Module 14 / # Redox Reactions

Describe the direction of electron transfer in oxidation/reduction reactions.	State the name of two common organic electron carriers and show familiarity with changes in the structure that occurs on oxidation/reduction.	Explain how to balance redox reactions.

Oxidation-reduction reactions, or **Redox** reactions are common in metabolic pathways. Generally, degradative (catabolic) pathways cause the net oxidation of compounds, releasing energy. In contrast, synthetic (anabolilc) pathways, are generally reductive pathways.

Oxidations involve the loss of electrons.

Reductions involve the gain of electrons.

Here are two mnemonics to help you remember where the electrons go during redox reactions:

1. **LEO GER:** "leo [the lion] goes grr". Lose electrons oxidation, gain electron reduction.
2. **OIL RIG:** Oxidation involves loss, reduction involves gain.

An example of an oxidation is the conversion of iron from its metallic state, Fe^{0}, to its rusted form, Fe^{+3}, by the loss of three electrons.

$$Fe^{o} \underset{\text{reduction}}{\overset{\text{oxidation}}{\rightleftharpoons}} Fe^{3+} + 3\,e^{-}$$

Oxidation and reduction of iron. Metallic iron, Fe^{0}, becomes oxidized to Fe^{+3} (otherwise known as rust) by the removal of 3 electrons.

The above reaction is an incomplete description of a redox reaction because it does not indicate the fate of the electrons that were obtained from iron. Since free electrons generally cannot exist, all oxidation reactions must be coupled to a corresponding reduction. Since the above reaction only describes one-half of the reaction it is referred to as a **half-reaction**. The oxidation of iron could be coupled to the reduction of copper ions, which is described by the following half-reaction:

$$Cu^{+2} + 1\,e^{-} \xrightarrow{\text{Reduction}} Cu^{+1}$$

Reduction of copper ion from its +2 state to +1 state by gain of an electron.

The complete reaction, balanced such that there are no free electrons, is:

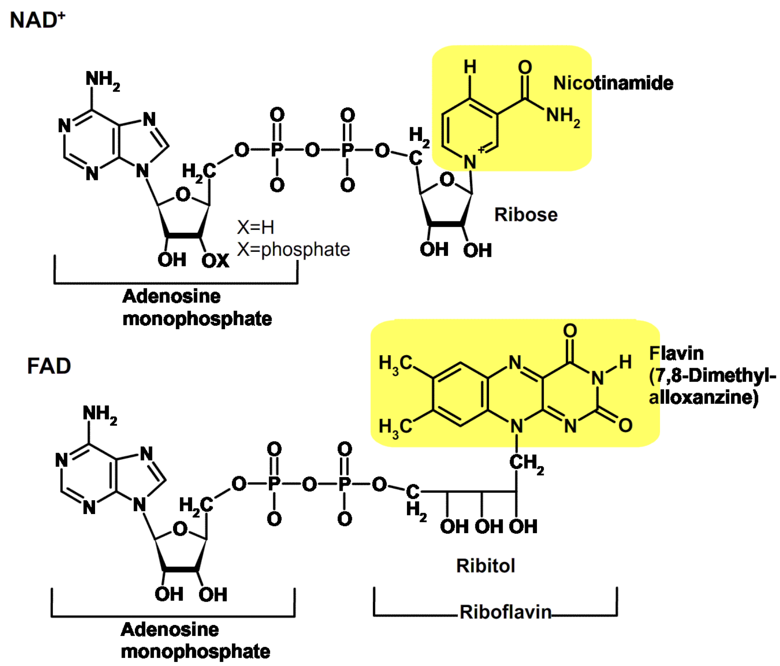
$$3\,Cu^{+2} + Fe^{o} \longrightarrow 3\,Cu^{+1} + Fe^{3+}$$

A balanced redox equation. Three copper^{2+} ions provide a total of three electrons to oxidize metallic iron to Fe^{3+}. Note that there are no free electrons.

The pair of compounds that exchange electrons are often referred to as a **redox couple**.

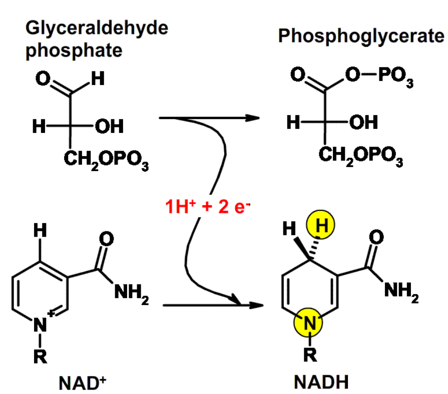
Redox Carriers

In most biochemical redox reactions a total of two electrons are transferred. These electrons are often transferred as hydrogen atoms, containing a proton and electron. Two common electron acceptors are NAD^+ (nicotinamide adenine dinucleotide) and FAD (flavin adenine dinucleotide). They both can accept two electrons, giving the reduced forms NADH and $FADH_2$, respectively. The structure of the oxidized forms of these compounds are shown below.



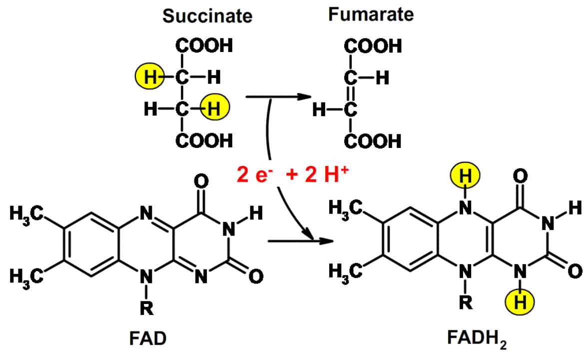
The chemical structures of nicotinamide adenine dinucleotide (NAD^+) and flavin adenine dinucleotide (FAD) are shown. These two compounds are commonly used as electron acceptors in metabolic pathways. The portion of each molecule that accepts electrons during the reduction process is highlighted in yellow.

Oxidation of NAD^+. In the oxidation of glyceraldehyde to phosphoglycerate an aldehyde is oxidized to a carboxylic acid and the released electrons are placed on to NAD^+ to form NADH.



The oxidation of an aldehyde to a carboxylic acid. The two electrons released by the aldehyde are transferred to NAD^+ to make NADH. In this diagram only the portion of NAD^+/NADH that undergoes chemical changes is shown. The remaining part of the NAD molecule is represented by 'R'.

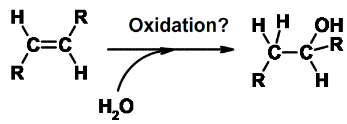
Oxidation of FAD. The oxidation of succinate to fumarate, using FAD as an electron acceptor is another example of a redox reaction found in a metabolic pathway. Two hydrogen atoms (= two electron plus two protons) are removed from succinate and placed on FAD, producing fumarate and $FADH_2$, oxidizing a carbon-carbon single bond to a double bond.



The oxidation of an alkane to an alkene. The two electrons released by the alkane are transferred to FAD to make $FADH_2$. In this diagram only the portion of FAD/$FADH_2$ that undergoes chemical changes is shown. The remaining part of the FAD molecule is represented by 'R'.

Balancing Redox Reactions

It is often difficult to determine from the structure of an organic compound whether it has been oxidized or reduced in a reaction. For example, the addition of a water molecule to an double bond (alkene) appears to be a redox reaction because an -OH group has been added .



The addition of water to a double bond is a common reaction in many pathways. Is it a redox reaction?

The rules for balancing redox reactions are as follows:

1. Make the number of oxygen atoms in the reactant and product equal by adding the appropriate number of water molecules to one side of the reaction or the other.
2. Use H^+, or $H^+ + e^-$, or e^- to balance hydrogen atoms and/or charge.
3. A redox reaction has occurred if electrons are consumed or released

The above reaction is balanced as is, and is therefore not a redox reaction.

Try the following mini-tutor to test your skill at assessing whether a redox reaction has occurred.

Flash Player needed! Please click here to install Flash Player.

did I get this

When a molecule participates in a redox reaction, which of the following properties of the molecule change?

- A double bond is converted to an alcohol, by the addition of oxygen from water.
- The number of electrons.
- The number of phosphate groups.
- The size of the molecule, by cleavage into two parts.

NEXT »

Reset this Activity

77

Open Learning Initiative

Unless otherwise noted this work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License.