Balancing Redox Equations

1. Determine the oxidation numbers for all atoms in the reaction.
2. Determine which atom is being oxidized and which is being reduced.
3. Write a half reaction for the reduction process, showing the species with the atom being reduced and the product containing that atom.
4. Write a half reaction for the oxidation process, showing the species with the atom being oxidized and the product containing that atom.
5. If the atoms being oxidized and reduced are not already balanced, balance them.
6. Add the appropriate number of electrons to each half reaction needed to bring about the reduction and oxidation.
7. Balance all other atoms in each half reaction **except** H and O.
8. Balance the H and O atoms as shown below:
   a. If the reaction is **acidic**, add H^+ and H_2O. Balance O first by adding H_2O, then balance H by adding H^+. Charge should now be balanced.
   b. If the reaction is **basic**, add OH^- and H_2O. Balance charge first by adding OH^-, then O by adding H_2O. The H should now be balanced.
9. Once the half reactions are balanced, find the lowest common denominator (LCD) for the electrons in the two half reactions.
10. Multiply each half reaction by a whole number so that the total number of electrons in the reduction half reaction equals the total number of electrons in the oxidation half reaction (and they each equal the LCD).
11. Add the two half reactions together and cancel those things that are common to both sides.
12. Check the equation to be sure that the equation is balanced by atoms and by charge.

Example of an acidic redox reacion:

	MnO_4^- +	$C_2O_4^{2-}$ →	Mn^{2+} +	CO_2
Oxidation numbers	Mn +7	C +3	Mn +2	C +4
	O –2	O –2		O –2

Reduction half reaction $MnO_4^- \rightarrow Mn^{2+}$ (Mn atoms balanced)

Oxidation half reaction $C_2O_4^{2-} \rightarrow 2CO_2$ (C atoms balanced)

Reduction half reaction $MnO_4^- + 5e^- \rightarrow Mn^{2+}$ (electrons added)

Oxidation half reaction $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ (electrons added)

Reduction half reaction $MnO_4^- + 5e^- \rightarrow Mn^{2+}$

Add H_2O to balance O — add 4 H_2O to the right side of the equation

Add H^+ to balance H — add 8 H^+ to the left side of the equation

Balanced reduction half reaction $\mathbf{MnO_4^- + 5e^- + 8H^+ \rightarrow Mn^{2+} + 4H_2O}$

Oxidation half reaction $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$

Add H_2O to balance O — add no H_2O since O is balanced

Add H^+ to balance H — add no H^+ since H is balanced

Balanced oxidation half reaction $\mathbf{C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-}$

The lowest common denominator for the 2 reactions is 10. Multiply the reduction equation by 2 and the oxidation equation by 5.

Reduction half reaction $2MnO_4^- + 10e^- + 16H^+ \rightarrow 2Mn^{2+} + 8H_2O$

Oxidation half reaction $5C_2O_4^{2-} \rightarrow 10CO_2 + 10e^-$

Cancel electrons since they are on both sides of the equation.

Overall equation: $\mathbf{2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2}$

Example of a basic redox reacion:

	MnO_4^- +	Br^- →	MnO_2 +	BrO_3^-
Oxidation numbers	Mn +7 O –2	Br -1	Mn +4 O -2	Br +5 O -2

Reduction half reaction $MnO_4^- \rightarrow MnO_2$ (Mn atoms balanced)

Oxidation half reaction $Br^- \rightarrow BrO_3^-$ (Br atoms balanced)

Reduction half reaction $MnO_4^- + 3e^- \rightarrow MnO_2$ (electrons added)

Oxidation half reaction $Br^- \rightarrow BrO_3^- + 6e^-$ (electrons added)

Reduction half reaction $MnO_4^- + 3e^- \rightarrow MnO_2$

Add OH^- to balance charge add 4 OH^- to the right side of the equation

Add H_2O to balance O add 2 H_2O to the left side of the equation

Balanced reduction half reaction $\mathbf{MnO_4^- + 3e^- + 2H_2O \rightarrow MnO_2 + 4OH^-}$

Oxidation half reaction $Br^- \rightarrow BrO_3^- + 6e^-$

Add OH- to balance charge add 6 OH^- to the left side of the equation

Add H_2O to balance O add 3 H_2O to the right side of the equation

Balanced oxidation half reaction $\mathbf{6OH^- + Br^- \rightarrow BrO_3^- + 6e^- + 3H_2O}$

The lowest common denominator for the 2 reactions is 6. Multiply the reduction equation by 2 and the oxidation equation by 1.

Reduction half reaction $2MnO_4^- + 6e^- + 4H_2O \rightarrow 2MnO_2 + 8OH^-$

Oxidation half reaction $6OH^- + Br^- \rightarrow BrO_3^- + 6e^- + 3H_2O$

Cancel electrons H^+ and H_2O since they are on both sides of the equation.

Overall equation: $\mathbf{2MnO_4^- + H_2O + Br^- \rightarrow 2MnO_2 + 2OH^- + BrO_3^-}$

Problems:

1. $Br_2 + SO_2 \rightarrow Br^- + HSO_4^-$ (acidic) **Solution**
2. $PbO_2 + Mn^{2+} \rightarrow Pb^{2+} + MnO_4^-$ (acidic) **Solution**
3. $MnO_4^- + SO_3^{2-} \rightarrow MnO_2 + SO_4^{2-}$ (basic) **Solution**
4. $Zn + NO_3^- \rightarrow NH_3 + Zn(OH)_4^{2-}$ (basic) **Solution**

Solutions:

1. $Br_2 + SO_2 \rightarrow Br^- + HSO_4^-$ (acidic)

	Br_2 +	$SO_2 \rightarrow$	Br^- +	HSO_4^-
Oxidation numbers	Br 0	S +4 O –2	Br –1	S +6 O -2 H +1

Reduction half reaction $Br_2 + 2e^- \rightarrow 2Br^-$

This equation is balanced for Br, electrons are included and no addition of H^+ or H_2O is needed since there are no H or O in the equation.

Balanced reduction half reaction: $Br_2 + 2e^- \rightarrow 2Br^-$

Oxidation half reaction $SO_2 \rightarrow HSO_4^- + 2e^-$

Add 2 H2O to the left side to balance the O and 3 H+ to the right side to balance H.

Balanced oxidation half reaction: $2H_2O + SO_2 \rightarrow HSO_4^- + 3H^+ + 2e^-$

Both equations have 2e- so there is no need to find a LCD. The only thing that cancels will be the electrons.

Balanced reduction half reaction $Br_2 + 2e^- \rightarrow 2Br^-$

Balanced oxidation half reaction $2H_2O + SO_2 \rightarrow HSO_4^- + 3H^+ + 2e^-$

Overall equation: $2H_2O + SO_2 + Br_2 \rightarrow HSO_4^- + 2Br^- + 3H^+$

Return to Problems

2. $PbO_2 + Mn^{2+} \rightarrow Pb^{2+} + MnO_4^-$ (acidic)

	PbO_2	+	Mn^{2+}	$\rightarrow$	Pb^{2+}	+	MnO_4^-
Oxidation numbers	Pb +4 O –2		Mn +2		Pb +2		Mn +7 O-2

Reduction half reaction $PbO_2 + 2e^- \rightarrow Pb^{2+}$

Add 2 H_2O to the right side to balance O, add 4 H^+ to the left side to balance H

Balanced reduction half reaction $\mathbf{PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O}$

Oxidation half reaction $Mn^{2+} \rightarrow MnO_4^- + 5e^-$

Add 4 H_2O to the left side to balance O, add 8 H^+ to the right side to balance H

Balanced oxidation half reaction $\mathbf{Mn^{2+} + 4H_2O \rightarrow MnO_4^- + 8H^+ + 5e^-}$

LCD is 10 so we need to multiply the reduction half reaction by 5 and the oxidation half reaction by 2.

Balanced reduction half reaction $5PbO_2 + 20H^+ + 10e^- \rightarrow 5Pb^{2+} + 10H_2O$

Balanced oxidation half reaction $2Mn^{2+} + 8H_2O \rightarrow 2MnO_4^- + 16H^+ + 10e^-$

Overall equation $\mathbf{5PbO_2 + 4H^+ + 2Mn^{2+} \rightarrow 5Pb^{2+} + 2H_2O + 2MnO_4^-}$

Return to Problems

3. $MnO_4^- + SO_3^{2-} \rightarrow MnO_2 + SO_4^{2-}$ (basic)

	MnO_4^-	+	SO_3^{2-}	$\rightarrow$	MnO_2	+	SO_4^{2-}
Oxidation numbers	Mn +7		S +4		Mn +4		S +6
	O –2		O –2		O –2		O –2

Reduction half reaction $MnO_4^- + 3e^- \rightarrow MnO_2$

Add 4 OH^- to the right side to balance charge, add 2 H_2O to the left side to balance O

Balanced reduction half reaction $\mathbf{MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-}$

Oxidation half reaction $SO_3^{2-} \rightarrow SO_4^{2-} + 2e^-$

Add 2 OH^- to the left side to balance charge, add 1 H_2O to the right side to balance O

Balanced oxidation half reaction $\mathbf{SO_3^{2-} + 2OH^- \rightarrow SO_4^{2-} + 2e^- + H_2O}$

LCD is 6 so we need to multiply the reduction half reaction by 2 and the oxidation half reaction by 3.

Balanced reduction half reaction $2MnO_4^- + 4H_2O + 6e^- \rightarrow 2MnO_2 + 8OH^-$

Balanced oxidation half reaction $3SO_3^{2-} + 6OH^- \rightarrow 3SO_4^{2-} + 6e^- + 3H_2O$

Overall equation $\mathbf{2MnO_4^- + H_2O + 3SO_3^{2-} \rightarrow 2MnO_2 + 2OH^- + 3SO_4^{2-}}$

Return to Problems

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

	Zn	+	NO_3^-	$\rightarrow$	NH_3	+	$Zn(OH)_4^{2-}$
Oxidation numbers	Zn 0		N +5		N –3		Zn +2
			O –2		H +1		O -2
							H +1

Reduction half reaction $NO_3^- + 8e^- \rightarrow NH_3$

Add 9 OH^- to the right side to balance charge, add 6 H_2O to the left side to balance O.

Balanced reduction half reaction $\mathbf{NO_3^- + 8e^- + 6H_2O \rightarrow NH_3 + 9OH^-}$

Oxidation half reaction $Zn \rightarrow Zn(OH)_4^{2-} + 2e^-$

Add 4 OH^- to the left side to balance charge, no addition of H_2O needed.

Balanced oxidation half reaction $\mathbf{Zn + 4OH^- \rightarrow Zn(OH)_4^{2-} + 2e^-}$

LCD is 8 so multiply the oxidation half reaction by 4 (no need to alter the reduction half reaction)

Balanced reduction half reaction $NO_3^- + 8e^- + 6H_2O \rightarrow NH_3 + 9OH^-$

Balanced oxidation half reaction $4Zn + 16OH^- \rightarrow 4Zn(OH)_4^{2-} + 8e^-$

Overall equation $\mathbf{4Zn + NO_3^- + 7OH^- + 6H_2O \rightarrow 4Zn(OH)_4^{2-} + NH_3}$

Return to Problems