Ion-electron method of balancing oxidation-reduction method

Reaction of dichromate and chlorine in **acidic solution**

1. Write two skeleton partial reactions and balance atoms **other than** hydrogen and oxygen.

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

$$2Cl^- \rightarrow Cl_2$$

2. Balance H and O atoms by adding H_2O to the side deficient in oxygen and H^+ to the side deficient in hydrogen.

$$14H^+ + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 7H_2O$$

$$2Cl^- \rightarrow Cl_2$$

3. Balance each half-reaction electrically using electrons.

$$6e^- + 14H^+ + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 7H_2O$$

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

4. Obtain the same number of electrons gained by one half-reaction and lost by the other half-reaction by multiplying by the appropriate factors. (In this example, the least common multiple of 6 and 2 is 6 and so the second half-reaction is multiplied by 3.

$$6e^- + 14H^+ + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 7H_2O$$

$$6Cl^- \rightarrow 3Cl_2 + 6e^-$$

5. Add partial equations to get final equation and cross off identical species on each side.

$$14H^+ + 6Cl^- + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 3Cl_2 + 7H_2O$$

Ion-electron Method/Acid Solution
Example 2

As_4O_6 reacts with MnO_4^- to produce H_3AsO_4 and Mn^{2+}

1. Write skeleton partial equations for half reactions.

$$MnO_4^- \rightarrow Mn^{2+}$$

$$As_4O_6 \rightarrow 4H_3AsO_4$$

2. Add H^+ and H_2O.

$$8H^+ + MnO_4^- \rightarrow Mn^{2+} + 4H_2O$$

$$10H_2O + As_4O_6 \rightarrow 4H_3AsO_4 + 8H^+$$

3. Balance net charges via electrons.

$$5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{2+} + 4H_2O$$

$$10H_2O + As_4O_6 \rightarrow 4H_3AsO_4 + 8H^+ + 8e^-$$

4. Multiply each equation through by appropriate factor to balance electrons gained with electrons lost.

$$40e^- + 64H^+ + 8MnO_4^- \rightarrow 8Mn^{2+} + 32H_2O$$

$$50H_2O + 5As_4O_6 \rightarrow 20H_3AsO_4 + 40H^+ + 40e^-$$

5. Add equations and cancel what is possible from each side.

$$24H^+ + 18H_2O + 5As_4O_6 + 8MnO_4^- \rightarrow 20H_3AsO_4 + 8Mn^{2+}$$

Ion-electron Method/Alkaline Solution

For alkaline solutions, all the steps are the same as in acid solution except the second one. H^+ **cannot** be used.
The following reaction takes place in alkaline solution.

1. $$Cr(OH)_6^{3-} \rightarrow CrO_4^{2-}$$

$$HO_2^- \rightarrow OH^-$$

2. For reactions occurring in alkaline solution, OH^- and H_2O are used to balance oxygen and hydrogen. For each oxygen that is needed, $2OH^-$ ions are added to the side of the partial equation that is deficient, and one H_2O molecule is added to the opposite side. For each hydrogen that is needed, one H_2O molecule is added to the side that is deficient, and one OH^- is added to the opposite side.

   In the first partial equation, the right side is deficient by 2 oxygen atoms. We add, therefore, $4OH^-$ to the right side and $2H_2O$ to the left. **This addition takes care of oxygen balance only.**

$$2H_2O + Cr(OH)_6^{3-} \rightarrow CrO_4^{2-} + 4OH^-$$

   We need (as we originally needed) 6 more hydrogen atoms on the right and therefore add $6H_2O$ to the right and $6OH^-$ to the left.

$$6OH^- + 2H_2O + Cr(OH)_6^{3-} \rightarrow CrO_4^{2-} + 4OH^- + 6H_2O$$

   We can consolidate our additions:

$$2OH^- + Cr(OH)_6^{3-} \rightarrow CrO_4^{2-} + 4H_2O$$

   The second partial equation is brought into material balance by the addition of $2OH^-$ to the right and one H_2O to the left.

$$H_2O + HO_2^- \rightarrow 3OH^-$$

3. $$2OH^- + Cr(OH)_6^{3-} \rightarrow CrO_4^{2-} + 4H_2O + 3e^-$$

$$2e^- + H_2O + HO_2^- \rightarrow 3OH^-$$

4. $$4OH^- + 2Cr(OH)_6^{3-} \rightarrow 2CrO_4^{2-} + 8H_2O + 6e^-$$

$$6e^- + 3H_2O + 3HO_2^- \rightarrow 9OH^-$$

5. $$2Cr(OH)_6^{3-} + 3HO_2^- \rightarrow 2CrO_4^{2-} + 5H_2O + 5OH^-$$

Ion-electron Method/Disproportionation or Auto-Oxidation-Reduction Reactions.

Consider the following skeleton equation for a reaction in alkaline solution.

$$Br_2 \rightarrow BrO_3^- + Br^-$$

In this reaction, the same substance, Br_2, is both oxidized and reduced.

1.

$$Br_2 \rightarrow 2BrO_3^-$$

$$Br_2 \rightarrow 2Br^-$$

2.

$$12OH^- + Br_2 \rightarrow 2BrO_3^- + 6H_2O$$

$$Br_2 \rightarrow 2Br^-$$

3.

$$12OH^- + Br_2 \rightarrow 2BrO_3^- + 6H_2O + 10e^-$$

$$2e^- + Br_2 \rightarrow 2Br^-$$

4.

$$12OH^- + Br_2 \rightarrow 2BrO_3^- + 6H_2O + 10e^-$$

$$10e^- + 5Br_2 \rightarrow 10Br^-$$

5.

$$12OH^- + 6Br_2 \rightarrow 2BrO_3^- + 10Br^- + 6H_2O$$

Oxidation number method for balancing reactions

For the reaction: $HNO_3 + H_2S \rightarrow NO + S + H_2O$

1) Identify and write oxidation numbers of elements undergoing oxidation or reduction.

$$\overset{5+}{H N}O_3 + H_2\overset{2-}{S} \rightarrow \overset{2+}{N}O + \overset{0}{S} + H_2O$$

2) Use coefficients to make the **total** decrease in oxidation number equal to the total increase in oxidation number.

N goes from 5+ to 2+, a change of -3
S goes from 2- to 0, a change of +2

Therefore, the nitrogen compounds take a coefficient of 2 and the sulfur a coefficient of 3.

$$2HNO_3 + 3H_2S \rightarrow 2NO + 3S + H_2O$$

3) Complete by inspection.

$$2HNO_3 + 3H_2S \rightarrow 2NO + 3S + 4H_2O$$

- Charge and atoms of each element must balance
- This method may be used for net or ionic equations , in which only those ions and molecules that actually take part in the reaction are shown. For example, the K^+ ion does not take part in the reaction of potassium chlorate, $KClO_3$, with iodine and is not shown in the equation.

1) $$H_2O + \overset{0}{I_2} + \overset{5+}{Cl}O_3^- \rightarrow \overset{5-}{I}O_3^- + \overset{1-}{Cl^-} + H^+$$

I: 0 to 5+, change of 5+ x 2(for each atom) = 10+

(Each iodine atom undergoes an increase of 5 so the total change in oxidation number here is 10+)

Cl: 5+ to 1-, change of 6- = 6-

Least common multiple is 30

2) $$H_2O + 3I_2 + 5ClO_3^- \rightarrow 6IO_3^- + 5Cl^- + H^+$$

3) Ignoring H_2O, there are now 15 oxygen atoms on the left and 18 oxygen atoms on the right. To make up 3 oxygen atoms on the left, $3H_2O$ molecules must be indicated. It then

follows that the coefficient of H^+ must be 6 to balance the hydrogens of the H_2O molecules.

$$3H_2O + 3I_2 + 5ClO_3^- \rightarrow 6IO_3^- + 5Cl^- + 6H^+$$

An ionic equation must indicate change balance as well as mass balance. Since the algebraic sum of charges on the left, 5-, equals that of the right, 5-, the equation is balanced.