Unit 27
Oxidation and Reduction Definitions (Chapter 8)

• Definition of oxidation and reduction as a gain or loss of oxygen (8.1)
• Definition of oxidation and reduction as gain or loss of hydrogen (8.1)
• Definition of oxidation and reduction as gain or loss of electrons (8.1)
• Identification of oxidizing agents and reducing agents (8.2)
• Oxidation and reduction always occur together – no process occurs that involves just one of the processes.

• Substances in reduced forms are high in energy – they have the capability of releasing energy when they are oxidized.
• Substances in oxidized forms are low in energy – they cannot release much in the way of energy.

• Historically oxidation was first associated with the addition of oxygen to compounds.

• Over time the recognition of the oxidation process has become much more broad.

• We will consider three processes for identifying species that are oxidized and those that are reduced.
In Terms of Oxygen Atoms (8.1)

• The definition of oxidation and reduction in terms of oxygen atoms is:
  
  • oxidation – the gain of oxygen atoms
  • reduction – the loss of oxygen atoms

• Example:

\[
\text{C}_3\text{H}_8 (g) + 5 \text{O}_2 (g) \rightarrow 3 \text{CO}_2 (g) + 4 \text{H}_2\text{O} (g)
\]

• The carbon and hydrogen have been oxidized – they have gained oxygen.
• So which element has been reduced? Oxygen is the only one left – it has been reduced. Alternatively, you could imagine that the oxygen was originally by itself and now is “sharing” itself with other atoms – it is no longer pure oxygen so it has “lost” oxygen.
In Terms of Hydrogen Atoms (8.1)

• The definition of oxidation and reduction in terms of hydrogen atoms is:
  
  - oxidation – the loss of hydrogen atoms
  - reduction – the gain of hydrogen atoms

• Example:

  \[
  C_3H_8 (g) + 5 O_2 (g) \rightarrow 3 CO_2 (g) + 4 H_2O (g)
  \]

  • The carbon has been oxidized – it has lost hydrogen.
  • The oxygen has been reduced – it has gained hydrogen.
In Terms of Electrons (8.1)

• The definition of oxidation and reduction in terms of hydrogen atoms is:
  • oxidation – the loss of electrons
  • reduction – the gain of electrons

• Example:

  $2 \text{Na} + \text{Cl}_2 \rightarrow 2 \text{Na}^+ + 2 \text{Cl}^-$

  The elemental Na has its full complement of 11 electrons – no electrical charge.

  The chlorine atoms have their full complement of 17 electrons each – no electrical charge.

  The sodium atoms are now ionic with a 1+ charge – they have lost an electron.

  These chlorine atoms are now ionic with a 1- charge each – they have gained an electron.

• The sodium has been oxidized – it has lost an electron.
• The chlorine has been reduced – it has gained an electron.
• The term oxidation number is sometimes used to refer to the charge on a simple ion, as well as in many other cases. For a neutral element, the oxidation number is zero.

• In the preceding example (reproduced below), the oxidation number of sodium is 0 initially since it is the elemental form and changes to +1 in going to the products. Thus a gain in oxidation number corresponds to a loss of electrons and an oxidation. We can say that oxidation occurs when the species gives up electrons or when the oxidation number increases.

• For chlorine, the oxidation number is 0 initially since it is the elemental form and changes to -1 in going to the products. Thus a decrease in oxidation number corresponds to a gain of electrons and an reduction. We can say that reduction occurs when the species gains electrons or when the oxidation number decreases.

\[ 2 \text{Na} + \text{Cl}_2 \rightarrow 2 \text{Na}^+ + 2 \text{Cl}^- \]
Which Approach to Use? (8.1)

• Which of the three oxidation-reduction definitions is best to use? It depends on the situation, though they will all result in the same determination of what is oxidized and what is reduced. Some points, a few of which will probably be obvious:

  • If oxygen is not present in the equation, the definition based on oxygen obviously cannot be used.
  • If hydrogen is not present in the equation, the definition based on hydrogen obviously cannot be used.
  • The definition in terms of electrons is the most general, but gets to be a little more complicated for some reactions.
  • Some fields of study will tend to use one approach more than the others. For example, many biochemical equations involve the transfer of hydrogen ions which makes the definition based on hydrogen the most useful.
Oxidizing and Reducing Agents (8.1)

• In ordinary English, an agent is something (or someone) that causes something to happen. The same terminology can be applied to oxidation and reduction.

  • Oxidizing agent – a substance that causes another material to be oxidized.
  • Reducing agent – a substance that causes another material to be reduced.

• Think in terms of the electron definition:

  • An oxidizing agent causes another material to be oxidized – i.e., to lose electrons. Therefore the oxidizing agent accepts the electrons and is itself reduced.
  • A reducing agent cause another material to be reduce – i.e., to gain electrons. Therefore the reducing agent itself loses electrons and is itself oxidized.
Oxidizing and Reducing Agents – Examples (8.1)

• Consider the reaction below:

\[
\text{SnO} + \text{H}_2 \rightarrow \text{Sn} + \text{H}_2\text{O}
\]

• Each Sn atom has one O atom

• Each Sn atom loses an oxygen and is reduced

• The SnO is reduced since it loses oxygen.
• The H\textsubscript{2} is oxidized because it gains oxygen.
• So, the SnO is reduced and serves as the oxidizing agent since it causes the oxidation of the H\textsubscript{2}.
• The H\textsubscript{2} is oxidized and serves as the reducing agent since it causes the reduction of the SnO.