is the correct reduction half-reaction?
1) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
2) $Cu^{2+}(aq) \rightarrow Cu(s) + 2e^-$
3) $Cu(s) + 2e^- \rightarrow Cu^{2+}(aq)$
4) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

37. 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) $Ca^2 + SO_4^{2-} \rightarrow CaSO_4$

38. In which reaction are electrons transferred from one reactant to another reactant?
1) $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$
2) $AgNO_3(aq) + KCl(aq) \rightarrow AgCl(s) + KNO_3(aq)$
3) $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(\ell)$
4) $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(\ell)$

39. Which balanced equation represents a redox reaction?
1) $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
2) $BaCl_2 + K_2CO_3 \rightarrow BaCO_3 + 2KCl$
3) $CuO + CO \rightarrow Cu + CO_2$
4) $HCl + KOH \rightarrow KCl + H_2O$

40. Which reaction occurs spontaneously?
1) $Cl_2(g) + 2NaBr(aq) \rightarrow Br_2(\ell) + 2NaCl(aq)$
2) $Cl_2(g) + 2NaF(aq) \rightarrow F_2(g) + 2NaCl(aq)$
3) $I_2(s) + 2NaBr(aq) \rightarrow Br_2(\ell) + 2NaI(aq)$
4) $I_2(s) + 2NaF(aq) \rightarrow F_2(g) + 2NaI(aq)$

41. Which metal reacts spontaneously with a solution containing zinc ions?
1) magnesium
2) nickel
3) copper
4) silver

42. According to Reference Table J, which of these metals will react most readily with 1.0 M HCl to produce $H_2(g)$?
1) Ca
2) K
3) Mg
4) Zn

43. Which metal can replace Cr in Cr_2O_3?
1) nickel
2) lead
3) copper
4) aluminum

44. According to Reference Table J, which of these ions is most easily reduced?
1) Ca^{2+}
2) Cr^{3+}
3) Cu^+
4) Ag^+

45. 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

46. Which expression correctly represents a balanced reduction half-reaction?
1) $Na^+ + e^- \rightarrow Na$
2) $Na \rightarrow Na^+ + e^-$
3) $Cl_2 + 2e^- \rightarrow Cl^-$
4) $2Cl^- \rightarrow Cl_2 + 2e^-$

47. Which equation shows conservation of charge?
1) $Fe \rightarrow Fe^{2+} + e^-$
2) $Fe + 2e^- \rightarrow Fe^{2+}$
3) $Fe \rightarrow Fe^{2+} + 2e^-$
4) $Fe + 2e^- \rightarrow Fe^{3+}$

48. When an equation is correctly balanced, it must show conservation of
1) charge but not of mass
2) mass but not of charge
3) both charge and mass
4) neither charge nor mass

49. A redox reaction always demonstrates the conservation of
1) mass, only
2) charge, only
3) both mass and charge
4) neither mass nor charge

50. A voltaic cell spontaneously converts chemical energy to
1) electrical energy
2) geothermal energy
3) mechanical energy
4) nuclear energy

51. Which half-reaction can occur at the anode in a voltaic cell?
1) $Ni^{2+} + 2e^- \rightarrow Ni$
2) $Sn + 2e^- \rightarrow Sn^{2+}$
3) $Zn \rightarrow Zn^{2+} + 2e^-$
4) $Fe^{3+} \rightarrow Fe^{2+} + e^-$

52. Which statement is true for any electrochemical cell?
1) Oxidation occurs at the anode, only.
2) Reduction occurs at the anode, only.
3) Oxidation occurs at both the anode and the cathode.
4) Reduction occurs at both the anode and the cathode.

53. Given the nickel-cadmium battery reaction:

$$2NiOOH + Cd + 2H_2O \underset{charge}{\overset{discharge}{\rightleftharpoons}}$$
$$2Ni(OH)_2 + Cd(OH)_2$$

What occurs during discharge in the nickel-cadmium battery?
1) Ni^{3+} is reduced to Ni^{2+}
2) Ni^{2+} is reduced to Ni^{3+}
3) Ni^{3+} is oxidized to Ni^{2+}
4) Ni^{2+} is oxidized to Ni^{3+}

54. Given the equation for the overall reaction in a lead-acid storage battery:

$$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \underset{charge}{\overset{discharge}{\rightleftharpoons}}$$
$$2PbSO_4(s) + 2H_2O(\ell)$$
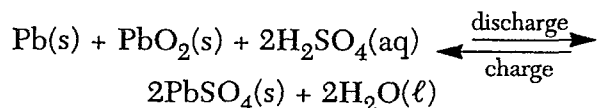
Which occurs during the charging of the battery?
1) The concentration of H_2SO_4 decreases and the number of moles of $Pb(s)$ increases.
2) The concentration of H_2SO_4 decreases and the number of moles of $H_2O(\ell)$ increases.
3) The concentration of H_2SO_4 increases and the number of moles of $Pb(s)$ decreases.
4) The concentration of H_2SO_4 increases and the number of moles of $H_2O(\ell)$ decreases.

55. 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

56. 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
2) a battery
3) a cathode
4) a salt bridge

57. Given the balanced equation representing the reaction occurring in a voltaic cell:
$$Zn(s) + Pb^{2+}(aq) \rightarrow Zn^{2+}(aq) + Pb(s)$$
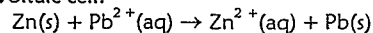
In the completed external circuit, the electrons flow from
1) $Pb(s)$ to $Zn(s)$
2) $Pb^{2+}(aq)$ to $Zn^{2+}(aq)$
3) $Zn(s)$ to $Pb(s)$
4) $Zn^{2+}(aq)$ to $Pb^{2+}(aq)$

58. Where does oxidation occur in an electrochemical cell?
1) at the cathode in both an electrolytic cell and a voltaic cell
2) at the cathode in an electrolytic cell and at the anode in a voltaic cell
3) at the anode in both an electrolytic cell and a voltaic cell
4) at the anode in an electrolytic cell and at the cathode in a voltaic cell

59. Which component of an electrochemical 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

60. An electrochemical setup consists of two half-cells, an anode, a cathode, an external circuit, and a salt bridge. When a reaction occurs, ion migration takes place through the
1) anode
2) cathode
3) salt bridge
4) external circuit

1. ___3___
2. ___2___
3. ___4___
4. ___1___
5. ___1___
6. ___3___
7. ___2___
8. ___3___
9. ___3___
10. ___2___
11. ___4___
12. ___2___
13. ___2___
14. ___3___
15. ___1___

16. ___3___
17. ___1___
18. ___2___
19. ___1___
20. ___3___
21. ___2___
22. ___2___
23. ___2___
24. ___4___
25. ___1___
26. ___2___
27. ___3___
28. ___1___
29. ___1___
30. ___1___

31. ___1___
32. ___1___
33. ___2___
34. ___2___
35. ___2___
36. ___1___
37. ___1___
38. ___1___
39. ___3___
40. ___1___
41. ___1___
42. ___2___
43. ___4___
44. ___4___
45. ___2___

46. ___1___
47. ___3___
48. ___3___
49. ___3___
50. ___1___
51. ___3___
52. ___1___
53. ___1___
54. ___4___
55. ___3___
56. ___4___
57. ___3___
58. ___3___
59. ___4___
60. ___3___