Multiple Choice Questions

1. Which of the following is correct as the cell operates?

<table>
<thead>
<tr>
<th>Direction of NO₃⁻ Migration</th>
<th>pH near the Pt Electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>towards Pt</td>
<td>increases</td>
</tr>
<tr>
<td>towards Pt</td>
<td>decreases</td>
</tr>
<tr>
<td>towards Ag</td>
<td>increases</td>
</tr>
<tr>
<td>towards Ag</td>
<td>decreases</td>
</tr>
</tbody>
</table>
2. Which of the following describes the direction of electron flow and the change in mass of the Ag electrode as the cell operates?

<table>
<thead>
<tr>
<th>Direction of Electron Flow</th>
<th>Mass of Ag Electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. from Pt to Ag</td>
<td>increases</td>
</tr>
<tr>
<td>B. from Pt to Ag</td>
<td>decreases</td>
</tr>
<tr>
<td>C. from Ag to Pt</td>
<td>increases</td>
</tr>
<tr>
<td>D. from Ag to Pt</td>
<td>decreases</td>
</tr>
</tbody>
</table>

3. An iron pipeline can be protected from rusting by connecting it to a...
   A. silver electrode buried beside the pipeline
   B. copper electrode buried beside the pipeline
   C. positive terminal of a direct current power supply
   D. negative terminal of a direct current power supply

4. The electrolysis of molten NaCl is an industrial process. What does the electrolysis produce?
   A. Na and Cl₂
   B. H₂ and O₂
   C. Na⁺ and Cl⁻
   D. NaOH and Cl₂
5. The reduced substance in a chemical reaction can best be described as a substance that…

A. is the reducing agent and loses electrons.
B. is the reducing agent and gains electrons.
C. is the oxidizing agent and loses electrons.
D. is the oxidizing agent and gains electrons.

6. Consider the following redox reaction for a lead-acid storage cell…

$$\text{Pb} + \text{PbO}_2 + 4\text{H}^+ + 2\text{SO}_4^{2-} \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O}$$

The balanced, reduction half-reaction is…

A. $\text{Pb} + \text{SO}_4^{2-} \rightarrow \text{PbSO}_4 + 2\text{e}^-$
B. $\text{Pb} + 2\text{H}^+ + \text{SO}_4^{2-} \rightarrow \text{PbSO}_4 + \text{H}_2\text{O} + 2\text{e}^-$
C. $\text{PbO}_2 + 4\text{H}^+ + \text{SO}_4^{2-} + 2\text{e}^- \rightarrow \text{PbSO}_4 + 2\text{H}_2\text{O}$
D. $\text{PbO}_2 + \text{SO}_4^{2-} + 4\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{PbSO}_4 + 4\text{OH}^-$
Which of the following statements apply to this electrochemical cell?

I. Electrons flow through the wire toward the copper electrode.
II. The copper electrode increases in mass.
III. Anions move toward the Zn half cell.

A. I and II only
B. I and III only
C. II and III only
D. I, II and III
8. At equilibrium, the voltage of the cell above is...

A. - 1.10 V  
B. + 0.00 V  
C. + 0.42 V  
D. + 1.10 V

9. Consider the following reaction...

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

The potential for the reaction is +0.36 V. What is the reduction potential for the cadmium ion?

A. - 1.12 V  
B. - 0.40 V  
C. + 0.40 V  
D. + 1.12 V

10. Which of the following involves a non-spontaneous redox reaction?

A. fuel cell  
B. electroplating  
C. redox titration  
D. carbon dry cell
11. Ethanol, \( \text{C}_2\text{H}_5\text{OH} \), is oxidized by an acidified dichromate solution according to the following equation:

\[
2\text{Cr}_2\text{O}_7^{2-} + 16\text{H}^+ + 3\text{C}_2\text{H}_5\text{OH} \rightarrow 4\text{Cr}^{3+} + 11\text{H}_2\text{O} + 3\text{CH}_3\text{COOH}
\]

The \( E^\circ \) for the reaction above is 2.98V. The \( E^\circ \) for the oxidation of ethanol is...

A. 0.52V
B. 1.23V
C. 1.75V
D. 2.98V

12. Which of the following must be present to produce rust by the corrosion of iron?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>water</td>
</tr>
<tr>
<td>II</td>
<td>oxygen</td>
</tr>
<tr>
<td>III</td>
<td>salt</td>
</tr>
</tbody>
</table>

A. I only
B. II only
C. I and II only
D. I, II and III

13. Why can an object not be plated with magnesium using 1.0 M MgI₂?

A. Water is a stronger reducing agent than I⁻
B. Water is a stronger oxidizing agent than I⁻
C. Water is a stronger reducing agent than Mg²⁺
D. Water is a stronger oxidizing agent than Mg²⁺

14. In the electrolysis of 1.0 M Na₂SO₄, what is formed at the cathode?

A. \( \text{O}_2 \)
B. \( \text{H}_2 \)
C. \( \text{H}_2\text{SO}_3 \)
D. \( \text{S}_2\text{O}_8^{2-} \)
15. Which of the following is capable of acting both as an oxidizing agent and a reducing agent?

A. H⁺
B. Na⁺
C. Sn^{2+}
D. MnO_4^-

16. Consider the following redox reaction:

\[
C_2H_2O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O
\]

The substance undergoing reduction is…

A. O₂
B. CO₂
C. H₂O
D. C₆H₁₂O₆

17. The oxidation number of P in H₄P₂O₇ is…

A. -10
B. -5
C. +5
D. +10

18. Consider the following redox reaction…

\[
2MnO_4^- + 16H^+ + 5Sn^{2+} \rightarrow 2Mn^{2+} + 8H_2O + 5Sn^{4+}
\]

In a redox titration, 0.060 mol of KMnO₄ reacts completely with a solution of Sn(NO₃)₂. How many moles of Sn(NO₃)₂ were present in the solution?

A. 0.024 mol
B. 0.060 mol
C. 0.15 mol
D. 0.30 mol
19. What substances are formed at the anode and cathode during electrolysis of molten sodium chloride, NaCl(l)?

<table>
<thead>
<tr>
<th>ANODE</th>
<th>CATHODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. O₂</td>
<td>H₂</td>
</tr>
<tr>
<td>B. Na</td>
<td>Cl₂</td>
</tr>
<tr>
<td>C. Cl₂</td>
<td>H₂</td>
</tr>
<tr>
<td>D. Cl₂</td>
<td>Na</td>
</tr>
</tbody>
</table>

20. What is the minimum voltage required to form nickel from an aqueous solution of Ni²⁺ using inert electrodes?

A. 0.26 V  
B. 0.28 V  
C. 0.54 V  
D. 0.80 V

21. Which of the following represents a redox reaction?

A. CaCO₃ → CaO + CO₂  
B. SiCl₄ + 2Mg → Si + 2MgCl₂  
C. 2NaOH + H₂SO₄ → 2H₂O + Na₂SO₄  
D. AgBr + 2Sₒ₃²⁻ → Ag(S₂O₃)₂⁻ + Br⁻

22. Consider the following reaction...

\[ \text{TiCl}_4 + O_2 \rightarrow \text{TiO}_2 + 2\text{Cl}_2 \]

Each oxygen atom is...

A. reduced and loses 2e⁻  
B. reduced and gains 2e⁻  
C. oxidized and loses 2e⁻  
D. oxidized and gains 2e⁻
23. When NO₂ acts as a reducing agent, a possible product is…

A. NO  
B. N₂O  
C. N₂O₄  
D. N₂O₅

24. Which of the following 1.0 M solutions will react spontaneously with lead?

A.  
B. CuCl₂  
C. ZnCl₂  
D. MgCl₂

25. Consider the following redox reaction…

\[ \text{I}_2 + 2\text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + 2\text{I}^- \]

In a titration, 40.00mL of Na₂S₂O₃ is needed to react completely with 4.0x10⁻³ mol I₂. What is the concentration of Na₂S₂O₃?

A. 0.10 M  
B. 0.16 M  
C. 0.20 M  
D. 0.32 M

26. In an operating electrochemical cell the function of a salt bridge is to…

A. allow hydrolysis to occur  
B. allow a non-spontaneous reaction to occur  
C. permit the migration of ions within the cell  
D. transfer electrons from the cathode to the anode
27. As the cell operates, electrons flow toward…

A. the Pb electrode, where Pb is oxidized
B. the Cd electrode, where Cd is oxidized
C. the Pb electrode, where Pb\(^{2+}\) is reduced
D. the Cd electrode, where Cd\(^{2+}\) is reduced
28. The $E^\circ$ value for the reduction of Cd$^{2+}$ is...

![Electrochemical cell diagram]

$E^\circ$ cell = 0.27 V

A. - 0.40 V
B. - 0.27 V
C. + 0.14 V
D. + 0.40 V

29. The following reaction occurs in an electrochemical cell:

$$3\text{Cu}^{2+} + 2\text{Cr} \rightarrow 2\text{Cr}^{3+} + 3\text{Cu}$$

The $E^\circ$ for the cell is...

A. 0.40 V
B. 0.75 V
C. 1.08 V
D. 2.50 V

30. During the corrosion of magnesium, the anode reaction is...

A. $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$
B. $\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg}$
C. $4\text{OH}^- \rightarrow \text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^-$
D. $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$
31. A molten binary salt, ZnCl₂, undergoes electrolysis. The cathode reaction is…

A. Zn → Zn²⁺ + 2e⁻  
B. 2Cl⁻ → Cl₂ + 2e⁻  
C. Cl₂ + 2e⁻ → 2Cl⁻  
D. Zn²⁺ + 2e⁻ → Zn

32. Manganese has an oxidation number of +4 in…

A. MnO  
B. MnO₂  
C. Mn₂O₃  
D. Mn₂O₇

33. In which reaction is nitrogen reduced?

A. 2NO + O₂ → 2NO₂  
B. 4NH₃ + 5O₂ → 4NO + 6H₂O  
C. Cu²⁺ + 2NO₂ + 2H₂O → Cu + 4H⁺ + 2NO₃⁻  
D. 4Zn + 10H⁺ + NO₃⁻ → 4Zn²⁺ + NH₄⁺ + 3H₂O

34. An oxidizing agent will cause which of the following changes?

A. PtO₂ → PtO  
B. PtO₃ → PtO₂  
C. Pt(OH)₂ → Pt  
D. Pt(OH)₂²⁺ → PtO₃

35. Consider the overall reaction of the rechargeable nickel-cadmium battery…

NiO₂(s) + Cd(s) + 2H₂O(l) → Ni(OH)₂(s) + Cd(OH)(s)

Which of the following occurs at the anode as the reaction proceeds?

A. Cd loses 2e⁻ and forms Cd(OH)₂(s)  
B. Cd gains 2e⁻ and forms Cd(OH)₂(s)  
C. NiO₂ loses 2e⁻ and forms Ni(OH)₂(s)  
D. NiO₂ gains 2e⁻ and forms Ni(OH)₂(s)
36. Which of the following will oxidize Fe\(^{2+}\)?

A. I\(_2\) (s)
B. Ni(s)
C. Zn(s)
D. Br\(_2\) (l)

37. Consider the following half-reaction in a basic solution:

\[
\text{Ag}_2\text{O}_3 \rightarrow \text{AgO} \quad \text{(basic)}
\]

The balanced half-reaction is...

A. \(\text{Ag}_2\text{O}_3 + 4\text{H}^+ + 4\text{e}^- \rightarrow \text{AgO} + 2\text{H}_2\text{O}\)
B. \(\text{Ag}_2\text{O}_3 + 2\text{H}^+ + 2\text{e}^- \rightarrow 2\text{AgO} + \text{H}_2\text{O}\)
C. \(\text{Ag}_2\text{O}_3 + \text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{AgO} + 2\text{OH}^-\)
D. \(\text{Ag}_2\text{O}_3 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow \text{AgO} + 4\text{OH}^-\)

38. The concentration of Fe\(^{2+}\) (aq) can be determined by a redox titration using...

A. KBr
B. SnCl\(_2\)
C. KMnO\(_4\) (basic)
D. KBrO\(_3\) (acidic)
39. Consider the following electrochemical cell...

Which of the following occurs as the cell operates?

A. Zinc electrode is reduced and increases in mass
B. Zinc electrode is reduced and decreases in mass
C. Zinc electrode is oxidized and increases in mass
D. Zinc electrode is oxidized and decreases in mass

40. Which of the following reactants would produce an $E^\circ$ of +0.63 V?

A. $\text{Ag}^+ + \text{I}_2$
B. $\text{Pb}^{2+} + \text{Zn}$
C. $\text{Mg}^{2+} + \text{Ca}$
D. $\text{Zn}^{2+} + \text{Mn}$

41. The process of applying an electric current through a cell to produce a chemical change is called...

A. corrosion
B. ionization
C. hydrolysis
D. electrolysis
42. Consider the following electrolytic cell...

The cathode reaction is...

A. $2I^- \rightarrow I_2 + 2e^-$
B. $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$
C. $H_2O \rightarrow 0.5O_2 + 2H^+ + 2e^-$
D. $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

43. A substance that is reduced during a redox reaction...

A. loses mass
B. is the anode
C. is the reducing agent
D. is the oxidizing agent

44. The oxidation number of As in $H_4As_2O_7$ is...

A. +4
B. +5
C. +9
D. +10
45. In a reaction, the oxidation number of Cr decreases by 3. This indicates that Cr is...

A. reduced  
B. oxidized  
C. neutralized  
D. a reducing agent

46. Consider the following redox reaction:

\[ \text{C}_2\text{H}_5\text{OH} + 2\text{Cr}_2\text{O}_7^{2-} + 16\text{H}^+ \rightarrow 2\text{CO}_2 + 4\text{Cr}^{3+} + 11\text{H}_2\text{O} \]

Each carbon atom loses...

A. 2 electrons  
B. 4 electrons  
C. 6 electrons  
D. 12 electrons

47. In which of the following 1.0 M solutions will both ions react spontaneously with tin?

A. Ag\(^{+}\) and Cu\(^{2+}\)  
B. Ni\(^{2+}\) and Cu\(^{2+}\)  
C. Zn\(^{2+}\) and Ni\(^{2+}\)  
D. Mg\(^{2+}\) and Zn\(^{2+}\)

48. Consider the following half-reaction:

\[ \text{Bi}_2\text{O}_4 \rightarrow \text{BiO}^+ \text{ (acidic)} \]

The balanced equation for this half-reaction is...

A. \(\text{Bi}_2\text{O}_4 + 6\text{H}^+ + 5\text{e}^- \rightarrow \text{BiO}^+ + 3\text{H}_2\text{O}\)  
B. \(\text{Bi}_2\text{O}_4 + 8\text{H}^+ + 6\text{e}^- \rightarrow 2\text{BiO}^+ + 4\text{H}_2\text{O}\)  
C. \(\text{Bi}_2\text{O}_4 + 4\text{H}^+ + 2\text{e}^- \rightarrow 2\text{BiO}^+ + 2\text{H}_2\text{O}\)  
D. \(\text{Bi}_2\text{O}_4 + 4\text{H}^+ + 3\text{e}^- \rightarrow 2\text{BiO}^+ + 2\text{H}_2\text{O}\)
49. To determine the concentration of Fe$^{2+}$(aq) by a redox titration, we could use an acidified standard solution of...

A. Sn$^{2+}$
B. Pb$^{2+}$
C. HCl
D. H$_2$O$_2$

50. Consider the following redox reactions...

\[2\text{Ag}^+ + \text{Cd} \rightarrow 2\text{Ag} + \text{Cd}^{2+}, \ E^\circ = 1.20 \text{V}\]
\[3\text{Cd}^{2+} + 2\text{Nb} \rightarrow 2\text{Nb}^{3+} + 3\text{Cd}, \ E^\circ = 0.70 \text{V}\]

What is the \(E^\circ\) for \(\text{Nb}^{3+} + 3e^- \rightarrow \text{Nb}\)?

A. -1.90 V
B. -1.10 V
C. -0.50 V
D. -0.40 V

51. Consider the overall reaction for the rechargeable nickel-cadmium battery:

\[\text{Cd} + \text{NiO}_2 + 2\text{H}_2\text{O} \rightarrow \text{Cd(OH)}_2 + \text{Ni(OH)}_2\]

Which of the following occurs at the cathode as the reaction proceeds?

A. Cd loses 2e$^-$ and Cd(OH)$_2$ forms
B. Cd gains 2e$^-$ and Cd(OH)$_2$ forms
C. NiO$_2$ loses 2e$^-$ and Ni(OH)$_2$ forms
D. NiO$_2$ gains 2e$^-$ and Ni(OH)$_2$ forms
52. Consider the following diagram of a piece of iron, cathodically protected by magnesium...

Water containing dissolved oxygen

Iron Magnesium

What is happening during this process?

A. Iron acts as the anode and water is oxidized.
B. Iron acts as the cathode and oxygen is reduced.
C. Magnesium acts as the anode and iron is oxidized.
D. Magnesium acts as the cathode and iron is reduced.
53. Consider the following operating cell...

![Diagram of an operating cell with electrodes and a power source.]

Which of the following describes the cell above?

<table>
<thead>
<tr>
<th>Electrode #1</th>
<th>Electrode #2</th>
<th>Gas Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. anode</td>
<td>cathode</td>
<td>H₂(g)</td>
</tr>
<tr>
<td>B. anode</td>
<td>cathode</td>
<td>O₂(g)</td>
</tr>
<tr>
<td>C. cathode</td>
<td>anode</td>
<td>H₂(g)</td>
</tr>
<tr>
<td>D. cathode</td>
<td>anode</td>
<td>O₂(g)</td>
</tr>
</tbody>
</table>

54. A chemical process involving the loss of electrons is a definition of...

A. oxidation  
B. reduction  
C. galvanization  
D. cathodic protection
55. Which of the following is not a redox reaction?

A. $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
B. $\text{SO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{S}_2\text{O}_7$
C. $\text{CuS} + 2\text{O}_2 + \text{C} \rightarrow \text{Cu} + \text{SO}_2 + \text{CO}_2$
D. $4\text{Ag} + 2\text{H}_2\text{S} + \text{O}_2 \rightarrow 2\text{Ag}_2\text{S} + 2\text{H}_2\text{O}$

56. A reducing agent will cause which of the following changes?

A. $\text{ClO}_3^- \rightarrow \text{ClO}_2$
B. $\text{NO}_2^- \rightarrow \text{N}_2\text{O}_4$
C. $\text{H}_3\text{PO}_3 \rightarrow \text{H}_3\text{PO}_4$
D. $\text{HS}_2\text{O}_4^- \rightarrow \text{H}_2\text{SO}_3$

57. The oxidation number of zinc in a reaction increases by 2. This indicates that...

A. zinc is reduced and loses 2 electrons
B. zinc is reduced and gains 2 electrons
C. zinc is oxidized and loses 2 electrons
D. zinc is oxidized and gains 2 electrons

58. Which metal will react spontaneously with water?

A. Ca
B. Ni
C. Pb
D. Hg

59. Which of the following describes an electrochemical cell?

<table>
<thead>
<tr>
<th>$E^\circ_{\text{cell}}$</th>
<th>Type of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>positive</td>
<td>spontaneous</td>
</tr>
<tr>
<td>positive</td>
<td>non-spontaneous</td>
</tr>
<tr>
<td>negative</td>
<td>spontaneous</td>
</tr>
<tr>
<td>negative</td>
<td>non-spontaneous</td>
</tr>
</tbody>
</table>
60. Which of the following aqueous solutions should not be used as an electrolyte in an electrolytic cell?

A. 1.0 M KOH
B. 1.0 M H₂SO₄
C. 1.0 M CuSO₄
D. 1.0 M C₆H₁₂O₆

61. When 1.0 M Na₂SO₄ is electrolyzed, the solution near the anode becomes...

A. basic and bubbles form
B. acidic and bubbles form
C. basic and no bubbles form
D. acidic and no bubbles form

62. Which of the following represents a redox reaction?

A. H₂ + I₂ → 2HI
B. HCl + NH₃ → NH₄Cl
C. H₂O + CO₂ → H₂CO₃
D. 2NaI + Pb(NO₃)₂ → Pbl₂ + 2NaNO₃

63. In an experiment, Ag⁺ reacts spontaneously with Ru but not with Pd. The relative strength of the metals from strongest to weakest reducing agent is...

A. Ag > Ru > Pd
B. Pd > Ag > Ru
C. Ru > Ag > Pd
D. Ru > Pd > Ag

64. A piece of Ag does not react spontaneously with 1.0 M Ti²⁺ because...

A. Ag⁺ is a weaker reducing agent than Ti²⁺
B. Ag⁺ is a weaker oxidizing agent than Ti²⁺
C. Ag⁺ is a stronger reducing agent than Ti²⁺
D. Ag⁺ is a stronger oxidizing agent than Ti²⁺
65. Which of the following will react spontaneously with Ag₂S at standard conditions?

A. Al
B. Au
C. Co
D. Pb

66. When a piece of Cu is placed in 1.0 M HNO₃…

A. the [H⁺] increases
B. the [Cu²⁺] decreases
C. the [NO₃⁻] decreases
D. no change occurs

67. When MnO₂ changes to Mn₂O₃ in an alkaline battery, manganese atoms…

A. lose electrons and are reduced
B. gain electrons and are reduced
C. lose electrons and are oxidized
D. gain electrons and are oxidized
68. Which of the following diagrams represents the relationship between the mass of the Cu electrode and the mass of the Ag electrode as the cell is in operation?
69. The \( E^\circ \) for the cell is...

\[ \begin{align*}
\text{Cu} & | 1.0 \text{ M Cu(NO}_3\text{)}_2 & | 1.0 \text{ M AgNO}_3 & | \text{Ag}
\end{align*} \]

A. - 1.14 Volts  
B. - 0.46 Volts  
C. + 0.46 Volts  
D. + 1.14 Volts

70. The value of \( E^\circ \) for a cell can be used to determine...

A. rate  
B. spontaneity  
C. temperature  
D. activation energy

71. How is the formation of rust on an iron can inhibited by a tin coating?

A. The tin is a sacrificial anode  
B. The tin cathodically protects the iron  
C. The tin is a weaker reducing agent than iron  
D. The tin keeps the oxygen away from the iron

72. The electrolysis of 1.0M \( \text{CuF}_2 \) using inert electrodes will produce...

A. copper and oxygen  
B. copper and fluorine  
C. hydrogen and oxygen  
D. hydrogen and fluorine
73. Consider the following spontaneous reaction...

\[ 2\text{Al(s)} + 3\text{Cu}^{2+}(\text{aq}) \rightarrow 2\text{Al}^{3+}(\text{aq}) + 3\text{Cu(s)} \]

In this reaction, the oxidizing agent is…

A. Al
B. Cu
C. Al^{3+}
D. Cu^{2+}

74. Bromine has an oxidation number of +3 in…

A. KBrO
B. KBrO_2
C. KBrO_3
D. KBrO_4

75. In an experiment, Te reacts spontaneously with \text{Ag}^+ but not with \text{Ti}^{2+}. The relative strength of oxidizing agents from strongest to weakest is…

A. \text{Ag}^+ > \text{Te}^{4+} > \text{Ti}^{2+}
B. \text{Ag}^+ > \text{Ti}^{2+} > \text{Te}^{4+}
C. \text{Te}^{4+} > \text{Ti}^{2+} > \text{Ag}^+
D. \text{Ti}^{2+} > \text{Te}^{4+} > \text{Ag}^+

76. A piece of Au does not react spontaneously with 1.0 M HCl. Which of the following statements is true?

A. Au is a weaker reducing agent than H_2
B. Au is a stronger reducing agent than H_2
C. Au is a weaker oxidizing agent than H^+
D. Au is a stronger oxidizing agent than H^+

77. Which two species will react spontaneously with each other at standard conditions?

A. Cl_2 and Br^-
B. Zn and Al^{3+}
C. Au and Sn^{2+}
D. I_2 and SO_4^{2-}
78. What occurs when a piece of Zn is placed in 1.0 M Cu(NO$_3$)$_2$?

A. [Cu$^{2+}$] decreases
B. [Zn$^{2+}$] decreases
C. [NO$_3^-$] increases
D. no change occurs
79. Which of the following diagrams represents the relationship between \([\text{Zn}^{2+}]\) and \([\text{Ni}^{2+}]\) as the cell is in operation?

A. \[
\begin{array}{c}
\text{[Ni}^{2+}] \\
\text{[Zn}^{2+}]
\end{array}
\]

B. \[
\begin{array}{c}
\text{[Ni}^{2+}] \\
\text{[Zn}^{2+}]
\end{array}
\]

C. \[
\begin{array}{c}
\text{[Ni}^{2+}] \\
\text{[Zn}^{2+}]
\end{array}
\]

D. \[
\begin{array}{c}
\text{[Ni}^{2+}] \\
\text{[Zn}^{2+}]
\end{array}
\]
80. The $E^\circ$ for the cell in the diagram is…

A. - 1.02 Volts  
B. - 0.50 Volts  
C. + 0.50 Volts  
D. + 1.02 Volts

81. Which of the following is the balanced half-reaction for…

$N_2O \rightarrow NH_3OH^+$, (acidic)

A. $N_2O + 4H^+ + 3e^- \rightarrow NH_3OH^+$  
B. $N_2O + 3H^+ + H_2O \rightarrow NH_3OH^+ + 2e^-$  
C. $N_2O + 6H^+ + H_2O \rightarrow 2NH_3OH^+ + 4e^-$  
D. $N_2O + 6H^+ + H_2O + 4e^- \rightarrow 2NH_3OH^+$
82. Which material could be used as the cathode to produce an $E_{\text{cell}}^\circ = +0.46 \text{ V}$?

A. Pb  
B. Co  
C. Ag  
D. MnO$_2$

83. In what directions do the electrons and cations move?

<table>
<thead>
<tr>
<th>Direction of Electrons</th>
<th>Direction of Cations</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. toward the cathode</td>
<td>toward the anode</td>
</tr>
<tr>
<td>B. toward the cathode</td>
<td>toward the cathode</td>
</tr>
<tr>
<td>C. toward the anode</td>
<td>toward the anode</td>
</tr>
<tr>
<td>D. toward the anode</td>
<td>toward the cathode</td>
</tr>
</tbody>
</table>
84. The concentration of \( \text{Cu}^{2+} \) in the copper half-cell will...

A. increase as Cu loses electrons and is reduced
B. increase as Cu loses electrons and is oxidized
C. decrease as Cu gains electrons and is reduced
D. decrease as Cu gains electrons and is oxidized

85. Which of the following metals could be used to cathodically protect iron?

A. tin
B. lead
C. zinc
D. copper

86. Which of the following is formed at the anode during the electrolysis of 1.0 M KF?

A. K
B. \( \text{F}_2 \)
C. \( \text{H}_2 \)
D. \( \text{O}_2 \)

87. Which of the following describes a strong oxidizing agent?

A. a substance which loses electrons readily
B. a substance which gains electrons readily
C. a substance which has a large increase in oxidation number
D. a substance which has a small increase in oxidation number
88. Consider the following unbalanced redox reaction...

\[ \text{Sn}^{2+}\text{MnO}_4^- \rightarrow \text{Sn}^{4+}\text{+Mn}^{2+} \]

Which of the following describes the change in \( \text{Sn}^{2+} \)?

A. loses electrons and is reduced  
B. gains electrons and is reduced  
C. loses electrons and is oxidized  
D. gains electrons and is oxidized

89. A solution containing \( \text{Pd}^{2+} \) reacts spontaneously with \( \text{Ga} \) to produce \( \text{Pd} \) and \( \text{Ga}^{3+} \). However, a solution containing \( \text{Pd}^{2+} \) does not react with \( \text{Pt} \). The metals, in order of increasing strength as reducing agents, are...

A. \( \text{Pt} \) &lt; \( \text{Pd} \) &lt; \( \text{Ga} \)  
B. \( \text{Pt} \) &lt; \( \text{Ga} \) &lt; \( \text{Pd} \)  
C. \( \text{Ga} \) &lt; \( \text{Pt} \) &lt; \( \text{Pd} \)  
D. \( \text{Ga} \) &lt; \( \text{Pd} \) &lt; \( \text{Pt} \)

90. Which of the following can act as an oxidizing agent, but not as a reducing agent?

A. \( \text{Cr} \)  
B. \( \text{Cl}^- \)  
C. \( \text{Cu}^+ \)  
D. \( \text{Na}^+ \)

91. Solid copper forms spontaneously in the following reaction...

\[ \text{V}^-\text{Cu}^{2+} \rightarrow \text{Cu}^+\text{V}^{2+} \]

Based on this observation, \( \text{Cu}^{2+} \) is a...

A. weaker reducing agent than \( \text{V}^{2+} \)  
B. weaker oxidizing agent than \( \text{V}^{2+} \)  
C. stronger reducing agent than \( \text{V}^{2+} \)  
D. stronger oxidizing agent than \( \text{V}^{2+} \)
92. Which of the following could be used to determine the \( [\text{Fe}^{2+}] \) by a redox titration?

A. \( I_2 \)
B. \( \text{Cl}^- \)
C. \( \text{Cu}^{2+} \)
D. \( \text{MnO}_4^- \) (acidified)

93. What happens to the lead electrode?

A. It loses mass as it is reduced.
B. It gains mass as it is reduced.
C. It loses mass as it is oxidized.
D. It gains mass as it is oxidized.
94. As the cell operates, what happens to the ions in the salt bridge?

A. $\text{K}^+$ and $\text{NO}_3^-$ will both migrate toward the Pb half cell.
B. $\text{K}^+$ and $\text{NO}_3^-$ will both migrate toward the Cu half cell.
C. $\text{K}^+$ will migrate toward the Cu half cell and $\text{NO}_3^-$ will migrate toward the Pb half cell.
D. $\text{K}^+$ will migrate toward the Pb half cell and $\text{NO}_3^-$ will migrate toward the Cu half cell.

95. What is the initial cell voltage?

A. $+0.02\text{V}$
B. $+0.21\text{V}$
C. $+0.28\text{V}$
D. $+0.47\text{V}$
96. Consider the following…

I. electrolysis of water
II. electroplating of copper
III. rusting of iron

Which of the above involve non-spontaneous redox reactions?

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

97. A copper spoon was electroplated with silver. Which of the following reactions occurred at the cathode during electroplating?

A. \( \text{Ag} \rightarrow \text{Ag}^{+} + \text{e}^- \)
B. \( \text{Ag}^+ + \text{e}^- \rightarrow \text{Ag} \)
C. \( \text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^- \)
D. \( \text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu} \)

98. Which of the following is the strongest reducing agent?

A. \( \text{H}_2\text{S} \)
B. \( \text{H}_2\text{O} \)
C. \( \text{H}_2\text{Se} \)
D. \( \text{H}_2\text{Te} \)

99. Consider the following unbalanced half-reaction...

\( \text{H}_2\text{SeO}_3 \rightarrow \text{Se} \)

The oxidation number of Se…

A. increases as it undergoes oxidation.
B. increases as it undergoes reduction.
C. decreases as it undergoes oxidation.
D. decreases as it undergoes reduction.
100. Which of the following will react spontaneously with Br₂ but not with I₂?

A. F⁻  
B. Cr²⁺  
C. Fe²⁺  
D. Mn²⁺
Written Questions

1. Consider the following reactions for a fuel cell…

   A. Write the reaction at the anode. (1 mark)

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

   B. Discuss the advantage of a fuel-cell powered vehicle over an internal combustion powered vehicle by comparing the products formed. (1 mark)

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

2. Draw and label an electrochemical cell using a copper anode and having an $E^\circ$ value $> 1.00$ V. (2 marks)

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

3. During the production of magnesium metal from sea water, magnesium ions are first precipitated from sea water as magnesium hydroxide.

   A. The magnesium hydroxide is then neutralized by hydrochloric acid, producing magnesium chloride. Write the neutralization reaction. (1 mark)

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

   B. The salt produced, magnesium chloride, is dried, melted and undergoes electrolysis. Write the reaction occurring at each electrode. (2 marks)

<table>
<thead>
<tr>
<th>Anode:</th>
<th>Cathode:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   C. It is not possible to use electrolysis to remove Mg from a 1.0 M MgCl$_2$ solution. Why? (1 mark)

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
4. In the process of extracting tin from a sample of ore, the tin is removed as \( \text{Sn}^{2+} \) ions. A titration requires 21.43 mL of 0.0170 M \( \text{K}_2\text{Cr}_2\text{O}_7 \) to reach the equivalence point with the \( \text{Sn}^{2+} \) in a 0.750 g sample of the ore.

\[
3\text{Sn}^{2+} (\text{aq}) + \text{Cr}_2\text{O}_7^{2-} (\text{aq}) + 14\text{H}^+ (\text{aq}) \rightarrow 3\text{Sn}^{4+} (\text{aq}) + 2\text{Cr}^{3+} (\text{aq}) + 7\text{H}_2\text{O}(\text{l})
\]

Using the reaction, calculate the percent mass of tin in the ore sample. (4 marks)

5. Balance the following redox reaction in basic solution. (5 marks)

\[
\text{SO}_3^{2-} + \text{MnO}_4^- \rightarrow \text{SO}_4^{2-} + \text{MnO}_2 \quad \text{(basic)}
\]

6. Draw and label the parts of an operating electrochemical cell using a zinc anode that will produce an electric current having a voltage of 1.56 V at standard conditions. (4 marks)

7. Balance the following redox reaction in basic solution. (5 marks)

\[
\text{MnO}_4^- + \text{C}_2\text{O}_4^{2-} \rightarrow \text{MnO}_2 + \text{CO}_3^{2-} \quad \text{(basic)}
\]

8.

A. Draw and label the parts of an operating electrolytic cell during the electrolysis of molten potassium chloride \( \text{KCl(l)} \). (3 marks)

B. Define the term oxidizing agent. (1 mark)
9. Balance the following redox reaction in acidic solution… (3 marks)

\[
\text{MnO}_4^- + \text{Fe}^{2+} \rightarrow \text{Mn}^{2+} + \text{Fe}^{3+} \text{ (acidic)}
\]

10. Aluminum is a stronger reducing agent than copper. What is meant by the phrase “stronger reducing agent”? (2 marks)

11. Consider the electrolysis of water…

A. Draw and label the parts of an electrolytic cell capable of decomposing water. (3 marks)

B. Identify the gas produced at the anode. (1 mark)

12. Consider the following redox reaction in acidic solution:

\[
\text{MnO}_4^- + \text{H}_2\text{O}_2 \rightarrow \text{Mn}^{2+} + \text{O}_2, \text{ acidic}
\]

A. Write a balanced equation for the above reaction. (4 marks)

B. The above reaction was used for a redox titration. At the equivalence point 5.684 \times 10^{-4} \text{ mol} was required to titrate 5.00 \text{ mL} of solution. Calculate the \([\text{H}_2\text{O}_2]\). (2 marks)
13. Cathodic protection is one method used to inhibit the corrosion of iron.

A. Explain the principle of cathodic protection. (2 marks)

B. Identify two methods, other than cathodic protection, that could be used to inhibit the corrosion of iron. (2 marks)

Solution:

For Example:

Coating with paint or grease. ← 1 mark

Keep in totally dry atmosphere. ← 1 mark
14. Consider the following diagram…

Students are asked to produce hydrogen and oxygen gas by the electrolysis of water. They are given three substances (CuSO₄, K₂SO₄, and NaI) to choose from to prepare an electrolytic solution that will only produce hydrogen and oxygen.

A. Which substance should be selected? Explain why. (3 marks)

B. Write the equation for the half-reaction that occurs at the anode in the electrolytic cell. (1 mark)

C. Explain why it would not be acceptable to use a copper anode in this cell. (1 mark)
15. Balance the following redox reaction… (4 marks)

\[ \text{Ag}_2\text{O} + \text{Si} \rightarrow \text{Ag} + \text{SiO}_3^{2-} \] (acidic)

16. Sodium metal is produced commercially by the electrolysis of molten NaCl(l). Explain why sodium metal, Na(s), cannot be produced by electrolysis of aqueous NaCl(aq). (2 marks)

17. Blister copper is an impure sample of copper containing small amounts of zinc and gold. Blister copper is purified using electrolysis. Sufficient voltage is supplied to oxidize copper at the anode.

A. What happens to the zinc at the anode? Explain. (2 marks)
B. Write the equation for the half-reaction that occurs at the cathode. (1 mark)

18. Balance the following redox equation... (4 marks)

\[ \text{Ag}^+ + \text{NO}_3^- \rightarrow \text{Ag}^+ + \text{NO} \] (acidic)

19. Draw a diagram of an operating electrolytic cell used to extract pure lead from an impure lead sample. Identify the electrolyte and the material used for the anode. (3 marks)

20. A sample of copper is placed in HNO_3(aq) and another sample of copper is placed in HCl(aq).

A. In which acid does the copper react? (0.5 marks)

B. Calculate \( E^\circ \) for the reaction that occurs. (1.5 marks)

21. Balance the following redox equation... (4 marks)

\[ \text{ClO}_4^- + \text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + \text{Cl}^- \] (acidic)
22. State two characteristics of the overall reaction in an electrochemical cell. (2 marks)

23. Describe two chemically different methods of preventing the corrosion of iron. Explain how each method works. (3 marks)

<table>
<thead>
<tr>
<th>Method</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

24. Balance the following redox reaction… (4 marks)

\[ \text{Sb} + \text{NO}_3^- \rightarrow \text{Sb}_2\text{O}_3 + \text{NO} \text{ (acidic)} \]

25. A 1.0 M HCl solution is electrolyzed using a copper anode and an inert carbon cathode. Predict the half-reactions that will occur and describe what you would observe at each electrode. (4 marks)
26. Consider the following experimental results...

\[
\begin{align*}
\text{Ce}^{4+} + \text{Pd} & \rightarrow \text{Pd}^{2+} + \text{Ce}^{3+} \\
\text{In}^{3+} + \text{Cd} & \rightarrow \text{no reaction} \\
\text{Pd}^{2+} + \text{In}^{2+} & \rightarrow \text{In}^{3+} + \text{Pd} \\
\text{Cd}^{2+} + \text{Pd} & \rightarrow \text{no reaction}
\end{align*}
\]

Use these results to complete the table of reduction half-reactions below. (3 marks)

<table>
<thead>
<tr>
<th>Oxidizing Agents</th>
<th>Reducing Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{Ce}^{4+})</td>
<td>(\text{Pd}^{2+})</td>
</tr>
<tr>
<td>(\text{In}^{3+})</td>
<td>(\text{Pd})</td>
</tr>
<tr>
<td>(\text{Pd}^{2+})</td>
<td>(\text{In}^{3+})</td>
</tr>
<tr>
<td>(\text{Cd}^{2+})</td>
<td>(\text{Pd})</td>
</tr>
</tbody>
</table>

27. Balance the following equation… (3 marks)

\[
\text{Cr}_2\text{O}_7^{2-} + \text{C}_2\text{O}_4^{2-} \rightarrow \text{Cr}^{3+} + \text{CO}_2 \quad \text{(acidic)}
\]
28. Consider the following electrolytic cell which contains a porous barrier to prevent general mixing of solutions.

A. Label the anode and cathode in the space provided on the diagram above. (1 mark)

B. Write an equation for the overall cell reaction. (2 marks)

C. Calculate the minimum theoretical voltage required for this reaction under standard conditions. (1 mark)

29. Balance the following redox equation… (4 marks)

\[ \text{H}_2\text{S} + \text{CrO}_4^{2-} \rightarrow \text{S}_8 + \text{Cr}^{3+} \] (acidic)
30. An excess of copper solid is dropped into a solution which contains AgNO₃, Fe(NO₃)₃, and Zn(NO₃)₂. Write the equations for any reduction half-reactions that occur over time under standard conditions. (2 marks)

31. Consider the following diagrams...

A. Predict what should happen to the Fe in Beaker A. (1 mark)

B. Predict what should happen to the Fe in Beaker B. Explain. (2 marks)

Prediction:

Explanation:

32. A reaction occurs when copper metal is dropped into a solution of silver nitrate. Write the balanced formula equation and the balanced net ionic equation for this reaction. (3 marks)
33. When setting up the apparatus to electroplate a zinc object with copper, the object is suspended in a $\text{Cu}^{2+}$ solution. Explain why it is a good idea to turn on the power supply before immersing the electrodes in the solution. (1 mark)

34. Consider the following apparatus consisting of an electrochemical cell joined to an electrolytic cell…

A. On the diagram above, indicate the direction of electron flow in the top wire. (1 mark)

B. Which metal in cell A is the cathode? (1 mark)

C. Write the anode and cathode half-reactions for cell B. (3 marks)
35. Balance the following skeletal redox equation in acidic solution... (4 marks)

\[
\text{MnO}_4^- + \text{As}_2\text{O}_3 \rightarrow \text{Mn}^{2+} + \text{AsO}_4^{3-} \quad \text{(acidic)}
\]

36. Draw an electrolytic cell that could be used to plate an iron ring with gold. Be sure to include all of the necessary parts. In addition, label the anode, solution used and composition of the electrodes. (3 marks)

37. Balance the following redox reaction in basic solution... (4 marks)

\[
\text{ClO}_3^- + \text{N}_2\text{H}_4 \rightarrow \text{NO}_3^- + \text{Cl}^- \quad \text{(basic)}
\]

38. A 1.0 M solution of \(\text{CoSO}_4\) is electrolyzed using inert electrodes.

A. Write the anode and cathode half-reactions that would occur. (2 marks)

B. What is observed when bromthymol blue is added to the solution around the anode? (1 mark)

39. An impure sample of \(\text{CaC}_2\text{O}_4\) weighing 0.803 g is titrated with 15.70 mL of 0.101 M \(\text{KMnO}_4\). The net reaction is...

\[
2\text{MnO}_4^- + 5\text{C}_2\text{O}_4^{2-} + 16\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 10\text{CO}_2 + 8\text{H}_2\text{O}
\]

What is the percent by mass of the \(\text{CaC}_2\text{O}_4\) in the original sample? (4 marks)
40. A sample of Zn corrodes in moist air…

A. Write the reduction half-reaction. (1 mark)

<table>
<thead>
<tr>
<th>A. Write the reduction half-reaction. (1 mark)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

B. What metal could be attached to the sample to prevent the corrosion of the zinc? Explain. (2 marks)

<table>
<thead>
<tr>
<th>B. What metal could be attached to the sample to prevent the corrosion of the zinc? Explain. (2 marks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

41. A 2.000 g strip of cobalt metal is suspended in 100.0 mL of 0.20 M AgNO₃ and a reaction occurs. When the reaction is complete, there is an excess of cobalt. The excess cobalt is removed from the solution, washed and dried and its mass is found to be 1.411 g.

A. Using the table of Standard Reduction Potentials of Half-cells, write the balanced net ionic equation for the redox reaction. (2 marks)

<table>
<thead>
<tr>
<th>A. Using the table of Standard Reduction Potentials of Half-cells, write the balanced net ionic equation for the redox reaction. (2 marks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

B. Using the experimental data, calculate the moles of Co and Ag⁺ reacting, and show how these values support the balanced equation. (2 marks)

<table>
<thead>
<tr>
<th>B. Using the experimental data, calculate the moles of Co and Ag⁺ reacting, and show how these values support the balanced equation. (2 marks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

42. Draw a diagram of a standard electrochemical cell which could make use of the reaction \( \text{Zn(s)} + \text{Cl}_2\,(g) \rightarrow \text{Zn}^{2+}\,(aq) + 2\text{Cl}^-\,(aq) \). Identify all of the chemical species in the cell. (3 marks)

<table>
<thead>
<tr>
<th>42. Draw a diagram of a standard electrochemical cell which could make use of the reaction ( \text{Zn(s)} + \text{Cl}_2,(g) \rightarrow \text{Zn}^{2+},(aq) + 2\text{Cl}^-,(aq) ). Identify all of the chemical species in the cell. (3 marks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
43. In an unusual compound, IPO₄, iodine exists as Iodine (III). The compound decomposes as follows…

$$\text{IPO}_4 \rightarrow I_2 + \text{IO}_3^- + \text{PO}_4^{3-}, \text{acidic}$$

Balance this redox equation in acidic solution. (4 marks)

44. In separate electrolysis experiments, 1.0 M NaCl, 1.0 M KNO₃, 1.0 M LiSO₄ and 1.0 M Cs₃PO₄ all produce the same gas at their cathodes. Write the equation for the formation of this gas and explain why this same reaction occurs in all four cases. (3 marks)

45. Balance the following in acidic solution…

$$\text{FeS} + \text{NO}_2^- \rightarrow \text{NO} + \text{SO}_4^{2-} + \text{Fe}^{3+} \text{ (acidic)}$$ (4 marks)

46. The electrolysis of copper (II) sulphate solution using copper electrodes is used in the refining of copper. Write the anode and cathode half-reactions and describe what would be observed at each electrode as the cell operates. (3 marks)

Anode Half-Reaction:

Cathode Half-Reaction:

Observations:

Anode:

Cathode:
47. Balance the following redox equation in an acidic solution. (4 marks)

\[ \text{H}_2\text{O}_2 + \text{SCN}^- \rightarrow \text{NH}_4^+ + \text{H}_2\text{O} + \text{HCO}_3^- + \text{HSO}_4^- \], (acidic)

48. During the electrolysis of an ionic solution it was observed that gas bubbles formed on the anode, and a solid formed on the cathode. On the diagram below, provide substances for the two parts indicated and the anode half reaction. (3 marks)

49. Balance the following redox reaction in a basic solution. (4 marks)

\[ \text{O}_2 + \text{Co(NH}_3\text{)}_6^{2+} \rightarrow \text{Co(NH}_3\text{)}_6^{3+} \], (basic)
50. A solution of \( \text{MnSO}_4 \) is electrolyzed using inert electrodes. Write the anode and cathode half reactions and describe any observations at the cathode.

<table>
<thead>
<tr>
<th>Anode Half Reaction (1 mark)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathode Half Reaction (1 mark)</td>
</tr>
<tr>
<td>Cathode Observations (1 mark)</td>
</tr>
</tbody>
</table>

51. Balance the following redox equation in an acidic solution. (4 marks)

\[
\text{TeO}_4^- + \text{In} \rightarrow \text{In}_2\text{O}_3 + \text{Te}
\]
<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B</td>
<td>21</td>
<td>B</td>
<td>41</td>
<td>D</td>
<td>61</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>22</td>
<td>B</td>
<td>42</td>
<td>D</td>
<td>62</td>
</tr>
<tr>
<td>3</td>
<td>D</td>
<td>23</td>
<td>D</td>
<td>43</td>
<td>D</td>
<td>63</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>24</td>
<td>B</td>
<td>44</td>
<td>B</td>
<td>64</td>
</tr>
<tr>
<td>5</td>
<td>B</td>
<td>25</td>
<td>C</td>
<td>45</td>
<td>A</td>
<td>65</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>26</td>
<td>C</td>
<td>46</td>
<td>C</td>
<td>66</td>
</tr>
<tr>
<td>7</td>
<td>D</td>
<td>27</td>
<td>C</td>
<td>47</td>
<td>A</td>
<td>67</td>
</tr>
<tr>
<td>8</td>
<td>B</td>
<td>28</td>
<td>A</td>
<td>48</td>
<td>C</td>
<td>68</td>
</tr>
<tr>
<td>9</td>
<td>B</td>
<td>29</td>
<td>C</td>
<td>49</td>
<td>D</td>
<td>69</td>
</tr>
<tr>
<td>10</td>
<td>B</td>
<td>30</td>
<td>A</td>
<td>50</td>
<td>B</td>
<td>70</td>
</tr>
<tr>
<td>11</td>
<td>C</td>
<td>31</td>
<td>D</td>
<td>51</td>
<td>D</td>
<td>71</td>
</tr>
<tr>
<td>12</td>
<td>C</td>
<td>32</td>
<td>B</td>
<td>52</td>
<td>B</td>
<td>72</td>
</tr>
<tr>
<td>13</td>
<td>D</td>
<td>33</td>
<td>D</td>
<td>53</td>
<td>A</td>
<td>73</td>
</tr>
<tr>
<td>14</td>
<td>B</td>
<td>34</td>
<td>D</td>
<td>54</td>
<td>A</td>
<td>74</td>
</tr>
<tr>
<td>15</td>
<td>C</td>
<td>35</td>
<td>A</td>
<td>55</td>
<td>B</td>
<td>75</td>
</tr>
<tr>
<td>16</td>
<td>A</td>
<td>36</td>
<td>D</td>
<td>56</td>
<td>A</td>
<td>76</td>
</tr>
<tr>
<td>17</td>
<td>C</td>
<td>37</td>
<td>C</td>
<td>57</td>
<td>C</td>
<td>77</td>
</tr>
<tr>
<td>18</td>
<td>C</td>
<td>38</td>
<td>D</td>
<td>58</td>
<td>A</td>
<td>78</td>
</tr>
<tr>
<td>19</td>
<td>D</td>
<td>39</td>
<td>D</td>
<td>59</td>
<td>A</td>
<td>79</td>
</tr>
<tr>
<td>20</td>
<td>D</td>
<td>40</td>
<td>B</td>
<td>60</td>
<td>D</td>
<td>80</td>
</tr>
</tbody>
</table>
Written Questions Answer Key

1.

Solution:

For Example:

\[ 2\text{H}_2(\text{g}) + 4\text{OH}^-_{(aq)} \rightarrow 4\text{H}_2\text{O}(\ell) + 4\text{e}^- \]

\( \leftarrow 1 \) mark

Solution:

For Example:

The \( \text{NO}_2 \) produced by internal combustion cars is a source of acid rain. The \( \text{H}_2\text{O} \) from a fuel-cell car is non-polluting.

\( \leftarrow 1 \) mark

2.

Solution:

For Example:

\[ \text{anode} \quad \text{Salt Bridge} \quad \text{cathode} \]

\( \frac{1}{2} \) mark for suitable cathode — \( \text{Au} \) for example.

\( \frac{1}{2} \) mark for suitable ions — \( \text{Au}^{3+} \) and \( \text{Cu}^{2+} \) for example.

1 mark for diagram being an electrochemical cell, not an electrolytic cell.
3.

Solution:

\[
\text{Mg(OH)}_2(s) + 2\text{HCl}_{(aq)} \rightarrow \text{MgCl}_2_{(aq)} + 2\text{H}_2\text{O}_{(l)}
\]

\[\text{↔ 1 mark}\]

Solution:

Anode: \(2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-\)  \[\text{↔ 1 mark}\]

Cathode: \(\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg}\)  \[\text{↔ 1 mark}\]

Solution:

*For Example:*

Water is a stronger oxidizing agent than \(\text{Mg}^{2+}\).  \[\text{↔ 1 mark}\]

4.

Solution:

\[
\text{mol Cr}_2\text{O}_7^{2-} = (0.0170 \text{ mol/L Cr}_2\text{O}_7^{2-})(0.02143 \text{ L}) = 3.643 \times 10^{-4} \text{ mol Cr}_2\text{O}_7^{2-} \]

\[\text{↔ 1 mark}\]

\[
\text{mol Sn}^{2+} = 3.643 \times 10^{-4} \text{ mol Cr}_2\text{O}_7^{2-} \left(\frac{3 \text{ mol Sn}^{2+}}{1 \text{ mol Cr}_2\text{O}_7^{2-}}\right) = 1.093 \times 10^{-3} \text{ mol Sn}^{2+} \]

\[\text{↔ 1 mark}\]

\[
\text{mol Sn} = \text{mol Sn}^{2+} = 1.093 \times 10^{-3} \text{ mol Sn}
\]

\[
\text{g Sn} = 1.093 \times 10^{-3} \text{ mol Sn} \left(\frac{118.7 \text{ g Sn}}{1 \text{ mol Sn}}\right) = 1.297 \times 10^{-1} \text{ g Sn}
\]

\[\text{↔ 1 mark}\]

\[
\% \text{ Sn} = \frac{1.297 \times 10^{-1} \text{ g Sn}}{0.750 \text{ g Sn ore}} \times 100\% = 17.3\%
\]

\[\text{↔ 1 mark}\]
5.

Solution:

*For Example:*

\[
\begin{align*}
2 \times (2\text{H}_2\text{O} + 3\text{e}^- + \text{MnO}_4^- & \rightarrow \text{MnO}_2 + 4\text{OH}^-) \\
3 \times (2\text{OH}^- + \text{SO}_3^{2-} & \rightarrow \text{SO}_4^{2-} + 2\text{e}^- + \text{H}_2\text{O}) \\
\text{H}_2\text{O} + 2\text{MnO}_4^- + 3\text{SO}_3^{2-} & \rightarrow 3\text{SO}_4^{2-} + 2\text{MnO}_2 + 2\text{OH}^- \\
\end{align*}
\]

\[
\begin{align*}
\text{OR} \\
3 \times (\text{H}_2\text{O} + \text{SO}_3^{2-} & \rightarrow \text{SO}_4^{2-} + 2\text{H}^+ + 2\text{e}^-) \\
2 \times (3\text{e}^- + 4\text{H}^+ + \text{MnO}_4^- & \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O}) \\
2\text{H}^+ + 3\text{SO}_3^{2-} + 2\text{MnO}_4^- & \rightarrow 3\text{SO}_4^{2-} + 2\text{MnO}_2 + \text{H}_2\text{O} \\
\text{H}_2\text{O} + 3\text{SO}_3^{2-} + 2\text{MnO}_4^- & \rightarrow 3\text{SO}_4^{2-} + 2\text{MnO}_2 + 2\text{OH}^- \\
\end{align*}
\]

6.

Solution:

*For Example:*

![Diagram](image)

2 marks for set up.
1 mark for suitable cathode.
1 mark for suitable electrolytes.
7.

Solution:

*For Example:*

\[
2 \times (3e^- + 4H^+ + MnO_4^- \rightarrow MnO_2 + 2H_2O) \quad \text{2 marks (1 mark for each half cell)}
\]

\[
3 \times \left(2H_2O + C_2O_4^{2-} \rightarrow 2CO_3^{2-} + 4H^+ + 2e^- \right) \quad \text{1 mark for multiplication}
\]

\[
2H_2O + 2MnO_4^- + 3C_2O_4^{2-} \rightarrow 2MnO_2 + 6CO_3^{2-} + 4H^+ \quad \text{1 mark for addition}
\]

\[
4OH^- + 2MnO_4^- + 3C_2O_4^{2-} \rightarrow 2MnO_2 + 6CO_3^{2-} + 2H_2O \quad \text{1 mark for basic}
\]

8.

Solution:

*For Example:*

\begin{center}
\begin{tikzpicture}
\node (source) at (0,0) {DC Power Source};
\node (cathode) at (2,0) {Cathode};
\node (anode) at (-2,0) {Anode};
\node (chloride) at (0,-2) {Cl^-};
\node (potassium) at (0,-4) {K^+};
\draw[thick,->] (source) -- (cathode);
\draw[thick,->] (source) -- (anode);
\end{tikzpicture}
\end{center}

\[
1 \text{ mark for single container}
\]

\[
1 \text{ mark for power supply}
\]

\[
1 \text{ mark for electrodes}
\]

Solution:

*For Example:*

An oxidizing agent is a species which causes another to lose electrons.  \( \rightarrow 1 \text{ mark} \)
9.

Solution:

For Example:

\[
\begin{align*}
1 \times (\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- & \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}) \\
5 \times (\text{Fe}^{2+} & \rightarrow \text{Fe}^{3+} + \text{e}^-)
\end{align*}
\]

\[
\frac{\text{MnO}_4^- + 8\text{H}^+ + 5\text{Fe}^{2+} \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O} + 5\text{Fe}^{3+}}{\text{--- 3 marks} \text{---}}
\]

10.

Solution:

For Example:

Species that more readily loses electrons. \hspace{1cm} \text{--- 2 marks} \hspace{1cm}

11.

Solution:

For Example:

1 mark for inert electrodes
1 mark for electrolytic cell
1 mark for suitable electrolyte

1.0 M $\text{H}_2\text{SO}_4$
Solution:

\[ \text{O}_2 \quad (\text{1 mark}) \]

12.

Solution:

For Example:

\[
\frac{2 \times \left( \text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O} \right)}{5 \times \left( \text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}^+ + 2\text{e}^- \right)}
\]

\[ 2\text{MnO}_4^- + 6\text{H}^+ + 5\text{H}_2\text{O}_2 \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{O}_2 \]

\( \text{4 marks} \)

Solution:

For Example:

\[
\text{mol } \text{H}_2\text{O}_2 = 5.684 \times 10^{-4} \text{ mol MnO}_4^- \times \frac{5 \text{ mol } \text{H}_2\text{O}_2}{2 \text{ mol MnO}_4^-} = 1.421 \times 10^{-3} \text{ mol}
\]

\[
[\text{H}_2\text{O}_2] = \frac{1.421 \times 10^{-3} \text{ mol}}{0.00500 \text{ L}} = 0.284 \text{ M}
\]

\( \text{2 marks} \)

13.

Solution:

For Example:

The process of protecting a metal from oxidation by placing it in electrical contact with another metal that is a stronger reducing agent. The protected metal becomes a cathode and the other becomes a sacrificial anode.

\( \text{2 marks} \)

Solution:

For Example:

Coating with paint or grease. \( \text{1 mark} \)

Keep in totally dry atmosphere. \( \text{1 mark} \)
Solution:

*For Example:*

Substance: $\text{K}_2\text{SO}_4$ (1 mark)

Explanation: It is the only one of the three substances that will neither oxidize (1 mark) nor reduce (1 mark) before water does.

Solution:

*For Example:*

$$\text{H}_2\text{O} \rightarrow \frac{1}{2}\text{O}_2 + 2\text{H}^+ + 2\text{e}^-$$  \hspace{1cm} \leftarrow 1 \text{ mark}

Solution:

*For Example:*

A copper anode would oxidize.  \hspace{1cm} \leftarrow 1 \text{ mark}

15.

Solution:

*For Example:*

$$2 \times (2\text{e}^- + 2\text{H}^+ + \text{Ag}_2\text{O} \rightarrow 2\text{Ag} + \text{H}_2\text{O})$$  \hspace{1cm} \leftarrow 2 \text{ marks (1 mark for each half-reaction)}

$$\frac{1 \times (3\text{H}_2\text{O} + \text{Si} \rightarrow \text{SiO}_3^{2-} + 6\text{H}^+ + 4\text{e}^-)}{2\text{Ag}_2\text{O} + \text{H}_2\text{O} + \text{Si} \rightarrow 4\text{Ag} + \text{SiO}_3^{2-} + 2\text{H}^+}$$  \hspace{1cm} \leftarrow 1 \text{ mark for balancing electrons}

$$\leftarrow 1 \text{ mark for addition}

16.

Solution:

*For Example:*

$\text{H}_2\text{O}$ is more easily reduced than $\text{Na}^+$.  \hspace{1cm} \leftarrow 2 \text{ marks}
17.

Solution:

*For Example:*

Zn is oxidized. ← 1 mark
It is an even stronger reducing agent than the copper. ← 1 mark

Solution:

\[
\text{Cu}^{2+} + 2e^{-} \rightarrow \text{Cu}
\] ← 1 mark

18.

Solution:

*For Example:*

\[
3 \times (\text{Ag} \rightarrow \text{Ag}^{+} + 3e^{-})
\]
3e\(^-\) + 4H\(^+\) + NO\(_3^-\) \rightarrow NO + 2H\(_2\)O ← 2 marks (1 mark for each half-reaction)
3Ag + NO\(_3^-\) + 4H\(^+\) \rightarrow NO + 2H\(_2\)O + 3Ag\(^+\) ← 1 mark for balancing electrons
← 1 mark for addition

19.

Solution:

*For Example:*

![Diagram showing a battery with anode and cathode labeled with 1.0 M Pb(NO\(_3\))\(_2\) on the cathode side and 1 mark for addition.]}
20.

Solution:

For Example:

Copper reacts in HNO$_3$(aq). $\quad \leftarrow \frac{1}{2} \text{ mark}$

21.

Solution:

For Example:

$E^\circ$ is +0.62 volts $\quad \leftarrow 1\frac{1}{2} \text{ marks}$

22.

Solution:

For Example:

\[
6e^- + 6H^+ + ClO_3^- \rightarrow Cl^- + 3H_2O \\
3 \times (2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^-) \\
6H^+ + ClO_3^- + 6S_2O_3^{2-} \rightarrow Cl^- + 3H_2O + 3S_4O_6^{2-}
\]

(Deduct $\frac{1}{2} \text{ mark for incorrect significant figures.}$)

Any two of the following for 1 mark each:

- redox reaction
- spontaneous
- $+E^\circ$ value
- exothermic $\quad \leftarrow 2 \text{ marks}$
Solution:

*For Example:*

- Coating with paint or oil prevents contact between iron and oxygen. \[
\text{\{1 1/2 marks}\}
\]

- Attaching a more readily oxidized metal such as zinc—cathodic protection—turns the iron into a cathode, preventing oxidation. \[
\text{\{1 1/2 marks\}}
\]

24.

Solution:

*For Example:*

\[
\begin{align*}
(5\text{H}_2\text{O} + 2\text{Sb} \rightarrow \text{Sb}_2\text{O}_5 + 10\text{H}^+ + 10\text{e}^-) \times 3 \\
(3\text{e}^- + 4\text{H}^+ + \text{NO}_3^- \rightarrow \text{NO} + 2\text{H}_2\text{O}) \times 10 \\
15\text{H}_2\text{O} + 6\text{Sb} + 40\text{H}^+ + 10\text{NO}_3^- \rightarrow 3\text{Sb}_2\text{O}_5 + 30\text{H}^+ + 10\text{NO} + 20\text{H}_2\text{O} \\
10\text{H}^+ + 6\text{Sb} + 10\text{NO}_3^- \rightarrow 3\text{Sb}_2\text{O}_5 + 10\text{NO} + 5\text{H}_2\text{O}
\end{align*}
\]

2 marks (1 mark for each half-reaction)

1 mark for electron balance

1 mark for overall reaction

25.

Solution:

*For Example:*

Anode half-reaction: \(\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+} + 2\text{e}^-\)

Anode observations: 
Electrode is eaten away and solution turns blue. \[
\text{\{2 marks\}}
\]

Cathode half-reaction: \(2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2(\text{g})\)

Cathode observations: 
Bubbles form, but no change to electrode. \[
\text{\{2 marks\}}
\]
26.

Solution:

*For Example:*

<table>
<thead>
<tr>
<th>Oxidizing Agents</th>
<th>Reducing Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Ce}^{4+} + e^{-} \rightleftharpoons \text{Ce}^{3+}$</td>
<td></td>
</tr>
<tr>
<td>$\text{Pd}^{2+} + 2e^{-} \rightleftharpoons \text{Pd}$</td>
<td></td>
</tr>
<tr>
<td>$\text{Cd}^{2+} + 2e^{-} \rightleftharpoons \text{Cd}$</td>
<td></td>
</tr>
<tr>
<td>$\text{In}^{3+} + e^{-} \rightleftharpoons \text{In}^{2+}$</td>
<td></td>
</tr>
</tbody>
</table>

$\leftarrow 3$ marks

27.

Solution:

*For Example:*

\[
\frac{(6e^{-} + 14\text{H}^{+} + \text{Cr}_2\text{O}_7^{2-} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}) \times 1}{(\text{C}_7\text{O}_4^{2-} \rightarrow 2\text{CO}_2 + 2e^{-}) \times 3} \]

\[
14\text{H}^{+} + \text{Cr}_2\text{O}_7^{2-} + 3\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 6\text{CO}_2
\]

$\leftarrow 3$ marks
Solution:

For Example:

\[
\text{Sn}^{2+} + \text{Cu}_{(s)} \rightarrow \text{Cu}^{2+} + \text{Sn}_{(s)}
\]

\(\leftarrow 2 \text{ marks}\)

Solution:

For Example:

\[
0.48 \text{ V}
\]

\(\leftarrow 1 \text{ mark}\)

29.

Solution:

For Example:

\[
\frac{(8\text{H}_2\text{S} \rightarrow \text{S}_8 + 16\text{H}^+ + 16\text{e}^-) \times 3}
{(3\text{e}^- + 8\text{H}^+ + \text{CrO}_4^{2-} \rightarrow \text{Cr}^{3+} + 4\text{H}_2\text{O}) \times 16}
\]

\[
\frac{24\text{H}_2\text{S} + 1\text{28H}^+ + 16\text{CrO}_4^{2-} \rightarrow 3\text{S}_8 + 1\text{48H}^+ + 16\text{Cr}^{3+} + 64\text{H}_2\text{O}}
\]

\[
24\text{H}_2\text{S} + 80\text{H}^+ + 16\text{CrO}_4^{2-} \rightarrow 3\text{S}_8 + 16\text{Cr}^{3+} + 64\text{H}_2\text{O}
\]

\(\leftarrow 2 \text{ marks (1 mark for each half-reaction)}\)

\(1 \text{ mark for the correct electron ratio}\)

\(1 \text{ mark for the final balanced equation}\)
30.

Solution:

*For Example:*

\[
\text{Ag}^+ + e^- \rightarrow \text{Ag} \quad \leftarrow 1 \text{ mark}
\]

\[
\text{Fe}^{3+} + e^- \rightarrow \text{Fe}^{2+} \quad \leftarrow 1 \text{ mark}
\]

31.

Solution:

*For Example:*

Prediction: The iron is oxidized. \(\leftarrow 1 \text{ mark}\)

32.

Solution:

*For Example:*

Prediction: Nothing happens to the Fe. \(\leftarrow 1 \text{ mark}\)

Explanation: Zn is oxidized and protects the Fe.

\[
\begin{align*}
\text{OR} \\
\text{The Fe is cathodically protected by the Zn.}
\end{align*}
\]

\(\leftarrow 1 \text{ mark}\)

Formula equation:

\[
\text{Cu}(s) + 2\text{AgNO}_3(aq) \rightarrow \text{Cu(NO}_3)_2(aq) + 2\text{Ag}(s)
\]

\(\leftarrow 3 \text{ marks}\)

Net ionic equation:

\[
\text{Cu}(s) + 2\text{Ag}^+(aq) \rightarrow \text{Cu}^{2+} + 2\text{Ag}(s)
\]
Solution:

*For Example:*

If you did not turn on the power supply before immersing the electrodes in the solution, the Cu$^{2+}$ would react spontaneously with the zinc to be plated, oxidizing the zinc.

34.

Solution:

Cathode: Ag

*For Example:*

Anode: $\text{H}_2\text{O} \rightarrow 2\text{H}^+ + \frac{1}{2}\text{O}_2 + 2e^-$

Cathode: $2\text{H}_2\text{O} + 2e^- \rightarrow \text{H}_2 + 2\text{OH}^-$
35.

Solution:

*For Example:*

\[
\begin{align*}
(5e^- + 8H^+ + MnO_4^- & \rightarrow Mn^{2+} + 4H_2O) \times 4 \\
(5H_2O + As_2O_3 & \rightarrow 2AsO_4^{3-} + 10H^+ + 4e^-) \times 5 \\
20e^- + 32H^+ + 4MnO_4^- + 25H_2O + 5As_2O_3 & \rightarrow 4Mn^{2+} + 16H_2O + 10AsO_4^{3-} + 50H^+ + 20e^-
\end{align*}
\]

\[4MnO_4^- + 9H_2O + 5As_2O_3 \rightarrow 4Mn^{2+} + 10AsO_4^{3-} + 18H^+\]

\[\rightarrow 4 \text{ marks}\]

36.

Solution:

*For Example:*

---

[Diagram showing a cell with DC power source, Au (Anode), Iron Ring (Cathode), Au(NO$_3$)$_3$(aq)]

\[\rightarrow 3 \text{ marks}\]
37.

Solution:

For Example:

\[
\begin{align*}
(6e^- + 6H^+ + ClO_3^- & \rightarrow Cl^- + 3H_2O) \times 7 \\
(6H_2O + N_3H_4 & \rightarrow 2NO_3^- + 16H^+ + 14e^-) \times 3
\end{align*}
\]

\[
\begin{align*}
42e^- + 42H^+ + 7ClO_3^- + 18H_2O + 3N_3H_4 & \rightarrow 7Cl^- + 21H_2O + 6NO_3^- + 48H^+ + 42e^- \\
7ClO_3^- + 3N_3H_4 & \rightarrow 7Cl^- + 3H_2O + 6NO_3^- + 6H^+ \\
6OH^- & \rightarrow 6OH^{-}
\end{align*}
\]

\[
\begin{align*}
7ClO_3^- + 6OH^- + 3N_3H_4 & \rightarrow 7Cl^- + 9H_2O + 6NO_3^- \\
\end{align*}
\]

\[\left\{ \begin{array}{l}
\text{4 marks,}
\end{array} \right. \]

38.

Solution:

For Example:

- Anode: \( H_2O \rightarrow 2H^+ + \frac{1}{2}O_2(s) + 2e^- \) \[1\] mark

- Cathode: \( Co^{2+} + 2e^- \rightarrow Co(s) \) \[1\] mark

Solution:

For Example:

Bromthymol blue will turn yellow. \[1\] mark
39.

Solution:

*For Example:*

Moles of $\text{MnO}_4^-$ = $0.01570 \text{L} \times 0.101 \text{mol/L} = 1.5857 \times 10^{-3} \text{ mol}$

Moles of $\text{C}_2\text{O}_4^{2-} = 1.5857 \times 10^{-3} \text{ mol MnO}_4^- \times \frac{5 \text{ mol C}_2\text{O}_4^{2-}}{2 \text{ mol MnO}_4^-} = 3.9643 \times 10^{-3} \text{ mol}$

Moles $\text{CaC}_2\text{O}_4 = \text{Moles C}_2\text{O}_4^{2-}$

Mass of $\text{CaC}_2\text{O}_4 = 3.9643 \times 10^{-3} \text{ mol} \times \frac{128.1 \text{ g}}{1 \text{ mol}} = 5.0782 \times 10^{-1} \text{ g CaC}_2\text{O}_4$

$\% \text{ CaC}_2\text{O}_4 = \frac{0.50782 \text{ g}}{0.803 \text{ g}} \times 100\% = 63.2\%$

(Deduct $\frac{1}{2}$ mark for incorrect significant figures.)

40.

Solution:

*For Example:*

$$\frac{1}{2}\text{O}_2(g) + 2\text{H}^+(10^{-7} \text{M}) + 2\text{e}^- \rightarrow \text{H}_2\text{O}$$  

Solution:

*For Example:*

**Metal:** Magnesium (Mg)

**Explanation:** The magnesium is more easily oxidized than the zinc.  

$\rightarrow 2\text{ marks}$
Solution:

For Example:

\[
\text{Co} \rightleftharpoons \text{Co}^{2+} + 2e^- \\
2\left(\text{Ag}^+ + e^- \rightleftharpoons \text{Ag}\right) \\
\text{Co} + 2\text{Ag}^+ \rightarrow \text{Co}^{2+} + 2\text{Ag}
\] ← 2 marks

Solution:

For Example:

\[
\text{Mass of cobalt used} = 2.000\text{g} - 1.411\text{g} = 0.589\text{g} \\
\text{Moles of Co used} = 0.589\text{g} \times \frac{1\text{mol}}{58.9\text{g}} = 0.010\text{ moles} \\
\text{Moles of AgNO}_3\text{ used} = 0.20\text{ mol/L} \times 0.10\text{L} = 0.020\text{ moles} \\
\text{Mole ratio} = 1:2, \text{ as in the balanced equation}
\] ← 2 marks
42.

Solution:

**For Example:**

![Diagram of a galvanic cell with electrodes and solutions.

43.

Solution:

**For Example:**

\[
\begin{align*}
\left(6e^- + 2\text{PO}_4^{3-} \rightarrow \text{I}_2 + 2\text{PO}_4^{5-}\right) \times 1 \\
\left(3\text{H}_2\text{O} + \text{PO}_4^{3-} \rightarrow \text{IO}_3^- + \text{PO}_4^{5-} + 6\text{H}^+ + 2e^-\right) \times 3 \\
\frac{5\text{PO}_4 + 9\text{H}_2\text{O} \rightarrow \text{I}_2 + 3\text{IO}_3^- + 5\text{PO}_4^{5-} + 18\text{H}^+}{\text{}}
\end{align*}
\]

\[\text{← 4 marks}\]

44.

Solution:

**For Example:**

Equation:

\[2\text{H}_2\text{O} + 2e^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-\]

\[\text{← 2 marks}\]

Explanation:

Water is more easily reduced than any of the metal ions.

\[\text{← 1 mark}\]
45. Solution:

*For Example:*

\[
\begin{align*}
(4\text{H}_2\text{O} + \text{FeS} & \rightarrow \text{SO}_4^{2-} + \text{Fe}^{3+} + 8\text{H}^+ + 9e^-) \times 1 \\
(\text{e}^- + 2\text{H}^+ + \text{NO}_2^- & \rightarrow \text{NO} + \text{H}_2\text{O}) \times 9 \\
\text{4H}_2\text{O} + \text{FeS} + 18\text{H}^+ + 9\text{NO}_2^- & \rightarrow 9\text{NO} + 9\text{H}_2\text{O} + \text{SO}_4^{2-} + \text{Fe}^{3+} + 8\text{H}^+ \\
\text{FeS} + 10\text{H}^+ + 9\text{NO}_2^- & \rightarrow 9\text{NO} + 5\text{H}_2\text{O} + \text{SO}_4^{2-} + \text{Fe}^{3+}
\end{align*}
\]

\[\left\{ \text{3 marks} \right\}

\[\text{1 mark}\]

46. Solution:

*For Example:*

Anode half-reaction: \(\text{Cu} \rightarrow \text{Cu}^{2+} + 2e^-\)

\[\left\{ \text{1 mark} \right\}\]

Cathode half-reaction: \(\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}\)

\[\left\{ \text{1 mark} \right\}\]

Observations: The anode would decrease in size and the cathode would increase in size.

\[\left\{ \text{1 mark} \right\}\]

47. Solution:

*For Example:*

\[
\begin{align*}
(2e^- + 2\text{H}^+ + \text{H}_2\text{O}_2 & \rightarrow 2\text{H}_2\text{O}) \times 4 \\
(7\text{H}_2\text{O} + \text{SCN}^- & \rightarrow \text{NH}_4^+ + \text{HCO}_3^- + \text{HSO}_4^- + 8\text{H}^+ + 8e^-) \times 1 \\
8\text{H}^+ + 4\text{H}_2\text{O}_2 + 7\text{H}_2\text{O} + \text{SCN}^- & \rightarrow 8\text{H}_2\text{O} + \text{NH}_4^+ + \text{HCO}_3^- + \text{HSO}_4^- + 8\text{H}^+ \\
4\text{H}_2\text{O}_2 + \text{SCN}^- & \rightarrow \text{H}_2\text{O} + \text{NH}_4^+ + \text{HCO}_3^- + \text{HSO}_4^-
\end{align*}
\]

\[\left\{ \text{4 marks} \right\}\]

(Note: 1 mark if a student only uses guess and check, or inspection.)
Solution:

For Example:

\[
\begin{align*}
\text{Anode half-reaction:} & \\
\quad & H_2O \rightarrow \frac{1}{2} O_2 + 2H^+ + 2e^- \\
\quad & 1 \text{ mark}
\end{align*}
\]

49.

Solution:

For Example:

\[
\begin{align*}
\text{Anode half-reaction:} & \\
\quad & (4e^- + 4H^+ + O_2 \rightarrow 2H_2O) \times 1 \\
\quad & (\text{Co(NH}_3\text{)}^2^+ \rightarrow \text{Co(NH}_3\text{)}^{3+} + e^-) \times 4 \\
\quad & 4e^- + 4H^+ + O_2 + 4\text{Co(NH}_3\text{)}^2^+ \rightarrow 2H_2O + 4\text{Co(NH}_3\text{)}^{3+} + 4e^- \\
\quad & 4OH^- \quad 4OH^- \\
\quad & 2H_2O + O_2 + 4\text{Co(NH}_3\text{)}^2^+ \rightarrow 4\text{Co(NH}_3\text{)}^{3+} + 4OH^- \\
\quad & 1 \text{ mark}
\end{align*}
\]
Solution:

*For Example:*

Anode half-reaction: \( \text{H}_2\text{O} \rightarrow \frac{1}{2}\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \) \hspace{1cm} \leftarrow 1 \text{ mark}

Cathode half-reaction: \( 2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^- \) \hspace{1cm} \leftarrow 1 \text{ mark}

Cathode observation: gas bubbles form \hspace{1cm} \leftarrow 1 \text{ mark}

(Note: no mark for a conclusion such as “hydrogen is produced.” Must be an observation.)

51.

Solution:

*For Example:*

\[
\begin{align*}
(7\text{e}^- + 8\text{H}^+ + \text{TeO}_4^- & \rightarrow \text{Tc} + 4\text{H}_2\text{O}) \times 6 \\
(3\text{H}_2\text{O} + 2\text{In} & \rightarrow \text{In}_2\text{O}_3 + 6\text{H}^+ + 6\text{e}^-) \times 7 \\
48\text{H}^+ + 6\text{TeO}_4^- + 21\text{H}_2\text{O} + 14\text{In} & \rightarrow 6\text{Tc} + 24\text{H}_2\text{O} + 7\text{In}_2\text{O}_3 + 42\text{H}^+ \\
6\text{H}^+ + 6\text{TeO}_4^- + 14\text{In} & \rightarrow 6\text{Tc} + 3\text{H}_2\text{O} + 7\text{In}_2\text{O}_3
\end{align*}
\]

\hspace{1cm} \leftarrow 4 \text{ marks}