**CK- 12 REDOX Introduction – Oxygen, Hydrogen, and electrons**

# Oxygen in Reactions

Many elements simply combine with oxygen to form the oxide of that [element](https://www.ck12.org/c/physical-science/element?referrer=crossref). The heating of magnesium in air allows it to combine with oxygen from the air to form magnesium oxide (see video below).

2 Mg(s) + O2(g) → 2 MgO(g)

Compounds can also react with oxygen, possibly creating oxides of more than one [element](https://www.ck12.org/c/physical-science/element?referrer=crossref). When methane burns, carbon dioxide and [water](https://www.ck12.org/c/biology/water?referrer=crossref) are produced.

CH4(g) + 2 O2(g) → CO2(g) + 2 H2O(g)

Carbon dioxide is an oxide of carbon, while [water](https://www.ck12.org/c/biology/water?referrer=crossref) is an oxide of hydrogen. Early scientists viewed oxidation as a process in which a substance was reacted with oxygen to produce one or more oxides. In the previous examples, magnesium and methane are being oxidized.

Oxidation is also defined as a loss of hydrogen atoms. In the following equation, ethanol is oxidized to acetaldehyde by the loss of two hydrogen atoms:

CH3CH2OH(l) → CH3CHO(l) + H2(g)

Oxidation does not necessarily require heating. Iron that is exposed to air and [water](https://www.ck12.org/c/biology/water?referrer=crossref)slowly oxidizes in a process commonly known as rusting. Bleaches contain various compounds such as sodium hypochlorite (NaClO), which release oxygen that oxidizes stains. Hydrogen peroxide (H2O2) releases oxygen as it spontaneously decomposes. It acts as a bleach and an antiseptic that kills [bacteria](https://www.ck12.org/c/biology/bacteria?referrer=crossref) by oxidizing them.

The [chemical reaction](https://www.ck12.org/c/physical-science/chemical-reaction?referrer=crossref) that is the opposite of oxidation is called reduction. Following from the notion that oxidation was originally thought to mean only the addition of oxygen, reduction was thought to be only the removal of oxygen from a substance. Many naturally occurring metal ores are present as oxides. The pure [metals](https://www.ck12.org/c/physical-science/metals?referrer=crossref) can be extracted by reduction. Iron is obtained from iron(III) oxide by reacting with carbon at high temperatures.

2 Fe2O3(s) + 3 C(s) → 4 FE(s) + 3 CO2(g)

The removal of oxygen from the Fe2O3 means that it is being reduced to Fe. Note that an oxidation process is simultaneously occurring. The carbon reactant is being oxidized to CO2. This is an important concept. Oxidation and reduction must happen together. Neither can happen alone in a reaction.

Reduction can also be considered as a gain of hydrogen. The reverse of the ethanol → acetaldehyde reaction shown above is a reduction reaction:

CH3CHO(l) + H2(g) → CH3CH2OH(l)

The modern way of thinking about REDOX reactions is that they involve the movement of electrons between two chemical species. Most people refer this as meaning REDOX reactions involve the exchange of electrons. For example, hen zinc metal is submerged into a quantity of aqueous HCl, the following reaction occurs

Zn(s) + 2HCl(aq) → H2(g) + ZnCl2(aq)

This is one example of what is sometimes called a *single replacement reaction* because Zn replaces H in combination with Cl.

Because some of the substances in this reaction are aqueous, we can separate them into ions:

Zn(s) + 2H+(aq) + 2Cl−(aq) → H2(g) + Zn2+(aq) + 2Cl−(aq)

Viewed this way, the net reaction seems to be a charge transfer between zinc and hydrogen atoms. (There is no net change experienced by the chloride ion.) This change in charge of the Zinc and the hydrogen is the result of electrons transferred from the zinc atoms to the hydrogen atoms (which ultimately make a molecule of diatomic hydrogen), changing the charges on both elements.

To understand electron-transfer reactions like the one between zinc metal and hydrogen ions, chemists separate them into two parts: one part focuses on the loss of electrons, and one part focuses on the gain of electrons. The loss of electrons is called oxidation. The gain of electrons is called reduction. Because any loss of electrons by one substance must be accompanied by a gain in electrons by something else, oxidation and reduction always occur together. As such, electron-transfer reactions are also called oxidation-reduction reactions, or simply redox reactions. The atom that loses electrons is oxidized, and the atom that gains electrons is reduced. In addition, because we can think of the species being oxidized as causing the reduction, the species being oxidized is called the reducing agent, and the species being reduced is called the oxidizing agent.

Although the two reactions occur together, it can be helpful to write the oxidation and reduction reactions separately as half reactions. In half reactions, we include only the reactant being oxidized or reduced, the corresponding product species, any other species needed to balance the half reaction, and the electrons being transferred. Electrons that are lost by reactants are written as products; electrons that are gained by reactants are written as reactants. For example, in our earlier equation, now written as a net ionic equation:

Zn(s) + 2H+(aq) → Zn2+(aq) + H2(g)

Zinc atoms are oxidized to Zn2+. The half reaction for the oxidation reaction, omitting phase labels, is:

Zn → Zn2+ + 2e−

This half reaction is balanced in terms of the number of zinc atoms, and two electrons are shown as products. These are the two electrons lost by the zinc atom to become a 2+ ion. With half reactions, as well as balancing for the number of electrons on each side, the overall charge must be balanced on each side of the reaction. If you check each side of this reaction, you will note that both sides have a zero net charge.

Hydrogen is reduced in the reaction. The balanced reduction half reaction is as follows:

2H+ + 2e− → H2

There are two hydrogen atoms on each side, and the two electrons written as reactants serve to neutralize the 2+ charge on the reactant hydrogen ions. Again, the overall charge on both sides is zero.

The overall reaction is simply the combination of the two half reactions and is shown by adding them together.

Zn + 2H+ + 2e− → Zn2+ + 2e− + H2

As both sides have the same number of electrons gained and lost, this simplifies to:

Zn(s) + 2H+(aq) → Zn2+(aq) + H2(g)

For a balanced redox reaction: the electrons have to cancel exactly. If we check the charge on both sides of the equation, we see they are the same—2+. (In reality, this positive charge is balanced by the negative charges of the chloride ions, which are not included in this reaction because chlorine does not participate in the charge transfer.)

Summary

* Oxidation and reduction reactions must occur together.
* Oxidation and Reduction can be defined in three ways.

# Review

1. Give a definition of oxidation in terms of oxygen.
2. Give a definition of reduction in terms of oxygen.
3. Explain CH4(g) + 2O2(g) → CO2(g) + 2H2O(g) in terms of the definitions of oxidation and reduction: