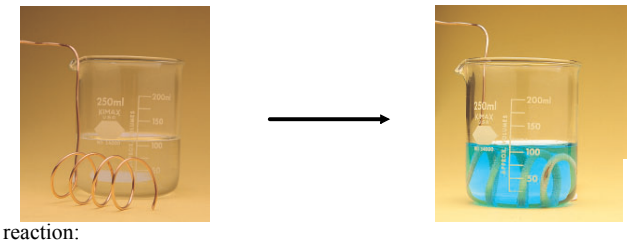
Topic 1 - Reduction and Oxidation Half Reactions

Single replacement reactions are a good illustration of electron transfer

All of these reactions share a common feature:

Ions are converted to atoms and atoms are converted to ions

Example: the reduction of aqueous silver nitrate to silver metal in the presence of solid copper



Non-ionic reaction:

$Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow 2Ag_{(s)} + Cu(NO_3)_{2(aq)}$

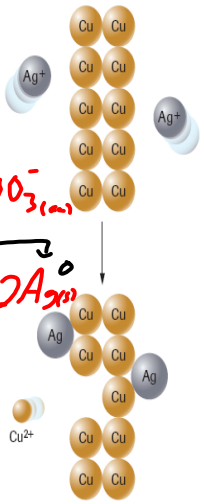
Total ionic reaction:

$Cu_{(s)} + 2Ag^{+}_{(aq)} + 2NO^{-}_{3(aq)} \rightarrow 2Ag_{(s)} + Cu^{2+}_{(aq)} + 2NO^{-}_{3(aq)}$

Net ionic reaction:

$Cu^{0}_{(s)} + 2Ag^{+}_{(aq)} \rightarrow Cu^{2+}_{(aq)} + 2Ag^{0}_{(s)}$

losing e⁻ - oxidation



Animation showing electron transfer

Oxidaon Numbers

To describe the oxidaon and reducon of atoms, ions, molecules and polyatomic ions, chemists developed a method of "electron bookkeeping" to keep track of the loss and gain of electrons

For atoms in **molecules and polyatomic ions,** chemists count a **shared pair** of electrons in a covalent bond as if it belongs enrely to the more electronegave atom in the bond

An ***oxidaon number*** is a posive or negave number that a atom **would have** if it completely lost/gained the electrons it shared with other atoms

For example, in a water molecule, the oxidaon number of the oxygen atom is -2 and the oxidaon number of each hydrogen atom is +1.

+1 -2
H_2O

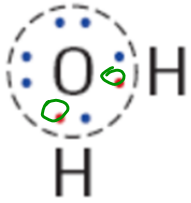


Table 1 Common Oxidation Numbers

Atom or ion	Oxidation number	Examples
all atoms in elements	0	Na is 0 Cl in Cl_2 is 0
hydrogen in all compounds, except hydrogen in hydrides	+1 −1	H in HCl is +1 H in LiH is −1
oxygen in all compounds, except oxygen in peroxides	−2 −1	O in H_2O is −2 O in H_2O_2 is −1
all monatomic ions	charge on ion	Na^+ is +1 S^{2-} is −2

SUMMARY ***Determining Oxidation Numbers***

Step 1: Assign common oxidation numbers (**Table 1** on page 583).
Step 2: The total of the oxidation numbers of atoms in a molecule or ion equals the value of the net electric charge on the molecule or ion.
(a) The sum of the oxidation numbers for a compound is zero.
(b) The sum of the oxidation numbers for a polyatomic ion equals the charge on the ion.
Step 3: Any unknown oxidation number is determined algebraically from the sum of the known oxidation numbers and the net charge on the entity.

Learning Tip

1. The sum of the oxidation numbers of any entity must equal the net charge on that entity: zero for neutral compounds, the ion charge for polyatomic ions.
2. The method only works if there is just one unknown after referring to **Table 1**. If there are two or more unknowns, a Lewis formula and electronegativities are required.

Examples

a. What is the oxidation number of carbon in methane?

-4 +1
CH_4
(-4) (+4) = 0

b. What is the oxidation number of manganese in the permanganate ion?

+7 -2
MnO_4^-
(+7) + (-8) = -1

c. What is the oxidation number of sulfur in sodium sulfate?

+1 +6 -2
Na_2SO_4
(+2) (+6) (-8) = 0

Na^+
SO_4^{2-}

1. Determine the oxidation number of
   (a) S in SO_2 +4
   (c) S in SO_4^{2-} +6
   (e) I in MgI_2 -1
   (b) Cl in $HClO_4$ +7
   (d) Cr in $Cr_2O_7^{2-}$ +6
   (f) H in CaH_2 -1

2. Determine the oxidation number of nitrogen in
   (a) $N_2O(g)$ +1
   (b) $NO(g)$ +2
   (c) $NO_2(g)$ +4
   (d) $NH_3(g)$ -3
   (e) $N_2H_4(g)$ -2
   (f) $NaNO_3(s)$ +5
   (g) $N_2(g)$ 0
   (h) $NH_4Cl(s)$ -3

$\overset{0}{N_2}$

$\overset{-3}{N}\overset{+1}{H_4}\overset{-1}{Cl}$
$-3 \quad (+4) \quad (-1) = 0$

3. Determine the oxidation number of carbon in
   (a) graphite (elemental carbon) $C(s)$
   (b) glucose
   (c) sodium carbonate
   (d) carbon monoxide

$\overset{0}{C_6}\overset{+1}{H_{12}}\overset{-2}{O_6}$
$0 \quad +12 \quad -12 = 0$

$\overset{+1}{Na_2}\overset{+4}{C}\overset{-2}{O_3}$
$(+2) \quad +4 \quad (-6) = 0$

$\overset{+2}{C}\overset{-2}{O}$
$+2 \quad -2 = 0$

4. Bruderheim, Alberta, is the site of several companies that produce sodium chlorate. Almost all of the sodium chlorate produced is sold to pulp and paper mills to produce chlorine dioxide as a bleaching agent (**Figure 2**). Determine the oxidation number of every atom or ion in the following chemical equation for the industrial production of chlorine dioxide.

$$\overset{+5\ -2}{2\,ClO_3^-}(aq) + 2\overset{-1}{Cl^-}(aq) + 4\overset{+1}{H^+}(aq) \rightarrow \overset{+4\ -2}{2\,ClO_2}(g) + \overset{0}{Cl_2}(g) + \overset{+1\ -2}{2\,H_2O}(l)$$

disproportionation

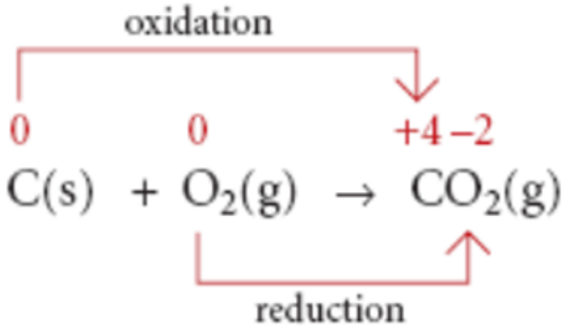
- Same element is oxidized and reduced

Determining what is oxidized and reduced using Oxidaon Numbers

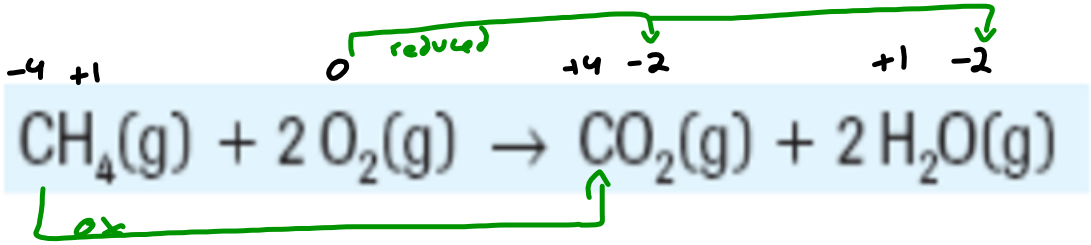
We can use oxidaon numbers to help us figure out what is oxidized and what is reduced in a redox reacon

Based on oxidaon numbers:

- an **increase** in the oxidaon number is defined as **oxidaon**
  - ↳ more + ive
- a **decrease** in the oxidaon number is a **reducon**
  - ↳ more - ive



Example:
When natural gas burns in a furnace, carbon dioxide and water form. Identify oxidation and reduction in this reaction.



Example:
What gets oxidized and what gets reduced in this reaction?