# Balancing Redox Reactions

Half-reactions, acidic & basic solutions • 15 parts • 150 questions • Answers at the back

Name: _____ Class: _____ Date: _____

## The half-reaction method (acidic solution)

| | | |
|---|---|---|
| 1 | **Split** | Write separate oxidation and reduction half-reactions. |
| 2 | **Main atoms** | Balance every element except O and H. |
| 3 | **Oxygen** | Add $H_2O$ to the side that needs O. |
| 4 | **Hydrogen** | Add $H^+$ to the side that needs H. |
| 5 | **Charge** | Add electrons ($e^-$) to the more positive side. |
| 6 | **Equalise** | Multiply each half so electrons lost = electrons gained. |
| 7 | **Add & cancel** | Add the halves; cancel electrons and anything on both sides. |
| 8 | **Basic solution** | Add $OH^-$ to both sides to turn every $H^+$ into $H_2O$, then cancel water. |
| 9 | **Check** | Atoms AND total charge must be equal on both sides. |

**Worked example (acidic):** $Fe^{2+} + MnO_4^- \rightarrow Fe^{3+} + Mn^{2+}$
Oxidation: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (× 5)
Reduction: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (× 1)
Overall: **$5\ Fe^{2+} + MnO_4^- + 8\ H^+ \rightarrow 5\ Fe^{3+} + Mn^{2+} + 4\ H_2O$** (5 electrons transferred; charge +17 = +17)

## What's inside

| Part | Questions | Level | Score |
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| Part 1: Simple Half-Reactions | 1 – 10 | Easy | _____ / 10 |
| Part 2: Half-Reactions in Acidic Solution | 11 – 20 | Medium | _____ / 10 |
| Part 3: Half-Reactions in Basic Solution | 21 – 30 | Medium | _____ / 10 |
| Part 4: Splitting into Half-Reactions | 31 – 40 | Medium | _____ / 10 |
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| Part 7: More Practice in Acidic Solution | 61 – 70 | Hard | _____ / 10 |
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| Part 10: Disproportionation Reactions | 91 – 100 | Hard | _____ / 10 |
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| **Total** | | | **_____ / 150** |

## Part 1: Simple Half-Reactions

Score: _____ / 10

*Balance the atoms, then add electrons to balance the charge. State whether each is oxidation or reduction.*

**1.** $Zn \rightarrow Zn^{2+}$

Answer: _____

**2.** $Cl_2 \rightarrow Cl^-$

Answer: _____

**3.** $Fe^{3+} \rightarrow Fe^{2+}$

Answer: _____

**4.** $Na \rightarrow Na^+$

Answer: _____

**5.** $O_2 \rightarrow O^{2-}$

Answer: _____

**6.** $Al \rightarrow Al^{3+}$

Answer: _____

**7.** $Br^- \rightarrow Br_2$

Answer: _____

**8.** $Cu^{2+} \rightarrow Cu$

Answer: _____

**9.** $Sn^{2+} \rightarrow Sn^{4+}$

Answer: _____

**10.** $I^- \rightarrow I_2$

Answer: _____

## Part 2: Half-Reactions in Acidic Solution

Score: _____ / 10

*Balance each half-reaction in ACIDIC solution: balance the main atom, then O with $H_2O$, then H with $H^+$, then charge with $e^-$.*

**11.** $MnO_4^- \rightarrow Mn^{2+}$

Answer: _____

**12.** $Cr_2O_7^{2-} \rightarrow Cr^{3+}$

Answer: _____

**13.** $NO_3^- \rightarrow NO$

Answer: _____

**14.** $NO_3^- \rightarrow NO_2$

Answer: _____

**15.** $SO_4^{2-} \rightarrow SO_2$

Answer: _____

**16.** $H_2O_2 \rightarrow H_2O$

Answer: _____

**17.** $H_2O_2 \rightarrow O_2$

Answer: _____

**18.** $H_2C_2O_4 \rightarrow CO_2$

Answer: _____

**19.** $IO_3^- \rightarrow I_2$

Answer: _____

**20.** $PbO_2 \rightarrow Pb^{2+}$

Answer: _____

## Part 3: Half-Reactions in Basic Solution

Score: _____ / 10

*Balance in BASIC solution: balance as in acid, then add $OH^-$ to both sides to cancel every $H^+$.*

**21.** $MnO_4^- \rightarrow MnO_2$

Answer: _____

**22.** $ClO^- \rightarrow Cl^-$

Answer: _____

**23.** $Cr(OH)_3 \rightarrow CrO_4^{2-}$

Answer: _____

**24.** $Al \rightarrow Al(OH)_4^-$

Answer: _____

**25.** $NO_3^- \rightarrow NH_3$

Answer: _____

**26.** $SO_3^{2-} \rightarrow SO_4^{2-}$

Answer: _____

**27.** $O_2 \rightarrow OH^-$

Answer: _____

**28.** $ClO_3^- \rightarrow Cl^-$

Answer: _____

**29.** $H_2O_2 \rightarrow O_2$

Answer: _____

**30.** $Ag_2O \rightarrow Ag$

Answer: _____

## Part 4: Splitting into Half-Reactions

Score: _____ / 10

*Write the balanced oxidation and reduction half-reactions for each unbalanced equation. Do not combine them yet.*

**31.** $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

Answer: _____

**32.** $Fe^{2+} + Cl_2 \rightarrow Fe^{3+} + Cl^-$

Answer: _____

**33.** $Mg + Ag^{+} \rightarrow Mg^{2+} + Ag$

Answer: _____

**34.** $Fe^{2+} + MnO_4^- \rightarrow Fe^{3+} + Mn^{2+}$ (acidic solution)

Answer: _____

**35.** $I^- + Cr_2O_7^{2-} \rightarrow I_2 + Cr^{3+}$ (acidic solution)

Answer: _____

**36.** $Cu + NO_3^- \rightarrow Cu^{2+} + NO$ (acidic solution)

Answer: _____

**37.** $I^- + H_2O_2 \rightarrow I_2 + H_2O$ (acidic solution)

Answer: _____

**38.** $Sn^{2+} + Fe^{3+} \rightarrow Sn^{4+} + Fe^{2+}$

Answer: _____

**39.** $Br^- + Cl_2 \rightarrow Br_2 + Cl^-$

Answer: _____

**40.** $SO_2 + MnO_4^- \rightarrow SO_4^{2-} + Mn^{2+}$ (acidic solution)

Answer: _____

## Part 5: Combining Half-Reactions (No H or O)

Score: _____ / 10

*Balance each half-reaction, multiply so the electrons are equal, then add and cancel the electrons.*

**41.** $Al + Cu^{2+} \rightarrow Al^{3+} + Cu$

Answer: _____

**42.** $Zn + Ag^{+} \rightarrow Zn^{2+} + Ag$

Answer: _____

**43.** $Fe^{2+} + Cl_2 \rightarrow Fe^{3+} + Cl^{-}$

Answer: _____

**44.** $Mg + Fe^{3+} \rightarrow Mg^{2+} + Fe$

Answer: _____

**45.** $Sn^{2+} + Fe^{3+} \rightarrow Sn^{4+} + Fe^{2+}$

Answer: _____

**46.** $I^{-} + Br_2 \rightarrow I_2 + Br^{-}$

Answer: _____

**47.** $Al + Ag^{+} \rightarrow Al^{3+} + Ag$

Answer: _____

**48.** $Cu + Ag^{+} \rightarrow Cu^{2+} + Ag$

Answer: _____

**49.** $Na + Cl_2 \rightarrow Na^{+} + Cl^{-}$

Answer: _____

**50.** $Cr + Ni^{2+} \rightarrow Cr^{3+} + Ni$

Answer: _____

## Part 6: Balancing in Acidic Solution

Score: _____ / 10

*Balance each equation in ACIDIC solution using the half-reaction method. Add $H_2O$ and $H^+$ where needed.*

**51.** $Fe^{2+} + MnO_4^- \rightarrow Fe^{3+} + Mn^{2+}$

Answer: _____

**52.** $I^- + Cr_2O_7^{2-} \rightarrow I_2 + Cr^{3+}$

Answer: _____

**53.** $Cu + NO_3^- \rightarrow Cu^{2+} + NO$

Answer: _____

**54.** $H_2C_2O_4 + MnO_4^- \rightarrow CO_2 + Mn^{2+}$

Answer: _____

**55.** $SO_2 + MnO_4^- \rightarrow SO_4^{2-} + Mn^{2+}$

Answer: _____

**56.** $Fe^{2+} + Cr_2O_7^{2-} \rightarrow Fe^{3+} + Cr^{3+}$

Answer: _____

**57.** $H_2O_2 + MnO_4^- \rightarrow O_2 + Mn^{2+}$

Answer: _____

**58.** $Sn^{2+} + Cr_2O_7^{2-} \rightarrow Sn^{4+} + Cr^{3+}$

Answer: _____

**59.** $Zn + NO_3^- \rightarrow Zn^{2+} + NH_4^+$

Answer: _____

**60.** $Cl^- + MnO_2 \rightarrow Cl_2 + Mn^{2+}$

Answer: _____

## Part 7: More Practice in Acidic Solution

Score: _____ / 10

*Balance in ACIDIC solution.*

**61.** $Ag + NO_3^- \rightarrow Ag^+ + NO$

Answer: _____

**62.** $Cu + NO_3^- \rightarrow Cu^{2+} + NO_2$

Answer: _____

**63.** $I^- + IO_3^- \rightarrow I_2$

Answer: _____

**64.** $H_2S + NO_3^- \rightarrow S + NO$

Answer: _____

**65.** $As_2O_3 + NO_3^- \rightarrow H_3AsO_4 + NO$

Answer: _____

**66.** $Mn^{2+} + BiO_3^- \rightarrow MnO_4^- + Bi^{3+}$

Answer: _____

**67.** $HNO_2 + MnO_4^- \rightarrow NO_3^- + Mn^{2+}$

Answer: _____

**68.** $I_2 + NO_3^- \rightarrow IO_3^- + NO_2$

Answer: _____

**69.** $Cu + SO_4^{2-} \rightarrow Cu^{2+} + SO_2$

Answer: _____

**70.** $Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + H_2O$

Answer: _____

## Part 8: Balancing in Basic Solution

Score: _____ / 10

*Balance in BASIC solution. Balance as if acidic, then add $OH^-$ to both sides to remove $H^+$.*

**71.** $CN^- + MnO_4^- \rightarrow CNO^- + MnO_2$

Answer: _____

**72.** $Cr(OH)_3 + ClO^- \rightarrow CrO_4^{2-} + Cl^-$

Answer: _____

**73.** $Al + NO_3^- \rightarrow Al(OH)_4^- + NH_3$

Answer: _____

**74.** $SO_3^{2-} + MnO_4^- \rightarrow SO_4^{2-} + MnO_2$

Answer: _____

**75.** $I^- + MnO_4^- \rightarrow IO_3^- + MnO_2$

Answer: _____

**76.** $Zn + NO_3^- \rightarrow Zn(OH)_4^{2-} + NH_3$

Answer: _____

**77.** $Cr(OH)_3 + H_2O_2 \rightarrow CrO_4^{2-} + OH^-$

Answer: _____

**78.** $CrO_2^- + ClO^- \rightarrow CrO_4^{2-} + Cl^-$

Answer: _____

**79.** $N_2H_4 + Ag_2O \rightarrow N_2 + Ag$

Answer: _____

**80.** $Fe(OH)_2 + H_2O_2 \rightarrow Fe(OH)_3 + OH^-$

Answer: _____

## Part 9: More Practice in Basic Solution

Score: _____ / 10

*Balance in BASIC solution.*

**81.** $C_2O_4^{2-} + MnO_4^- \rightarrow CO_3^{2-} + MnO_2$

Answer: _____

**82.** $S^{2-} + ClO_3^- \rightarrow S + Cl^-$

Answer: _____

**83.** $Sn(OH)_4^{2-} + Bi(OH)_3 \rightarrow Sn(OH)_6^{2-} + Bi$

Answer: _____

**84.** $NH_3 + ClO^- \rightarrow N_2 + Cl^-$

Answer: _____

**85.** $Mn(OH)_2 + H_2O_2 \rightarrow MnO_2 + OH^-$

Answer: _____

**86.** $SO_3^{2-} + CrO_4^{2-} \rightarrow SO_4^{2-} + Cr(OH)_3$

Answer: _____

**87.** $Al + H_2O \rightarrow Al(OH)_4^- + H_2$

Answer: _____

**88.** $Fe(OH)_2 + O_2 \rightarrow Fe(OH)_3 + OH^-$

Answer: _____

**89.** $N_2H_4 + Cu(OH)_2 \rightarrow N_2 + Cu$

Answer: _____

**90.** $Br^- + MnO_4^- \rightarrow BrO_3^- + MnO_2$

Answer: _____

## Part 10: Disproportionation Reactions

Score: _____ / 10

*One substance is both oxidised and reduced. Write two half-reactions from the same starting substance, then combine.*

**91.** $Cl_2 \rightarrow Cl^- + ClO_3^-$ (basic solution)

Answer: _____

**92.** $Cl_2 \rightarrow Cl^- + ClO^-$ (basic solution)

Answer: _____

**93.** $H_2O_2 \rightarrow H_2O + O_2$

Answer: _____

**94.** $NO_2 \rightarrow NO_3^- + NO$ (acidic solution)

Answer: _____

**95.** $Cu^+ \rightarrow Cu + Cu^{2+}$

Answer: _____

**96.** $ClO^- \rightarrow Cl^- + ClO_3^-$

Answer: _____

**97.** $P_4 \rightarrow PH_3 + H_2PO_2^-$ (basic solution)

Answer: _____

**98.** $Br_2 \rightarrow Br^- + BrO_3^-$ (basic solution)

Answer: _____

**99.** $HNO_2 \rightarrow NO_3^- + NO$ (acidic solution)

Answer: _____

**100.** $MnO_4^{2-} \rightarrow MnO_4^- + MnO_2$ (basic solution)

Answer: _____

## Part 11: Full Molecular Equations

Score: _____ / 10

*Use the oxidation-number method: find the change for each element, make electrons lost = electrons gained, then balance the rest by inspection.*

**101.** $Cu + HNO_3 \rightarrow Cu(NO_3)_2 + NO + H_2O$

Answer: _____

**102.** $Cu + HNO_3 \rightarrow Cu(NO_3)_2 + NO_2 + H_2O$

Answer: _____

**103.** $KMnO_4 + HCl \rightarrow KCl + MnCl_2 + Cl_2 + H_2O$

Answer: _____

**104.** $K_2Cr_2O_7 + HCl \rightarrow KCl + CrCl_3 + Cl_2 + H_2O$

Answer: _____

**105.** $MnO_2 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O$

Answer: _____

**106.** $Zn + HNO_3 \rightarrow Zn(NO_3)_2 + NH_4NO_3 + H_2O$

Answer: _____

**107.** $C + HNO_3 \rightarrow CO_2 + NO_2 + H_2O$

Answer: _____

**108.** $Cu + H_2SO_4 \rightarrow CuSO_4 + SO_2 + H_2O$

Answer: _____

**109.** $KMnO_4 + FeSO_4 + H_2SO_4 \rightarrow K_2SO_4 + MnSO_4 + Fe_2(SO_4)_3 + H_2O$

Answer: _____

**110.** $P + HNO_3 \rightarrow H_3PO_4 + NO_2 + H_2O$

Answer: _____

## Part 12: Counting Electrons Transferred

Score: _____ / 10

*Balance each equation (acidic solution where H/O are needed) and state the total number of electrons transferred.*

**111.** $Zn + Ag^{+} \rightarrow Zn^{2+} + Ag$

Answer: _____

**112.** $Al + Cu^{2+} \rightarrow Al^{3+} + Cu$

Answer: _____

**113.** $Fe^{2+} + MnO_4^{-} \rightarrow Fe^{3+} + Mn^{2+}$

Answer: _____

**114.** $I^{-} + Cr_2O_7^{2-} \rightarrow I_2 + Cr^{3+}$

Answer: _____

**115.** $Cu + NO_3^{-} \rightarrow Cu^{2+} + NO$

Answer: _____

**116.** $H_2C_2O_4 + MnO_4^{-} \rightarrow CO_2 + Mn^{2+}$

Answer: _____

**117.** $Sn^{2+} + MnO_4^{-} \rightarrow Sn^{4+} + Mn^{2+}$

Answer: _____

**118.** $Fe^{2+} + O_2 \rightarrow Fe^{3+} + H_2O$

Answer: _____

**119.** $Mg + NO_3^{-} \rightarrow Mg^{2+} + N_2$

Answer: _____

**120.** $H_2S + Cr_2O_7^{2-} \rightarrow S + Cr^{3+}$

Answer: _____

## Part 13: Balance and Name the Agents

Score: _____ / 10

*Balance in acidic solution, then name the oxidising agent and the reducing agent.*

**121.** $Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + H_2O$

Answer: _____

**122.** $I^- + H_2O_2 \rightarrow I_2 + H_2O$

Answer: _____

**123.** $Br^- + MnO_4^- \rightarrow Br_2 + Mn^{2+}$

Answer: _____

**124.** $SO_2 + Cr_2O_7^{2-} \rightarrow SO_4^{2-} + Cr^{3+}$

Answer: _____

**125.** $Sn^{2+} + IO_3^- \rightarrow Sn^{4+} + I^-$

Answer: _____

**126.** $Cu + Ag^+ \rightarrow Cu^{2+} + Ag$

Answer: _____

**127.** $Mn^{2+} + PbO_2 \rightarrow MnO_4^- + Pb^{2+}$

Answer: _____

**128.** $H_2S + Fe^{3+} \rightarrow S + Fe^{2+}$

Answer: _____

**129.** $NO_2^- + MnO_4^- \rightarrow NO_3^- + Mn^{2+}$

Answer: _____

**130.** $Cl^- + PbO_2 \rightarrow Cl_2 + Pb^{2+}$

Answer: _____

## Part 14: Organic Redox Reactions

Score: _____ / 10

*Balance in ACIDIC solution. Organic molecules are oxidised; dichromate or permanganate is reduced.*

**131.** $C_2H_5OH + Cr_2O_7^{2-} \rightarrow CH_3COOH + Cr^{3+}$

Answer: _____

**132.** $CH_3OH + MnO_4^- \rightarrow HCOOH + Mn^{2+}$

Answer: _____

**133.** $HCHO + MnO_4^- \rightarrow CO_2 + Mn^{2+}$

Answer: _____

**134.** $CH_3CHO + Cr_2O_7^{2-} \rightarrow CH_3COOH + Cr^{3+}$

Answer: _____

**135.** $C_2H_5OH + Cr_2O_7^{2-} \rightarrow CH_3CHO + Cr^{3+}$

Answer: _____

**136.** $H_2C_2O_4 + Cr_2O_7^{2-} \rightarrow CO_2 + Cr^{3+}$

Answer: _____

**137.** $C_6H_{12}O_6 + MnO_4^- \rightarrow CO_2 + Mn^{2+}$

Answer: _____

**138.** $CH_3OH + Cr_2O_7^{2-} \rightarrow CO_2 + Cr^{3+}$

Answer: _____

**139.** $C_2H_5OH + MnO_4^- \rightarrow CO_2 + Mn^{2+}$

Answer: _____

**140.** $HCOOH + MnO_4^- \rightarrow CO_2 + Mn^{2+}$

Answer: _____

## Part 15: Challenge Equations

Score: _____ / 10

*More than one element may change oxidation number. Find the total change for each substance before balancing.*

**141.** $As_2S_3 + NO_3^- \rightarrow H_3AsO_4 + SO_4^{2-} + NO$ (acidic solution)

Answer: _____

**142.** $CrI_3 + Cl_2 \rightarrow CrO_4^{2-} + IO_4^- + Cl^-$ (basic solution)

Answer: _____

**143.** $Cu_2S + NO_3^- \rightarrow Cu^{2+} + SO_4^{2-} + NO$ (acidic solution)

Answer: _____

**144.** $P_4 + NO_3^- \rightarrow H_3PO_4 + NO$ (acidic solution)

Answer: _____

**145.** $Zn + NO_3^- \rightarrow Zn^{2+} + NH_4^+$ (acidic solution)

Answer: _____

**146.** $Al + NO_3^- \rightarrow Al(OH)_4^- + NH_3$ (basic solution)

Answer: _____

**147.** $FeS_2 + O_2 \rightarrow Fe_2O_3 + SO_2$

Answer: _____

**148.** $MnO_4^- + C_2O_4^{2-} \rightarrow MnO_2 + CO_3^{2-}$ (basic solution)

Answer: _____

**149.** $Fe(CN)_6^{4-} + MnO_4^- \rightarrow Fe^{3+} + CO_2 + NO_3^- + Mn^{2+}$ (acidic solution)

Answer: _____

**150.** $CuFeS_2 + O_2 \rightarrow Cu + FeO + SO_2$

Answer: _____

# Answer Key

Balanced equations in green. Half-reactions and multipliers are shown for the half-reaction method.

## Part 1: Simple Half-Reactions

1. $Zn \rightarrow Zn^{2+} + 2\ e^-$ (oxidation)
2. $Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$ (reduction)
3. $Fe^{3+} + e^- \rightarrow Fe^{2+}$ (reduction)
4. $Na \rightarrow Na^+ + e^-$ (oxidation)
5. $O_2 + 4\ e^- \rightarrow 2\ O^{2-}$ (reduction)
6. $Al \rightarrow Al^{3+} + 3\ e^-$ (oxidation)
7. $2\ Br^- \rightarrow Br_2 + 2\ e^-$ (oxidation)
8. $Cu^{2+} + 2\ e^- \rightarrow Cu$ (reduction)
9. $Sn^{2+} \rightarrow Sn^{4+} + 2\ e^-$ (oxidation)
10. $2\ I^- \rightarrow I_2 + 2\ e^-$ (oxidation)

## Part 2: Half-Reactions in Acidic Solution

11. $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (reduction)
12. $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (reduction)
13. $NO_3^- + 4\ H^+ + 3\ e^- \rightarrow NO + 2\ H_2O$ (reduction)
14. $NO_3^- + 2\ H^+ + e^- \rightarrow NO_2 + H_2O$ (reduction)
15. $SO_4^{2-} + 4\ H^+ + 2\ e^- \rightarrow SO_2 + 2\ H_2O$ (reduction)
16. $H_2O_2 + 2\ H^+ + 2\ e^- \rightarrow 2\ H_2O + 2\ H_2O$ (reduction)
17. $H_2O_2 \rightarrow O_2 + 2\ H^+ + 2\ e^-$ (oxidation)
18. $H_2C_2O_4 \rightarrow 2\ CO_2 + 2\ H^+ + 2\ e^-$ (oxidation)
19. $2\ IO_3^- + 12\ H^+ + 10\ e^- \rightarrow I_2 + 6\ H_2O$ (reduction)
20. $PbO_2 + 4\ H^+ + 2\ e^- \rightarrow Pb^{2+} + 2\ H_2O$ (reduction)

## Part 3: Half-Reactions in Basic Solution

21. $MnO_4^- + 2\ H_2O + 3\ e^- \rightarrow MnO_2 + 4\ OH^-$ (reduction)
22. $ClO^- + H_2O + 2\ e^- \rightarrow Cl^- + 2\ OH^-$ (reduction)
23. $Cr(OH)_3 + 5\ OH^- \rightarrow CrO_4^{2-} + 4\ H_2O + 3\ e^-$ (oxidation)
24. $Al + 4\ OH^- \rightarrow Al(OH)_4^- + 3\ e^-$ (oxidation)
25. $NO_3^- + 6\ H_2O + 8\ e^- \rightarrow NH_3 + 9\ OH^-$ (reduction)
26. $SO_3^{2-} + 2\ OH^- \rightarrow SO_4^{2-} + H_2O + 2\ e^-$ (oxidation)
27. $O_2 + 2\ H_2O + 4\ e^- \rightarrow 4\ OH^- + 4\ OH^-$ (reduction)
28. $ClO_3^- + 3\ H_2O + 6\ e^- \rightarrow Cl^- + 6\ OH^-$ (reduction)
29. $2\ H_2O_2 \rightarrow O_2 + 2\ H_2O$ (reduction)
30. $Ag_2O + H_2O + 2\ e^- \rightarrow 2\ Ag + 2\ OH^-$ (reduction)

## Part 4: Splitting into Half-Reactions

**31.** Oxidation: **$Zn \rightarrow Zn^{2+} + 2\ e^-$**; reduction: **$Cu^{2+} + 2\ e^- \rightarrow Cu$**

**32.** Oxidation: **$Fe^{2+} \rightarrow Fe^{3+} + e^-$**; reduction: **$Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$**

**33.** Oxidation: **$Mg \rightarrow Mg^{2+} + 2\ e^-$**; reduction: **$Ag^+ + e^- \rightarrow Ag$**

**34.** Oxidation: **$Fe^{2+} \rightarrow Fe^{3+} + e^-$**; reduction: **$MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$**

**35.** Oxidation: **$2\ I^- \rightarrow I_2 + 2\ e^-$**; reduction: **$Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$**

**36.** Oxidation: **$Cu \rightarrow Cu^{2+} + 2\ e^-$**; reduction: **$NO_3^- + 4\ H^+ + 3\ e^- \rightarrow NO + 2\ H_2O$**

**37.** Oxidation: **$2\ I^- \rightarrow I_2 + 2\ e^-$**; reduction: **$H_2O_2 + 2\ H^+ + 2\ e^- \rightarrow 2\ H_2O + 2\ H_2O$**

**38.** Oxidation: **$Sn^{2+} \rightarrow Sn^{4+} + 2\ e^-$**; reduction: **$Fe^{3+} + e^- \rightarrow Fe^{2+}$**

**39.** Oxidation: **$2\ Br^- \rightarrow Br_2 + 2\ e^-$**; reduction: **$Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$**

**40.** Oxidation: **$SO_2 + 2\ H_2O \rightarrow SO_4^{2-} + 4\ H^+ + 2\ e^-$**; reduction: **$MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$**

## Part 5: Combining Half-Reactions (No H or O)

**41.** Ox: $Al \rightarrow Al^{3+} + 3\ e^-$ (×2); Red: $Cu^{2+} + 2\ e^- \rightarrow Cu$ (×3) → **$2\ Al + 3\ Cu^{2+} \rightarrow 2\ Al^{3+} + 3\ Cu$**

**42.** Ox: $Zn \rightarrow Zn^{2+} + 2\ e^-$ (×1); Red: $Ag^+ + e^- \rightarrow Ag$ (×2) → **$Zn + 2\ Ag^+ \rightarrow Zn^{2+} + 2\ Ag$**

**43.** Ox: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (×2); Red: $Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$ (×1) → **$2\ Fe^{2+} + Cl_2 \rightarrow 2\ Fe^{3+} + 2\ Cl^-$**

**44.** Ox: $Mg \rightarrow Mg^{2+} + 2\ e^-$ (×3); Red: $Fe^{3+} + 3\ e^- \rightarrow Fe$ (×2) → **$3\ Mg + 2\ Fe^{3+} \rightarrow 3\ Mg^{2+} + 2\ Fe$**

**45.** Ox: $Sn^{2+} \rightarrow Sn^{4+} + 2\ e^-$ (×1); Red: $Fe^{3+} + e^- \rightarrow Fe^{2+}$ (×2) → **$Sn^{2+} + 2\ Fe^{3+} \rightarrow Sn^{4+} + 2\ Fe^{2+}$**

**46.** Ox: $2\ I^- \rightarrow I_2 + 2\ e^-$ (×1); Red: $Br_2 + 2\ e^- \rightarrow 2\ Br^-$ (×1) → **$2\ I^- + Br_2 \rightarrow I_2 + 2\ Br^-$**

**47.** Ox: $Al \rightarrow Al^{3+} + 3\ e^-$ (×1); Red: $Ag^+ + e^- \rightarrow Ag$ (×3) → **$Al + 3\ Ag^+ \rightarrow Al^{3+} + 3\ Ag$**

**48.** Ox: $Cu \rightarrow Cu^{2+} + 2\ e^-$ (×1); Red: $Ag^+ + e^- \rightarrow Ag$ (×2) → **$Cu + 2\ Ag^+ \rightarrow Cu^{2+} + 2\ Ag$**

**49.** Ox: $Na \rightarrow Na^+ + e^-$ (×2); Red: $Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$ (×1) → **$2\ Na + Cl_2 \rightarrow 2\ Na^+ + 2\ Cl^-$**

**50.** Ox: $Cr \rightarrow Cr^{3+} + 3\ e^-$ (×2); Red: $Ni^{2+} + 2\ e^- \rightarrow Ni$ (×3) → **$2\ Cr + 3\ Ni^{2+} \rightarrow 2\ Cr^{3+} + 3\ Ni$**

## Part 6: Balancing in Acidic Solution

**51.** Ox: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×1) → **$5\ Fe^{2+} + MnO_4^- + 8\ H^+ \rightarrow 5\ Fe^{3+} + Mn^{2+} + 4\ H_2O$**

**52.** Ox: $2\ I^- \rightarrow I_2 + 2\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$6\ I^- + Cr_2O_7^{2-} + 14\ H^+ \rightarrow 3\ I_2 + 2\ Cr^{3+} + 7\ H_2O$**

**53.** Ox: $Cu \rightarrow Cu^{2+} + 2\ e^-$ (×3); Red: $NO_3^- + 4\ H^+ + 3\ e^- \rightarrow NO + 2\ H_2O$ (×2) → **$3\ Cu + 2\ NO_3^- + 8\ H^+ \rightarrow 3\ Cu^{2+} + 2\ NO + 4\ H_2O$**

**54.** Ox: $H_2C_2O_4 \rightarrow 2\ CO_2 + 2\ H^+ + 2\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×2) → **$5\ H_2C_2O_4 + 2\ MnO_4^- + 6\ H^+ \rightarrow 10\ CO_2 + 2\ Mn^{2+} + 8\ H_2O$**

**55.** Ox: $SO_2 + 2\ H_2O \rightarrow SO_4^{2-} + 4\ H^+ + 2\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×2) → **$5\ SO_2 + 2\ MnO_4^- + 2\ H_2O \rightarrow 5\ SO_4^{2-} + 2\ Mn^{2+} + 4\ H^+$**

**56.** Ox: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (×6); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$6\ Fe^{2+} + Cr_2O_7^{2-} + 14\ H^+ \rightarrow 6\ Fe^{3+} + 2\ Cr^{3+} + 7\ H_2O$**

**57.** Ox: $H_2O_2 \rightarrow O_2 + 2\ H^+ + 2\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×2) → **$5\ H_2O_2 + 2\ MnO_4^- + 6\ H^+ \rightarrow 5\ O_2 + 2\ Mn^{2+} + 8\ H_2O$**

**58.** Ox: $Sn^{2+} \rightarrow Sn^{4+} + 2\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$3\ Sn^{2+} + Cr_2O_7^{2-} + 14\ H^+ \rightarrow 3\ Sn^{4+} + 2\ Cr^{3+} + 7\ H_2O$**

**59.** Ox: $Zn \rightarrow Zn^{2+} + 2\ e^-$ (×4); Red: $NO_3^- + 10\ H^+ + 8\ e^- \rightarrow NH_4^+ + 3\ H_2O$ (×1) → **$4\ Zn + NO_3^- + 10\ H^+ \rightarrow 4\ Zn^{2+} + NH_4^+ + 3\ H_2O$**

**60.** Ox: $2\ Cl^- \rightarrow Cl_2 + 2\ e^-$ (×1); Red: $MnO_2 + 4\ H^+ + 2\ e^- \rightarrow Mn^{2+} + 2\ H_2O$ (×1) → **$2\ Cl^- + MnO_2 + 4\ H^+ \rightarrow Cl_2 + Mn^{2+} + 2\ H_2O$**

## Part 7: More Practice in Acidic Solution

**61.** Ox: $Ag \rightarrow Ag^+ + e^-$ (×3); Red: $NO_3^- + 4\,H^+ + 3\,e^- \rightarrow NO + 2\,H_2O$ (×1) → **$3\,Ag + NO_3^- + 4\,H^+ \rightarrow 3\,Ag^+ + NO + 2\,H_2O$**

**62.** Ox: $Cu \rightarrow Cu^{2+} + 2\,e^-$ (×1); Red: $NO_3^- + 2\,H^+ + e^- \rightarrow NO_2 + H_2O$ (×2) → **$Cu + 2\,NO_3^- + 4\,H^+ \rightarrow Cu^{2+} + 2\,NO_2 + 2\,H_2O$**

**63.** Ox: $2\,I^- \rightarrow I_2 + 2\,e^-$ (×5); Red: $2\,IO_3^- + 12\,H^+ + 10\,e^- \rightarrow I_2 + 6\,H_2O$ (×1) → **$5\,I^- + IO_3^- + 6\,H^+ \rightarrow 3\,I_2 + 3\,H_2O$**

**64.** Ox: $H_2S \rightarrow S + 2\,H^+ + 2\,e^-$ (×3); Red: $NO_3^- + 4\,H^+ + 3\,e^- \rightarrow NO + 2\,H_2O$ (×2) → **$3\,H_2S + 2\,NO_3^- + 2\,H^+ \rightarrow 3\,S + 2\,NO + 4\,H_2O$**

**65.** Ox: $As_2O_3 + 5\,H_2O \rightarrow 2\,H_3AsO_4 + 4\,H^+ + 4\,e^-$ (×3); Red: $NO_3^- + 4\,H^+ + 3\,e^- \rightarrow NO + 2\,H_2O$ (×4) → **$3\,As_2O_3 + 4\,NO_3^- + 7\,H_2O + 4\,H^+ \rightarrow 6\,H_3AsO_4 + 4\,NO$**

**66.** Ox: $Mn^{2+} + 4\,H_2O \rightarrow MnO_4^- + 8\,H^+ + 5\,e^-$ (×2); Red: $BiO_3^- + 6\,H^+ + 2\,e^- \rightarrow Bi^{3+} + 3\,H_2O$ (×5) → **$2\,Mn^{2+} + 5\,BiO_3^- + 14\,H^+ \rightarrow 2\,MnO_4^- + 5\,Bi^{3+} + 7\,H_2O$**

**67.** Ox: $HNO_2 + H_2O \rightarrow NO_3^- + 3\,H^+ + 2\,e^-$ (×5); Red: $MnO_4^- + 8\,H^+ + 5\,e^- \rightarrow Mn^{2+} + 4\,H_2O$ (×2) → **$5\,HNO_2 + 2\,MnO_4^- + H^+ \rightarrow 5\,NO_3^- + 2\,Mn^{2+} + 3\,H_2O$**

**68.** Ox: $I_2 + 6\,H_2O \rightarrow 2\,IO_3^- + 12\,H^+ + 10\,e^-$ (×1); Red: $NO_3^- + 2\,H^+ + e^- \rightarrow NO_2 + H_2O$ (×10) → **$I_2 + 10\,NO_3^- + 8\,H^+ \rightarrow 2\,IO_3^- + 10\,NO_2 + 4\,H_2O$**

**69.** Ox: $Cu \rightarrow Cu^{2+} + 2\,e^-$ (×1); Red: $SO_4^{2-} + 4\,H^+ + 2\,e^- \rightarrow SO_2 + 2\,H_2O$ (×1) → **$Cu + SO_4^{2-} + 4\,H^+ \rightarrow Cu^{2+} + SO_2 + 2\,H_2O$**

**70.** Ox: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (×2); Red: $H_2O_2 + 2\,H^+ + 2\,e^- \rightarrow 2\,H_2O + 2\,H_2O$ (×1) → **$2\,Fe^{2+} + H_2O_2 + 2\,H^+ \rightarrow 2\,Fe^{3+} + 2\,H_2O + 2\,H_2O$**

## Part 8: Balancing in Basic Solution

**71.** Ox: $CN^- + 2\,OH^- \rightarrow CNO^- + H_2O + 2\,e^-$ (×3); Red: $MnO_4^- + 2\,H_2O + 3\,e^- \rightarrow MnO_2 + 4\,OH^-$ (×2) → **$3\,CN^- + 2\,MnO_4^- + H_2O \rightarrow 3\,CNO^- + 2\,MnO_2 + 2\,OH^-$**

**72.** Ox: $Cr(OH)_3 + 5\,OH^- \rightarrow CrO_4^{2-} + 4\,H_2O + 3\,e^-$ (×2); Red: $ClO^- + H_2O + 2\,e^- \rightarrow Cl^- + 2\,OH^-$ (×3) → **$2\,Cr(OH)_3 + 3\,ClO^- + 4\,OH^- \rightarrow 2\,CrO_4^{2-} + 3\,Cl^- + 5\,H_2O$**

**73.** Ox: $Al + 4\,OH^- \rightarrow Al(OH)_4^- + 3\,e^-$ (×8); Red: $NO_3^- + 6\,H_2O + 8\,e^- \rightarrow NH_3 + 9\,OH^-$ (×3) → **$8\,Al + 3\,NO_3^- + 18\,H_2O + 5\,OH^- \rightarrow 8\,Al(OH)_4^- + 3\,NH_3$**

**74.** Ox: $SO_3^{2-} + 2\,OH^- \rightarrow SO_4^{2-} + H_2O + 2\,e^-$ (×3); Red: $MnO_4^- + 2\,H_2O + 3\,e^- \rightarrow MnO_2 + 4\,OH^-$ (×2) → **$3\,SO_3^{2-} + 2\,MnO_4^- + H_2O \rightarrow 3\,SO_4^{2-} + 2\,MnO_2 + 2\,OH^-$**

**75.** Ox: $I^- + 6\,OH^- \rightarrow IO_3^- + 3\,H_2O + 6\,e^-$ (×1); Red: $MnO_4^- + 2\,H_2O + 3\,e^- \rightarrow MnO_2 + 4\,OH^-$ (×2) → **$I^- + 2\,MnO_4^- + H_2O \rightarrow IO_3^- + 2\,MnO_2 + 2\,OH^-$**

**76.** Ox: $Zn + 4\,OH^- \rightarrow Zn(OH)_4^{2-} + 2\,e^-$ (×4); Red: $NO_3^- + 6\,H_2O + 8\,e^- \rightarrow NH_3 + 9\,OH^-$ (×1) → **$4\,Zn + NO_3^- + 6\,H_2O + 7\,OH^- \rightarrow 4\,Zn(OH)_4^{2-} + NH_3$**

**77.** Ox: $Cr(OH)_3 + 5\,OH^- \rightarrow CrO_4^{2-} + 4\,H_2O + 3\,e^-$ (×2); Red: $H_2O_2 + 2\,e^- \rightarrow 2\,OH^- + 2\,OH^-$ (×3) → **$2\,Cr(OH)_3 + 3\,H_2O_2 + 4\,OH^- + 4\,OH^- \rightarrow 2\,CrO_4^{2-} + 8\,H_2O$**

**78.** Ox: $CrO_2^- + 4\,OH^- \rightarrow CrO_4^{2-} + 2\,H_2O + 3\,e^-$ (×2); Red: $ClO^- + H_2O + 2\,e^- \rightarrow Cl^- + 2\,OH^-$ (×3) → **$2\,CrO_2^- + 3\,ClO^- + 2\,OH^- \rightarrow 2\,CrO_4^{2-} + 3\,Cl^- + H_2O$**

**79.** Ox: $N_2H_4 + 4\,OH^- \rightarrow N_2 + 4\,H_2O + 4\,e^-$ (×1); Red: $Ag_2O + H_2O + 2\,e^- \rightarrow 2\,Ag + 2\,OH^-$ (×2) → **$N_2H_4 + 2\,Ag_2O \rightarrow N_2 + 4\,Ag + 2\,H_2O$**

**80.** Ox: $Fe(OH)_2 + OH^- \rightarrow Fe(OH)_3 + e^-$ (×2); Red: $H_2O_2 + 2\,e^- \rightarrow 2\,OH^- + 2\,OH^-$ (×1) → **$2\,Fe(OH)_2 + H_2O_2 \rightarrow 2\,Fe(OH)_3$**

## Part 9: More Practice in Basic Solution

**81.** Ox: $C_2O_4^{2-} + 4\ OH^- \rightarrow 2\ CO_3^{2-} + 2\ H_2O + 2\ e^-$ (×3); Red: $MnO_4^- + 2\ H_2O + 3\ e^- \rightarrow MnO_2 + 4\ OH^-$ (×2) → **$3\ C_2O_4^{2-} + 2\ MnO_4^- + 4\ OH^- \rightarrow 6\ CO_3^{2-} + 2\ MnO_2 + 2\ H_2O$**

**82.** Ox: $S^{2-} \rightarrow S + 2\ e^-$ (×3); Red: $ClO_3^- + 3\ H_2O + 6\ e^- \rightarrow Cl^- + 6\ OH^-$ (×1) → **$3\ S^{2-} + ClO_3^- + 3\ H_2O \rightarrow 3\ S + Cl^- + 6\ OH^-$**

**83.** Ox: $Sn(OH)_4^{2-} + 2\ OH^- \rightarrow Sn(OH)_6^{2-} + 2\ e^-$ (×3); Red: $Bi(OH)_3 + 3\ e^- \rightarrow Bi + 3\ OH^-$ (×2) → **$3\ Sn(OH)_4^{2-} + 2\ Bi(OH)_3 \rightarrow 3\ Sn(OH)_6^{2-} + 2\ Bi$**

**84.** Ox: $2\ NH_3 + 6\ OH^- \rightarrow N_2 + 6\ H_2O + 6\ e^-$ (×1); Red: $ClO^- + H_2O + 2\ e^- \rightarrow Cl^- + 2\ OH^-$ (×3) → **$2\ NH_3 + 3\ ClO^- \rightarrow N_2 + 3\ Cl^- + 3\ H_2O$**

**85.** Ox: $Mn(OH)_2 + 2\ OH^- \rightarrow MnO_2 + 2\ H_2O + 2\ e^-$ (×1); Red: $H_2O_2 + 2\ e^- \rightarrow 2\ OH^-$ + $2\ OH^-$ (×1) → **$Mn(OH)_2 + H_2O_2 \rightarrow MnO_2 + 2\ H_2O$**

**86.** Ox: $SO_3^{2-} + 2\ OH^- \rightarrow SO_4^{2-} + H_2O + 2\ e^-$ (×3); Red: $CrO_4^{2-} + 4\ H_2O + 3\ e^- \rightarrow Cr(OH)_3 + 5\ OH^-$ (×2) → **$3\ SO_3^{2-} + 2\ CrO_4^{2-} + 5\ H_2O \rightarrow 3\ SO_4^{2-} + 2\ Cr(OH)_3 + 4\ OH^-$**

**87.** Ox: $Al + 4\ OH^- \rightarrow Al(OH)_4^- + 3\ e^-$ (×2); Red: $2\ H_2O + 2\ H_2O + 2\ e^- \rightarrow H_2 + 2\ OH^-$ (×3) → **$2\ Al + 6\ H_2O + 6\ H_2O + 2\ OH^- \rightarrow 2\ Al(OH)_4^- + 3\ H_2$**

**88.** Ox: $Fe(OH)_2 + OH^- \rightarrow Fe(OH)_3 + e^-$ (×4); Red: $O_2 + 2\ H_2O + 4\ e^- \rightarrow 4\ OH^-$ + $4\ OH^-$ (×1) → **$4\ Fe(OH)_2 + O_2 + 2\ H_2O \rightarrow 4\ Fe(OH)_3$**

**89.** Ox: $N_2H_4 + 4\ OH^- \rightarrow N_2 + 4\ H_2O + 4\ e^-$ (×1); Red: $Cu(OH)_2 + 2\ e^- \rightarrow Cu + 2\ OH^-$ (×2) → **$N_2H_4 + 2\ Cu(OH)_2 \rightarrow N_2 + 2\ Cu + 4\ H_2O$**

**90.** Ox: $Br^- + 6\ OH^- \rightarrow BrO_3^- + 3\ H_2O + 6\ e^-$ (×1); Red: $MnO_4^- + 2\ H_2O + 3\ e^- \rightarrow MnO_2 + 4\ OH^-$ (×2) → **$Br^- + 2\ MnO_4^- + H_2O \rightarrow BrO_3^- + 2\ MnO_2 + 2\ OH^-$**

## Part 10: Disproportionation Reactions

**91.** **$3\ Cl_2 + 6\ OH^- \rightarrow 5\ Cl^- + ClO_3^- + 3\ H_2O$** (the same element is both oxidised and reduced)

**92.** **$Cl_2 + 2\ OH^- \rightarrow Cl^- + ClO^- + H_2O$** (the same element is both oxidised and reduced)

**93.** **$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$** (the same element is both oxidised and reduced)

**94.** **$3\ NO_2 + H_2O \rightarrow 2\ NO_3^- + NO + 2\ H^+$** (the same element is both oxidised and reduced)

**95.** **$2\ Cu^+ \rightarrow Cu + Cu^{2+}$** (the same element is both oxidised and reduced)

**96.** **$3\ ClO^- \rightarrow 2\ Cl^- + ClO_3^-$** (the same element is both oxidised and reduced)

**97.** **$P_4 + 3\ H_2O + 3\ OH^- \rightarrow PH_3 + 3\ H_2PO_2^-$** (the same element is both oxidised and reduced)

**98.** **$3\ Br_2 + 6\ OH^- \rightarrow 5\ Br^- + BrO_3^- + 3\ H_2O$** (the same element is both oxidised and reduced)

**99.** **$3\ HNO_2 \rightarrow NO_3^- + 2\ NO + H_2O + H^+$** (the same element is both oxidised and reduced)

**100.** **$3\ MnO_4^{2-} + 2\ H_2O \rightarrow 2\ MnO_4^- + MnO_2 + 4\ OH^-$** (the same element is both oxidised and reduced)

## Part 11: Full Molecular Equations

**101.** **$3\ Cu + 8\ HNO_3 \rightarrow 3\ Cu(NO_3)_2 + 2\ NO + 4\ H_2O$**

**102.** **$Cu + 4\ HNO_3 \rightarrow Cu(NO_3)_2 + 2\ NO_2 + 2\ H_2O$**

**103.** **$2\ KMnO_4 + 16\ HCl \rightarrow 2\ KCl + 2\ MnCl_2 + 5\ Cl_2 + 8\ H_2O$**

**104.** **$K_2Cr_2O_7 + 14\ HCl \rightarrow 2\ KCl + 2\ CrCl_3 + 3\ Cl_2 + 7\ H_2O$**

**105.** **$MnO_2 + 4\ HCl \rightarrow MnCl_2 + Cl_2 + 2\ H_2O$**

**106.** **$4\ Zn + 10\ HNO_3 \rightarrow 4\ Zn(NO_3)_2 + NH_4NO_3 + 3\ H_2O$**

**107.** **$C + 4\ HNO_3 \rightarrow CO_2 + 4\ NO_2 + 2\ H_2O$**

**108.** **$Cu + 2\ H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2\ H_2O$**

**109.** **$2\ KMnO_4 + 10\ FeSO_4 + 8\ H_2SO_4 \rightarrow K_2SO_4 + 2\ MnSO_4 + 5\ Fe_2(SO_4)_3 + 8\ H_2O$**

**110.** **$P + 5\ HNO_3 \rightarrow H_3PO_4 + 5\ NO_2 + H_2O$**

## Part 12: Counting Electrons Transferred

**111.** Ox: $Zn \rightarrow Zn^{2+} + 2\ e^-$ (×1); Red: $Ag^+ + e^- \rightarrow Ag$ (×2) → **$Zn + 2\ Ag^+ \rightarrow Zn^{2+} + 2\ Ag$; 2 electrons transferred**

**112.** Ox: $Al \rightarrow Al^{3+} + 3\ e^-$ (×2); Red: $Cu^{2+} + 2\ e^- \rightarrow Cu$ (×3) → **$2\ Al + 3\ Cu^{2+} \rightarrow 2\ Al^{3+} + 3\ Cu$; 6 electrons transferred**

**113.** Ox: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×1) → **$5\ Fe^{2+} + MnO_4^- + 8\ H^+ \rightarrow 5\ Fe^{3+} + Mn^{2+} + 4\ H_2O$; 5 electrons transferred**

**114.** Ox: $2\ I^- \rightarrow I_2 + 2\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$6\ I^- + Cr_2O_7^{2-} + 14\ H^+ \rightarrow 3\ I_2 + 2\ Cr^{3+} + 7\ H_2O$; 6 electrons transferred**

**115.** Ox: $Cu \rightarrow Cu^{2+} + 2\ e^-$ (×3); Red: $NO_3^- + 4\ H^+ + 3\ e^- \rightarrow NO + 2\ H_2O$ (×2) → **$3\ Cu + 2\ NO_3^- + 8\ H^+ \rightarrow 3\ Cu^{2+} + 2\ NO + 4\ H_2O$; 6 electrons transferred**

**116.** Ox: $H_2C_2O_4 \rightarrow 2\ CO_2 + 2\ H^+ + 2\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×2) → **$5\ H_2C_2O_4 + 2\ MnO_4^- + 6\ H^+ \rightarrow 10\ CO_2 + 2\ Mn^{2+} + 8\ H_2O$; 10 electrons transferred**

**117.** Ox: $Sn^{2+} \rightarrow Sn^{4+} + 2\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×2) → **$5\ Sn^{2+} + 2\ MnO_4^- + 16\ H^+ \rightarrow 5\ Sn^{4+} + 2\ Mn^{2+} + 8\ H_2O$; 10 electrons transferred**

**118.** Ox: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (×4); Red: $O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O + 2\ H_2O$ (×1) → **$4\ Fe^{2+} + O_2 + 4\ H^+ \rightarrow 4\ Fe^{3+} + 2\ H_2O + 2\ H_2O$; 4 electrons transferred**

**119.** Ox: $Mg \rightarrow Mg^{2+} + 2\ e^-$ (×5); Red: $2\ NO_3^- + 12\ H^+ + 10\ e^- \rightarrow N_2 + 6\ H_2O$ (×1) → **$5\ Mg + 2\ NO_3^- + 12\ H^+ \rightarrow 5\ Mg^{2+} + N_2 + 6\ H_2O$; 10 electrons transferred**

**120.** Ox: $H_2S \rightarrow S + 2\ H^+ + 2\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$3\ H_2S + Cr_2O_7^{2-} + 8\ H^+ \rightarrow 3\ S + 2\ Cr^{3+} + 7\ H_2O$; 6 electrons transferred**

## Part 13: Balance and Name the Agents

**121.** Ox: $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (×2); Red: $H_2O_2 + 2\ H^+ + 2\ e^- \rightarrow 2\ H_2O + 2\ H_2O$ (×1) → **$2\ Fe^{2+} + H_2O_2 + 2\ H^+ \rightarrow 2\ Fe^{3+} + 2\ H_2O + 2\ H_2O$**; oxidising agent **$H_2O_2$**, reducing agent **$Fe^{2+}$**

**122.** Ox: $2\ I^- \rightarrow I_2 + 2\ e^-$ (×1); Red: $H_2O_2 + 2\ H^+ + 2\ e^- \rightarrow 2\ H_2O + 2\ H_2O$ (×1) → **$2\ I^- + H_2O_2 + 2\ H^+ \rightarrow I_2 + 2\ H_2O + 2\ H_2O$**; oxidising agent **$H_2O_2$**, reducing agent **$I^-$**

**123.** Ox: $2\ Br^- \rightarrow Br_2 + 2\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×2) → **$10\ Br^- + 2\ MnO_4^- + 16\ H^+ \rightarrow 5\ Br_2 + 2\ Mn^{2+} + 8\ H_2O$**; oxidising agent **$MnO_4^-$**, reducing agent **$Br^-$**

**124.** Ox: $SO_2 + 2\ H_2O \rightarrow SO_4^{2-} + 4\ H^+ + 2\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$3\ SO_2 + Cr_2O_7^{2-} + 2\ H^+ \rightarrow 3\ SO_4^{2-} + 2\ Cr^{3+} + H_2O$**; oxidising agent **$Cr_2O_7^{2-}$**, reducing agent **$SO_2$**

**125.** Ox: $Sn^{2+} \rightarrow Sn^{4+} + 2\ e^-$ (×3); Red: $IO_3^- + 6\ H^+ + 6\ e^- \rightarrow I^- + 3\ H_2O$ (×1) → **$3\ Sn^{2+} + IO_3^- + 6\ H^+ \rightarrow 3\ Sn^{4+} + I^- + 3\ H_2O$**; oxidising agent **$IO_3^-$**, reducing agent **$Sn^{2+}$**

**126.** Ox: $Cu \rightarrow Cu^{2+} + 2\ e^-$ (×1); Red: $Ag^+ + e^- \rightarrow Ag$ (×2) → **$Cu + 2\ Ag^+ \rightarrow Cu^{2+} + 2\ Ag$**; oxidising agent **$Ag^+$**, reducing agent **Cu**

**127.** Ox: $Mn^{2+} + 4\ H_2O \rightarrow MnO_4^- + 8\ H^+ + 5\ e^-$ (×2); Red: $PbO_2 + 4\ H^+ + 2\ e^- \rightarrow Pb^{2+} + 2\ H_2O$ (×5) → **$2\ Mn^{2+} + 5\ PbO_2 + 4\ H^+ \rightarrow 2\ MnO_4^- + 5\ Pb^{2+} + 2\ H_2O$**; oxidising agent **$PbO_2$**, reducing agent **$Mn^{2+}$**

**128.** Ox: $H_2S \rightarrow S + 2\ H^+ + 2\ e^-$ (×1); Red: $Fe^{3+} + e^- \rightarrow Fe^{2+}$ (×2) → **$H_2S + 2\ Fe^{3+} \rightarrow S + 2\ Fe^{2+} + 2\ H^+$**; oxidising agent **$Fe^{3+}$**, reducing agent **$H_2S$**

**129.** Ox: $NO_2^- + H_2O \rightarrow NO_3^- + 2\ H^+ + 2\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×2) → **$5\ NO_2^- + 2\ MnO_4^- + 6\ H^+ \rightarrow 5\ NO_3^- + 2\ Mn^{2+} + 3\ H_2O$**; oxidising agent **$MnO_4^-$**, reducing agent **$NO_2^-$**

**130.** Ox: $2\ Cl^- \rightarrow Cl_2 + 2\ e^-$ (×1); Red: $PbO_2 + 4\ H^+ + 2\ e^- \rightarrow Pb^{2+} + 2\ H_2O$ (×1) → **$2\ Cl^- + PbO_2 + 4\ H^+ \rightarrow Cl_2 + Pb^{2+} + 2\ H_2O$**; oxidising agent **$PbO_2$**, reducing agent **$Cl^-$**

## Part 14: Organic Redox Reactions

**131.** Ox: $C_2H_5OH + H_2O \rightarrow CH_3COOH + 4\ H^+ + 4\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×2) → **$3\ C_2H_5OH + 2\ Cr_2O_7^{2-} + 16\ H^+ \rightarrow 3\ CH_3COOH + 4\ Cr^{3+} + 11\ H_2O$**

**132.** Ox: $CH_3OH + H_2O \rightarrow HCOOH + 4\ H^+ + 4\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×4) → **$5\ CH_3OH + 4\ MnO_4^- + 12\ H^+ \rightarrow 5\ HCOOH + 4\ Mn^{2+} + 11\ H_2O$**

**133.** Ox: $HCHO + H_2O \rightarrow CO_2 + 4\ H^+ + 4\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×4) → **$5\ HCHO + 4\ MnO_4^- + 12\ H^+ \rightarrow 5\ CO_2 + 4\ Mn^{2+} + 11\ H_2O$**

**134.** Ox: $CH_3CHO + H_2O \rightarrow CH_3COOH + 2\ H^+ + 2\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$3\ CH_3CHO + Cr_2O_7^{2-} + 8\ H^+ \rightarrow 3\ CH_3COOH + 2\ Cr^{3+} + 4\ H_2O$**

**135.** Ox: $C_2H_5OH \rightarrow CH_3CHO + 2\ H^+ + 2\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$3\ C_2H_5OH + Cr_2O_7^{2-} + 8\ H^+ \rightarrow 3\ CH_3CHO + 2\ Cr^{3+} + 7\ H_2O$**

**136.** Ox: $H_2C_2O_4 \rightarrow 2\ CO_2 + 2\ H^+ + 2\ e^-$ (×3); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$3\ H_2C_2O_4 + Cr_2O_7^{2-} + 8\ H^+ \rightarrow 6\ CO_2 + 2\ Cr^{3+} + 7\ H_2O$**

**137.** Ox: $C_6H_{12}O_6 + 6\ H_2O \rightarrow 6\ CO_2 + 24\ H^+ + 24\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×24) → **$5\ C_6H_{12}O_6 + 24\ MnO_4^- + 72\ H^+ \rightarrow 30\ CO_2 + 24\ Mn^{2+} + 66\ H_2O$**

**138.** Ox: $CH_3OH + H_2O \rightarrow CO_2 + 6\ H^+ + 6\ e^-$ (×1); Red: $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$ (×1) → **$CH_3OH + Cr_2O_7^{2-} + 8\ H^+ \rightarrow CO_2 + 2\ Cr^{3+} + 6\ H_2O$**

**139.** Ox: $C_2H_5OH + 3\ H_2O \rightarrow 2\ CO_2 + 12\ H^+ + 12\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×12) → **$5\ C_2H_5OH + 12\ MnO_4^- + 36\ H^+ \rightarrow 10\ CO_2 + 12\ Mn^{2+} + 33\ H_2O$**

**140.** Ox: $HCOOH \rightarrow CO_2 + 2\ H^+ + 2\ e^-$ (×5); Red: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$ (×2) → **$5\ HCOOH + 2\ MnO_4^- + 6\ H^+ \rightarrow 5\ CO_2 + 2\ Mn^{2+} + 8\ H_2O$**

## Part 15: Challenge Equations

**141.** **$3\ As_2S_3 + 28\ NO_3^- + 4\ H_2O + 10\ H^+ \rightarrow 6\ H_3AsO_4 + 9\ SO_4^{2-} + 28\ NO$**

**142.** **$2\ CrI_3 + 27\ Cl_2 + 64\ OH^- \rightarrow 2\ CrO_4^{2-} + 6\ IO_4^- + 54\ Cl^- + 32\ H_2O$**

**143.** **$3\ Cu_2S + 10\ NO_3^- + 16\ H^+ \rightarrow 6\ Cu^{2+} + 3\ SO_4^{2-} + 10\ NO + 8\ H_2O$**

**144.** **$3\ P_4 + 20\ NO_3^- + 8\ H_2O + 20\ H^+ \rightarrow 12\ H_3PO_4 + 20\ NO$**

**145.** **$4\ Zn + NO_3^- + 10\ H^+ \rightarrow 4\ Zn^{2+} + NH_4^+ + 3\ H_2O$**

**146.** **$8\ Al + 3\ NO_3^- + 18\ H_2O + 5\ OH^- \rightarrow 8\ Al(OH)_4^- + 3\ NH_3$**

**147.** **$4\ FeS_2 + 11\ O_2 \rightarrow 2\ Fe_2O_3 + 8\ SO_2$**

**148.** **$2\ MnO_4^- + 3\ C_2O_4^{2-} + 4\ OH^- \rightarrow 2\ MnO_2 + 6\ CO_3^{2-} + 2\ H_2O$**

**149.** **$5\ Fe(CN)_6^{4-} + 61\ MnO_4^- + 188\ H^+ \rightarrow 5\ Fe^{3+} + 30\ CO_2 + 30\ NO_3^- + 61\ Mn^{2+} + 94\ H_2O$**

**150.** **$2\ CuFeS_2 + 5\ O_2 \rightarrow 2\ Cu + 2\ FeO + 4\ SO_2$**

## Notes: 15 Key Points to Remember

| | |
|---|---|
| **01** | **Two things must balance**<br>A redox equation is balanced only when both the atoms AND the total charge are equal on each side. |
| **02** | **OIL RIG**<br>Oxidation Is Loss of electrons (electrons appear as products). Reduction Is Gain of electrons (electrons appear as reactants). |
| **03** | **Electrons lost = electrons gained**<br>Multiply the half-reactions so both contain the same number of electrons; then they cancel when you add. |
| **04** | **Order of balancing**<br>Main atoms first, then O with $H_2O$, then H with $H^+$, then charge with electrons. Do not change this order. |
| **05** | **Only add $H_2O$, $H^+$, $OH^-$ and $e^-$**<br>Never add $O_2$, $H_2$ or other new substances to balance O or H. |
| **06** | **Electrons go on the positive side**<br>Add electrons to the side with the higher (more positive) total charge until both sides match. |
| **07** | **Basic solution trick**<br>Balance as if acidic, then add the same number of $OH^-$ to both sides as there are $H^+$. $H^+ + OH^- \rightarrow H_2O$. |
| **08** | **Cancel at the end**<br>After adding the halves, cancel electrons, $H_2O$, $H^+$ or $OH^-$ that appear on both sides. |
| **09** | **Smallest whole numbers**<br>Divide all coefficients by any common factor so the final equation uses the smallest whole numbers. |
| **10** | **Spectator ions**<br>Ions such as $K^+$, $Na^+$ and $SO_4^{2-}$ often do not change; you can leave them out and add them back at the end. |
| **11** | **Oxidation-number method**<br>For molecular equations, find each element's change in oxidation number, balance the total increase and decrease, then balance other atoms. |
| **12** | **Disproportionation**<br>One substance is both oxidised and reduced (e.g. $Cl_2 \rightarrow Cl^- + ClO_3^-$). Write both half-reactions from it. |
| **13** | **Agents are whole species**<br>The oxidising agent is the reactant that is reduced (e.g. $MnO_4^-$), not just the element (Mn). |
| **14** | **Common half-reactions**<br>$MnO_4^- \rightarrow Mn^{2+}$ gains $5e^-$; $Cr_2O_7^{2-} \rightarrow 2Cr^{3+}$ gains $6e^-$; $NO_3^- \rightarrow NO$ gains $3e^-$. |
| **15** | **Always check**<br>Count every element and add up the charges on each side. If either total differs, look again at the electrons or the multipliers. |