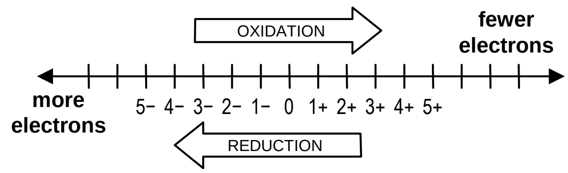
Learning Centre — Science

Chem 093 *by Gordon Wong*

Balancing Redox Reactions 1

Oxidation Numbers

During **oxidation** (loss of electrons), the oxidation number increases. During **reduction** (gain of electrons), the oxidation number decreases:



In chemical reactions involving **red**uction-**ox**idation (**redox**), the total number of electrons lost in the oxidation process must equal the total number of electrons gained during the reduction process.

In a redox reaction, the substance that gets <u>oxidized</u> (that loses electrons) is called the **reducing agent** because it reduces the other substance by giving its electrons. The substance that gets <u>reduced</u> (that gains electrons) is called the **oxidizing agent** because it oxidizes the other substance by removing its electrons.

The steps for balancing a redox reaction using the *oxidation number method* are:

[1] **Assign oxidation numbers** to all atoms in the equation.

[2] **Identify the atoms which change** oxidation number. Insert temporary coefficients so that there are the same number of atoms on each side. If an element has two different oxidation numbers on one side of the equation, duplicate the source of that element on the other side.

[3] **Determine the total change** in oxidation numbers for the oxidation and reduction using the coefficients from step 2.

[4] **Multiply the coefficients** by appropriate factors to make the total loss and gain of electrons the same.

[5] **Balance the rest of the equation** by inspection.

Example 1: Balance the following equation:

$$\underset{\text{tin (II)}}{Sn^{2+}} + \underset{\text{dichromate ion}}{Cr_2O_7^{\ 2-}} + \underset{\text{hydrogen ion}}{H^+} \rightarrow \underset{\text{tin (IV)}}{Sn^{4+}} + \underset{\text{chromium ion}}{Cr^{3+}} + \underset{\text{water}}{H_2O}$$

Solution: [1] Reagents: Sn: 2+, Cr: 6+, H: 1+, O: 2−
Products: Sn: 4+, Cr: 3+, H: 1+, O: 2−

[2] Tin gets oxidized (2+ → 4+) and chromium gets reduced (6+ → 3+)

Balance chromium:

$$\underset{\text{tin (II)}}{Sn^{2+}} + \underset{\text{dichromate ion}}{Cr_2O_7^{\ 2-}} + \underset{\text{hydrogen ion}}{H^+} \rightarrow \underset{\text{tin (IV)}}{Sn^{4+}} + \underset{\text{chromium ion}}{2\,Cr^{3+}} + \underset{\text{water}}{H_2O}$$

[3] The tin loses 2 electrons total at this stage of balancing, and the chromium gains 6 (3 electrons each).

[4] To balance the electrons, put a coefficient of 3 in front of both tin ions:

$$\underset{\text{tin (II)}}{3\,Sn^{2+}} + \underset{\text{dichromate ion}}{Cr_2O_7^{\ 2-}} + \underset{\text{hydrogen ion}}{H^+} \rightarrow \underset{\text{tin (IV)}}{3\,Sn^{4+}} + \underset{\text{chromium ion}}{2\,Cr^{3+}} + \underset{\text{water}}{H_2O}$$

[5] All that's left is the oxygen and hydrogen:

$$\underset{\text{tin (II)}}{3\,Sn^{2+}} + \underset{\text{dichromate ion}}{Cr_2O_7^{\ 2-}} + \underset{\text{hydrogen ion}}{14\,H^+} \rightarrow \underset{\text{tin (IV)}}{3\,Sn^{4+}} + \underset{\text{chromium ion}}{2\,Cr^{3+}} + \underset{\text{water}}{7\,H_2O}$$

Example 2: Balance the following equation:

$$\underset{\text{copper}}{Cu} + \underset{\text{nitric acid}}{HNO_3} \rightarrow \underset{\text{copper (II) nitrate}}{Cu(NO_3)_2} + \underset{\text{nitrogen monoxide}}{NO} + \underset{\text{water}}{H_2O}$$

Solution: [1] Reagents: Cu: 0, H: +1, N: +5, O: −2
Products: Cu: +2, H: +1, N: **+5 & +2**, O: −2

[2] Because nitrogen has different oxidation numbers on the products side, we know some of the nitrate ions stayed intact for the copper (II) nitrate and some reacted to make nitrogen monoxide. We rewrite the equation to reflect this:

$$Cu + \underset{\text{nitrate}}{HNO_3} + \underset{\text{oxidizing agent}}{HNO_3} \rightarrow \underset{\text{nitrate}}{Cu(NO_3)_2} + \underset{\text{reduced}}{NO} + H_2O$$

We can treat each of the nitric acids as a source for a different product containing nitrogen, and add them back together at the end. Copper is balanced in this equation, as is reduced nitrogen. We won't look at the nitrates until step [5].

[3] The copper loses 2 electrons at this stage of balancing and the nitrogen gains 3.

[4] Copper needs to be multiplied by 3 and nitrogen by 2 to make a total electronic exchange of 6 electrons:

$$3\,Cu + \underset{\text{nitrate}}{HNO_3} + \underset{\text{oxidizing agent}}{2\,HNO_3} \rightarrow \underset{\text{nitrate}}{3\,Cu(NO_3)_2} + \underset{\text{reduced}}{2\,NO} + H_2O$$

[5] We balance the rest of the equation:

$$3\,Cu + \underset{\text{nitrate}}{6\,HNO_3} + \underset{\text{oxidizing agent}}{2\,HNO_3} \rightarrow \underset{\text{nitrate}}{3\,Cu(NO_3)_2} + \underset{\text{reduced}}{2\,NO} + 4\,H_2O$$

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

EXERCISES

A. For each of the following equations, identify [a] the element which was oxidized, [b] the element which was reduced, [c] the oxidizing agent, and [d] the reducing agent.

1) $2\ ZnS + 3\ O_2 \rightarrow 2\ ZnO + 2\ SO_2$

2) $2\ Fe + 3\ C\ell_2 \rightarrow 2\ FeC\ell_3$

3) $3\ NaNO_3 + 2\ Fe \rightarrow 3\ NaNO_2 + Fe_2O_3$

4) $3\ Cu + 8\ H^+ + 2\ NO_3^- \rightarrow 3\ Cu^{2+} + 2\ NO + 4\ H_2O$

5) $4\ MnO_2 + 3\ O_2 + 4\ OH^- \rightarrow 4\ MnO_4^- + 2\ H_2O$

B. Balance the following redox reaction equations using the oxidation number method:

1) _____ Cu + _____ H^+ + _____ SO_4^{2-} $\rightarrow$ _____ Cu^{2+} + _____ SO_2 + _____ H_2O

2) _____ Ag + _____ H^+ + _____ NO_3^- $\rightarrow$ _____ Ag^+ + _____ NO + _____ H_2O

3) _____ I^- + _____ $Cr_2O_7^{2-}$ + _____ H^+ $\rightarrow$ _____ Cr^{3+} + _____ I_2 + _____ H_2O

4) ____ $Cr_2O_7^{2-}$ + ____ Fe^{2+} + ____ H^+ $\rightarrow$ ____ Cr^{3+} + ____ Fe^{3+} + ____ H_2O

5) ____ Fe^{2+} + ____ MnO_4^- + ____ H^+ $\rightarrow$ ____ Fe^{3+} + ____ Mn^{2+} + ____ H_2O

6) ____ BiO_3^- + ____ MnO_2 + ____ H^+ $\rightarrow$ ____ Bi^{3+} + ____ MnO_4^- + ____ H_2O

7) _____ C + _____ H_2SO_4 $\rightarrow$ _____ CO_2 + _____ SO_2 + _____ H_2O

8) ____ MnO_4^- + ____ S^{2-} + ____ H_2O $\rightarrow$ ____ MnO_2 + ____ SO_3^{2-} + ____ OH^-

9) _____ HNO_3 + _____ HI $\rightarrow$ _____ NO + _____ I_2 + _____ H_2O

10) ____ CrO_4^{2-} + ____ NH_3 + ____ H_2O $\rightarrow$ ____ NO_3^- + ____ OH^- + ____ Cr^{3+}

11) _____ KI + _____ H_2SO_4 $\rightarrow$ _____ H_2S + _____ H_2O + _____ I_2 + _____ K_2SO_4

12) ____ $KMnO_4$ + ____ $HC\ell$ $\rightarrow$ ____ $MnC\ell_2$ + ____ $C\ell_2$ + ____ H_2O + ____ $KC\ell$

SOLUTIONS

A. (1) S, O, O, S (2) Fe, Cℓ, Cℓ, Fe (3) Fe, N, N, Fe (4) Cu, N, N, Cu (5) Mn, O, O, Mn

B. The answers give coefficients of 1, but these should not be written in the answers:
(1) 1, 4, 1 – 1, 1, 2 (2) 3, 4, 1 – 3, 1, 2 (3) 6, 1, 14 – 2, 3, 7 (4) 1, 6, 14 – 2, 6, 7
(5) 5, 1, 8 – 5, 1, 4 (6) 3, 2, 10 – 3, 2, 5 (7) 1, 2 – 1, 2, 2 (8) 2, 1, 1 – 2, 1, 2
(9) 2, 6 – 2, 3, 4 (10) 8, 3, 14 – 3, 37, 8 (11) 8, 5 – 1, 4, 4, 4 (12) 2, 16 – 2, 5, 8, 2