VANCOUVER COMMUNITY COLLEGE

Balancing Redox Reactions 2:
The Ion-Electron Method

In the first redox reaction worksheet, we saw the oxidation number method of balancing equations. This worksheet shows you another method.

The steps for balancing a redox reaction using the *ion-electron method* are:

[1] **Break the equation into two half-reactions**, one for the oxidation step (loss of electrons) and one for the reduction step (gain of electrons). You will still need to use oxidation numbers to know which is which.

[2] Obtain material balance (i.e. **balance the atoms**) in each half-reaction.
- [a] Balance everything other than hydrogen and oxygen.
- [b] Balance oxygen by adding H_2O to the other side.
- [c] Balance hydrogen by adding H^+ to the other side.
- [d] IF THE REACTION IS IN BASIC SOLUTION, add equal amounts of OH^- to both sides to neutralize the H^+. The OH^- and H^+ combine to form water and leave excess OH^- on the other side. Cancel any water that appears on both sides. (ignore step d if solution is acidic)

[3] Obtain charge balance for each half-reaction by **adding electrons as a product/reactant to the more positive side**.

[4] **Combine the half-reactions to cancel the electrons.** You may have to multiply the equations by whole numbers to do this.

Example 1: Balance the following redox reaction using the ion-electron method:

$$NO + SO_4^{2-} \rightarrow NO_3^- + SO_2$$

Solution: Following the steps above:

[1] Nitrogen gets oxidized, and sulphur is reduced, so the half-reactions are:

$$NO \rightarrow NO_3^- \qquad\qquad SO_4^{2-} \rightarrow SO_2$$

[2] We balance the atoms:

$$NO + 2\,H_2O \rightarrow NO_3^- \qquad\qquad SO_4^{2-} \rightarrow SO_2 + 2\,H_2O$$
$$NO + 2\,H_2O \rightarrow NO_3^- + 4\,H^+ \qquad\qquad 4\,H^+ + SO_4^{2-} \rightarrow SO_2 + 2\,H_2O$$

[3] We add electrons so that the charge balances:

$$NO + 2\,H_2O \rightarrow NO_3^- + 4\,H^+ + 3\,e^- \qquad 4\,H^+ + SO_4^{2-} + 2\,e^- \rightarrow SO_2 + 2\,H_2O$$

[4] And finally we cancel the electrons:

$$2\,NO \cancel{+ 4\,H_2O} \rightarrow 2\,NO_3^- \cancel{+ 8\,H^+} \cancel{+ 6\,e^-}$$
$$^{4}\cancel{12}\,H^+ + 3\,SO_4^{2-} \cancel{+ 6\,e^-} \rightarrow 3\,SO_2 + \cancel{6}^{2}\,H_2O$$
$$\overline{2\,NO + 4\,H^+ + 3\,SO_4^{2-} \rightarrow 2\,NO_3^- + 3\,SO_2 + 2\,H_2O}$$

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[5] With sulphates and nitrates, this reaction is not likely to take place in basic solution, but if it were, we would not be able to have H^+ in the final equation. We would add OH^- to both sides to cancel the H^+ that is there:

$$\begin{aligned}
2\,NO + 4\,H^+ + 3\,SO_4^{2-} &\rightarrow 2\,NO_3^- + 3\,SO_2 + 2\,H_2O \\
2\,NO + 4\,H^+ + 4\,OH^- + 3\,SO_4^{2-} &\rightarrow 2\,NO_3^- + 3\,SO_2 + 2\,H_2O + 4\,OH^- \\
2\,NO + {}^{2}\cancel{4}\,H_2O + 3\,SO_4^{2-} &\rightarrow 2\,NO_3^- + 3\,SO_2 \cancel{+ 2\,H_2O} + 4\,OH^- \\
2\,NO + 2\,H_2O + 3\,SO_4^{2-} &\rightarrow 2\,NO_3^- + 3\,SO_2 + 4\,OH^-
\end{aligned}$$

EXERCISES

A. For each redox equation, determine (a) the oxidation half-reaction, (b) the reduction half-reaction, and (c) the balanced redox reaction.

1) $Fe^{3+} + Sn^{2+} \rightarrow Fe^{2+} + Sn^{4+}$

2) $Fe^{2+} + C\ell O_3^- + H^+ \rightarrow Fe^{3+} + C\ell^- + H_2O$

3) $Cu + NO_3^- + H^+ \rightarrow Cu^{2+} + NO + H_2O$

4) $S_2O_4^{2-} + Ag_2O + H_2O \rightarrow SO_3^{2-} + Ag + H^+$

5) $MnO_4^- + C\ell^- + H^+ \rightarrow Mn^{2+} + C\ell_2 + H_2O$

6) $MnO_4^- + S^{2-} + H_2O \rightarrow MnO_2 + S + OH^-$

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

8) $MnO_4^- + Sn \rightarrow MnO_2 + Sn(OH)_3^-$ *basic solution

9) $H_2O_2 \rightarrow H_2O + O_2$

SOLUTIONS

A. (1)a) $Sn^{2+} \rightarrow Sn^{4+} + 2\,e^-$ (b) $Fe^{3+} + e^- \rightarrow Fe^{2+}$
(c) a + 2b: $2\,Fe^{3+} + Sn^{2+} \rightarrow 2\,Fe^{2+} + Sn^{4+}$
(2)a) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (b) $C\ell O_3^- + 6\,H^+ + 6\,e^- \rightarrow C\ell^- + 3\,H_2O$
(c) 6a + b: $6\,Fe^{2+} + C\ell O_3^- + 6\,H^+ \rightarrow 6\,Fe^{3+} + C\ell^- + 3\,H_2O$
(3)a) $Cu \rightarrow Cu^{2+} + 2\,e^-$ (b) $NO_3^- + 4\,H^+ + 3\,e^- \rightarrow NO + 2\,H_2O$
(c) 3a + 2b: $3\,Cu + 2\,NO_3^- + 8\,H^+ \rightarrow 3\,Cu^{2+} + 2\,NO + 4\,H_2O$
(4)a) $S_2O_4^{2-} + 2\,H_2O \rightarrow 2\,SO_3^{2-} + 4\,H^+ + 2\,e^-$ (b) $Ag_2O + 2H^+ + 2\,e^- \rightarrow 2\,Ag + H_2O$
(c) a + b: $S_2O_4^{2-} + Ag_2O + H_2O \rightarrow 2\,SO_3^{2-} + 2\,Ag + 2\,H^+$
(5)a) $2\,C\ell^- \rightarrow C\ell_2 + 2\,e^-$ (b) $MnO_4^- + 5\,e^- + 8\,H^+ \rightarrow Mn^{2+} + 4\,H_2O$
(c) 5a + 2b: $2\,MnO_4^- + 10\,C\ell^- + 16\,H^+ \rightarrow 2\,Mn^{2+} + 5\,C\ell_2 + 8\,H_2O$
(6)a) $S^{2-} \rightarrow S + 2\,e^-$ (b) $MnO_4^- + 2\,H_2O + 3\,e^- \rightarrow MnO_2 + 4\,OH^-$
(c) 3a + 2b: $2\,MnO_4^- + 3\,S^{2-} + 4\,H_2O \rightarrow 2\,MnO_2 + 3\,S + 8\,OH^-$
(7)a) $2\,I^- \rightarrow I_2 + 2\,e^-$ (b) $Cr_2O_7^{2-} + 6\,e^- + 14\,H^+ \rightarrow 2\,Cr^{3+} + 7\,H_2O$
(c) 3a + b: $Cr_2O_7^{2-} + 6\,I^- + 14\,H^+ \rightarrow 2\,Cr^{3+} + 3\,I_2 + 7\,H_2O$
(8)a) $Sn + 3\,OH^- \rightarrow Sn(OH)_3^- + 2\,e^-$ (b) $MnO_4^- + 2\,H_2O + 3\,e^- \rightarrow MnO_2 + 4\,OH^-$
(c) 3a + 2b: $2\,MnO_4^- + 3\,Sn + OH^- + 4\,H_2O \rightarrow 2\,MnO_2 + 3\,Sn(OH)_3^-$
(9)a) $H_2O_2 \rightarrow O_2 + 2\,H^+ + 2\,e^-$ (b) $H_2O_2 + 2\,H^+ + 2\,e^- \rightarrow 2\,H_2O$
(c) a + b: $2\,H_2O_2 \rightarrow 2\,H_2O + O_2$