

# CFQ & PP: Reduction - Oxidation Reactions

## Reading

Oxtoby, Gillis and Nachtrieb: Chapter 12

## Lecture Handout

[Balancing Complex Oxidation – Reduction Equations](#)

## Suggested Text Exercises

Oxtoby, Gillis and Nachtrieb: Chapter 12: 1, 3, 5, 7

## Concept Focus Questions

1. What fundamental chemical process occurs in all oxidation and reduction reactions?
2. Define and give an example of oxidation and reduction reactions in both inorganic and organic systems.
3. What two factors must be balanced to write a balanced redox reaction?
4. Prepare a table or make a list that clearly illustrates all five common oxidation states of carbon.

## Concept Focus Questions Solutions

1. A change in the oxidation number of at least two atoms occurs in all oxidation and reduction reactions. Electron transfer (gain or loss) does not occur in every case, especially in reactions involving oxidation or reduction of organic molecules.
2. Oxidation:
  - Inorganic: Loss of electrons. Example:  $\text{Al}^0 \rightarrow \text{Al}^{3+}$
  - Organic: An increase in the number of bonds between carbon and elements that are more electronegative than carbon, usually oxygen. Example:  $\text{CH}_3\text{CH}_3 \rightarrow \text{CH}_3\text{CO}_2\text{H}$

### Reduction:

- Inorganic: Gain of electrons. Example:  $\text{Al}^{3+} \rightarrow \text{Al}^0$
  - Organic: An increase in the number of bonds between carbon and elements that are less electronegative than carbon, usually hydrogen. Example:  $\text{CH}_3\text{CO}_2\text{H} \rightarrow \text{CH}_3\text{CH}_2\text{OH}$
3. When writing a balanced redox reaction, the number of atoms of any element must equal the number of atoms of the same element on the other side. In addition, the number of electrons lost in the oxidation half-reaction(s) must equal the number of electrons gained by the reduction half-reaction(s).

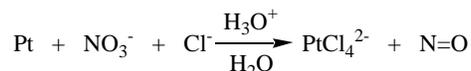
4. Oxidation Number	Example	Structure
-4	Methane	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$
-2	Methanol	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{OH} \\   \\ \text{H} \end{array}$
0	Formaldehyde	$\begin{array}{c} \text{H} \\ \diagdown \\ \text{C}=\text{O} \\ \diagup \\ \text{H} \end{array}$
+2	Formic acid	$\begin{array}{c} \text{HO} \\ \diagdown \\ \text{C}=\text{O} \\ \diagup \\ \text{H} \end{array}$
+4	Carbon dioxide	$\text{O}=\text{C}=\text{O}$

### Practice Problems

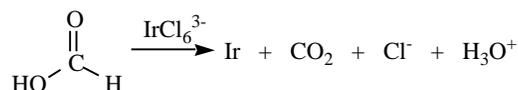
- The mnemonic "LEO says GER" was introduced in lecture to assist in recalling the definitions of oxidation and reduction in terms of electron transfer. A Chem 30A student once suggested "OIL RIG" as a mnemonic for the same purpose. Can you figure out what "OIL RIG" stands for?
- Write a complete reaction that illustrates the oxidation of an organic compound. Very briefly explain how you can tell the organic compound is being oxidized.
- When balancing any oxidation/reduction equation, we balance atoms as well as \_\_\_\_\_.
- In each reaction identify the species that is oxidized, and the species that is reduced.
  - $\text{KMnO}_4 + \text{Na}_2\text{SO}_3 \rightarrow \text{K}_2\text{MnO}_4 + \text{Na}_2\text{SO}_4$  (in basic solution)
  - $\text{Na}_2\text{Cr}_2\text{O}_7 + \text{NaCl} + \text{H}_3\text{O}^+ \rightarrow \text{Cl}_2 + \text{CrCl}_3$
  - $\text{Cu}^+ \rightarrow \text{Cu}^0 + \text{Cu}^{2+}$
  - $$\begin{array}{c} \text{O} \\ || \\ \text{H}_3\text{C}-\text{C}-\text{H} \end{array} + \begin{array}{c} \text{O} \\ || \\ \text{HO}-\text{Cr}-\text{OH} \\ || \\ \text{O} \end{array} \xrightarrow{\text{H}_2\text{SO}_4, \text{H}_2\text{O}} \begin{array}{c} \text{O} \\ || \\ \text{H}_3\text{C}-\text{C}-\text{OH} \end{array} + \text{Cr}^{3+}$$
  - $$\begin{array}{ccccccc} \text{O} & \text{OH} & \text{H} & \text{OH} & \text{OH} & & \\ || & | & | & | & | & & \\ \text{H}-\text{C}- & \text{C}- & \text{C}- & \text{C}- & \text{C}- & \text{CH}_2\text{OH} & \\ | & | & | & | & | & & \\ \text{H} & \text{HO} & \text{H} & \text{H} & \text{H} & & \end{array} \xrightarrow[\text{metabolism}]{\text{O}_2} \text{CO}_2 + \text{H}_2\text{O} + \text{energy}$$

Glucose

5. Balance equations 4 (a) – (e). Do not include spectator ions in the balanced equation.
6. Gold and platinum are insoluble in nitric acid (aqueous  $\text{HNO}_3$ ) or hydrochloric acid (aqueous  $\text{HCl}$ ) alone, but are rapidly attacked and dissolves by aqua regia ("royal water;" a mixture of nitric and hydrochloric acids). Balance the following equation describing the reaction of platinum with aqua regia.



7. In the reaction below, is formic acid ( $\text{HCO}_2\text{H}$ ) oxidized or reduced? Very briefly explain your answer.



8. Lead-acid storage batteries that are used in cars often end up in landfills when discarded. In order to reduce the environmental impact of these batteries it has been suggested that the lead be replaced with carbon monoxide. The unbalanced equation for this  $\text{CO}/\text{PbO}_2$  battery is:



- (a) Balance the equation for the  $\text{CO}/\text{PbO}_2$  battery. You may omit spectator ions.  
 (b) In this reaction is  $\text{CO}$  reduced, oxidized or neither?  
 (c) In this reaction is  $\text{H}_2\text{SO}_4$  reduced, oxidized or neither? Very briefly explain.

### Practice Problems Solutions

1. **Oxidation Involves Loss of electrons; Reduction Involves Gaining electrons.**
2. The carbon of an organic compound is oxidized when there is an increase in number of bonds between that carbon and atoms that are more electronegative than carbon. For the entire molecule to be oxidized there must be a net oxidation. A reaction in which one carbon is oxidized while another carbon in the same molecule is reduced is not an oxidation reaction. Example:

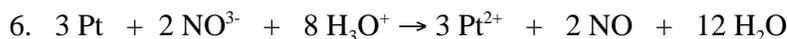


3. When balancing any oxidation/reduction equation, we balance atoms as well as electrons transferred between half-reactions.
4. (a)  $\text{Mn}^{7+}$  ( $\text{KMnO}_4$ )  $\rightarrow$   $\text{Mn}^{6+}$  ( $\text{K}_2\text{MnO}_4$ ) *Gain electrons = reduced.*  
 $\text{S}^{4+}$  ( $\text{Na}_2\text{SO}_3$ )  $\rightarrow$   $\text{S}^{6+}$  ( $\text{Na}_2\text{SO}_4$ ) *Lose electrons = oxidized.*

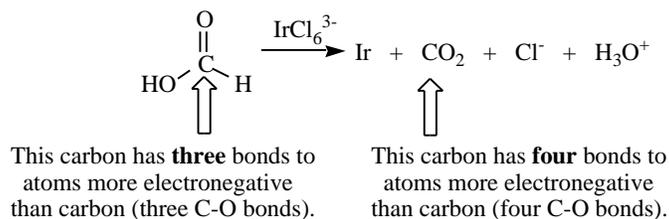
- (b)  $\text{Cr}^{6+} (\text{Na}_2\text{Cr}_2\text{O}_7) \rightarrow \text{Cr}^{3+} (\text{CrCl}_3)$  Gain electrons = reduced.  
 $\text{Cl}^- (\text{NaCl}) \rightarrow \text{Cl}^0 (\text{Cl}_2)$  Lose electrons = oxidized.
- (c)  $\text{Cu}^+ \rightarrow \text{Cu}^0$  Gain electron = reduced.  
 $\text{Cu}^+ \rightarrow \text{Cu}^{2+}$  Lose electron = oxidized.  
 This equation means that for every  $\text{Cu}^+$  ion that is reduced, another  $\text{Cu}^+$  ion is oxidized. It does not mean that each  $\text{Cu}^+$  ion is simultaneously reduced and oxidized.
- (d)  $\text{CH}_3\text{CHO} \rightarrow \text{CH}_3\text{CO}_2\text{H}$  The C=O carbon gains a bond to an atom which is more electronegative than carbon so it is oxidized.  
 $\text{Cr}^{6+} (\text{H}_2\text{CrO}_4) \rightarrow \text{Cr}^{3+}$  Gain electrons = reduction.
- (e) Glucose  $\rightarrow$   $\text{CO}_2$  The carbons all gain bonds to atoms which are more electronegative than carbon so glucose is oxidized.  
 $\text{O}^0 (\text{O}_2) \rightarrow \text{O}^{2-} (\text{CO}_2 \text{ and } \text{H}_2\text{O})$  Gain electrons = reduced.

5. The procedure used to balance these equations can be found in the lecture handout "Balancing Complex Oxidation – Reduction Equations."

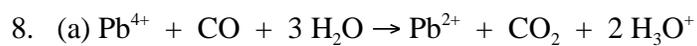
- (a)  $2 \text{MnO}_4^- + \text{SO}_3^{2-} + 2 \text{HO}^- \rightarrow 2 \text{MnO}_4^{2-} + \text{SO}_4^{2-} + \text{H}_2\text{O}$
- (b)  $\text{Cr}_2\text{O}_7^{2-} + 6 \text{Cl}^- + 14 \text{H}_3\text{O}^+ \rightarrow 2 \text{Cr}^{3+} + 3 \text{Cl}_2 + 21 \text{H}_2\text{O}$
- (c)  $2 \text{Cu}^+ \rightarrow \text{Cu}^0 + \text{Cu}^{2+}$  (This equation can easily be balanced by inspection without using the special oxidation/reduction balancing procedure.)
- (d)  $3 \text{CH}_3\text{CHO} + 2 \text{H}_2\text{CrO}_4 + 6 \text{H}_3\text{O}^+ \rightarrow 3 \text{CH}_3\text{CO}_2\text{H} + 2 \text{Cr}^{3+} + 11 \text{H}_2\text{O}$
- (e)  $\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2 \rightarrow 6 \text{CO}_2 + 6 \text{H}_2\text{O}$  (Redox reactions that occur under neutral conditions can usually be balanced by inspection, just like this one.)



7. Formic acid is oxidized because there is an increase in the number of bonds between the carbon atom and elements more electronegative than carbon.



Alternately, we can recall that a reaction that contains a reduction must also contain an oxidation. Iridium is reduced in this reaction ( $\text{Ir}^{3+} \rightarrow \text{Ir}^0$ ), so the formic acid must be oxidized.



(b) CO is oxidized, as the number of bonds between carbon and oxygen is increased.

(c) None of the atoms of  $\text{H}_2\text{SO}_4$  undergo oxidation number changes, so  $\text{H}_2\text{SO}_4$  is not reduced or oxidized.