CHEM 160 BALANCING HALF REACTIONS

Balancing Redox Reactions in Steps (Acidic Solution)

1. The first step is determining if it is a redox reaction
    a. There must be a component that is oxidized (increase in oxidation number)
    b. There must be a component that is reduced (decrease in oxidation number)
2. Balance elements in the equation other than O and H
3. Balance the oxygen atoms by adding the appropriate number of water (H_2O) molecules to the opposite side of the equation
4. Balance the hydrogen atoms (including those added in step 3 to balance the oxygen atoms) by adding H^+ ions to the opposite side of the equation
5. Add up the charges on each side. Make them equal by adding enough electrons (e^-) to the more positive side
6. The e^- on each side of the half reactions must be equal; if they are not equal, they must be multiplied by appropriate integers (the lowest common multiple) to be made the same.
7. The half reactions are added together, canceling out the electrons to form one balanced equation. Common terms should also be canceled out.
8. If in basic conditions, add enough OH^- ions to balance any H^+ ions present. Add the same amount of OH^- ions to each side.
9. Combine the OH^- ions and the H^+ ions to make H_2O.
10. Cancel any common terms.

Worked Example

$$\mathbf{Cr_2O_7^{2-}(aq) + HNO_2(aq) \rightarrow Cr^{3+}(aq) + NO_3^-(aq)}$$

1. Separate the half reactions
    a. Oxidation: $HNO_2(aq) \rightarrow NO_3^-(aq)$
    b. Reduction: $Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq)$
2. Balance atoms other than O and H
    In this case, only Cr needs to be balanced:
    $Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq)$
3. Balance the O atoms by adding water
    a. $HNO_2(aq) + H_2O(l) \rightarrow NO_3^-(aq)$
    b. $Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$
4. Balance the H atoms by adding H^+
    a. $HNO_2(aq) + H_2O(l) \rightarrow NO_3^-(aq) + 3H^+(aq)$
    b. $Cr_2O_7^{2-}(aq) + 14\ H^+(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$
5. Balance the charge by adding e^-
    a. $\underset{0}{HNO_2}(aq) + \underset{0}{H_2O}(l) \rightarrow \underset{-1}{NO_3^-}(aq) + \underset{3+}{3H^+}(aq) + 2\ e^-$
    b. $\underset{2-}{Cr_2O_7^{2-}}(aq) + \underset{14+}{14\ H^+}(aq) + 6\ e^- \rightarrow \underset{6+}{2\ Cr^{3+}}(aq) + \underset{0}{7\ H_2O}(l)$

6. Make the electrons equal by multiplying by the least common multiple
   a. ($HNO_2(aq) + H_2O(l) \rightarrow NO_3^-(aq) + 3H^+(aq) + 2\ e^-$) ***3**
      i. $3\ HNO_2(aq) + 3\ H_2O(l) \rightarrow 3\ NO_3^-(aq) + 9\ H^+(aq) + 6\ e^-$
   b. ($Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 6\ e^- \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$) ***1**
      i. $Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 6\ e^- \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$
7. Combine the half reactions and cancel out the common terms
   a. $3\ HNO_2(aq) + \cancel{3\ H_2O(l)} + Cr_2O_7^{2-}(aq) + \cancel{14}\ H^+(aq) + \cancel{6\ e^-} \rightarrow 3\ NO_3^-(aq) + \cancel{9\ H^+(aq)} + \cancel{6\ e^-} + 2\ Cr^{3+}(aq) + \cancel{7}\ H_2O(l)$
      i. $3\ HNO_2(aq) + Cr_2O_7^{2-}(aq) + 5\ H^+(aq) \rightarrow 3\ NO_3^-(aq) + 2\ Cr^{3+}(aq) + 4\ H_2O(l)$

Final Balanced equation (Acidic):

$HNO_2(aq) + Cr_2O_7^{2-}(aq) + 5\ H^+(aq) \rightarrow 3\ NO_3^-(aq) + 2\ Cr^{3+}(aq) + 4\ H_2O(l)$

8. (Basic) Add OH^- ions to balance out any H^+ ions present
   a. $3\ HNO_2(aq) + Cr_2O_7^{2-}(aq) + 5\ H^+(aq) + 5\ OH^-(aq) \rightarrow 3\ NO_3^-(aq) + 2\ Cr^{3+}(aq) + 4\ H_2O(l) + 5\ OH^-(aq)$
9. Combine any H^+ and OH^- ions to make H_2O
   a. $3\ HNO_2(aq) + Cr_2O_7^{2-}(aq) + 5\ H_2O(l) \rightarrow 3\ NO_3^-(aq) + 2\ Cr^{3+}(aq) + 4\ H_2O(l) + 5\ OH^-(aq)$
10. Cancel out the common terms
   a. $3\ HNO_2(aq) + Cr_2O_7^{2-}(aq) + \cancel{5}\ H_2O(l) \rightarrow 3\ NO_3^-(aq) + 2\ Cr^{3+}(aq) + \cancel{4\ H_2O(l)} + 5\ OH^-(aq)$
      i. $3\ HNO_2(aq) + Cr_2O_7^{2-}(aq) + H_2O(l) \rightarrow 3\ NO_3^-(aq) + 2\ Cr^{3+}(aq) + 5\ OH^-(aq)$

Final Balanced Equation (Basic):

$3\ HNO_2(aq) + Cr_2O_7^{2-}(aq) + H_2O(l) \rightarrow 3\ NO_3^-(aq) + 2\ Cr^{3+}(aq) + 5\ OH^-(aq)$

Tel:
STEM SC (N): (760) 750-4101
STEM SC (S): (760) 750-7324