Chemistry in Action
Photochromic Lenses

Photochromic eyeglasses darken when exposed to ultraviolet light and become transparent again in the absence of ultraviolet light. This process is the result of oxidation-reduction reactions. Silver chloride and copper(I) chloride are embedded in the lenses. The chloride ions absorb photons, and the silver chloride dissociates and forms chlorine atoms and silver atoms. The elemental silver darkens the lenses. Note that the chlorine ions are oxidized and the silver atoms are reduced. Then, the copper(I) ions reduce the chlorine atoms and form copper(II) ions. In the reverse process, the copper(II) ions oxidize the silver atoms back to the transparent silver ions.

appear as reactants in the reduction half-reaction. When metallic copper reacts in nitric acid, one copper atom is oxidized to Cu^{2+} as two nitrogen atoms are reduced from a +5 oxidation state to a +4 oxidation state. Atoms are conserved. This is illustrated by the balanced chemical equation for the reaction between copper and nitric acid.

If none of the atoms in a reaction change oxidation state, the reaction is *not* a redox reaction. For example, sulfur dioxide gas, SO_2, dissolves in water to form an acidic solution containing a low concentration of sulfurous acid, H_2SO_3.

$$\overset{+4\;-2}{SO_2} + \overset{+1\;-2}{H_2O} \longrightarrow \overset{+1\;+4\;-2}{H_2SO_3}$$

The oxidation states of all elemental species remain unchanged in this composition reaction. Therefore, it is *not* a redox reaction.

When a solution of sodium chloride is added to a solution of silver nitrate, an ion-exchange reaction occurs and white silver chloride precipitates.

$$\overset{+1}{Na^+} + \overset{-1}{Cl^-} + \overset{+1}{Ag^+} + \overset{+5\;-2}{NO_3^-} \longrightarrow \overset{+1}{Na^+} + \overset{+5\;-2}{NO_3^-} + \overset{+1\;-1}{AgCl}$$

The oxidation state of each monatomic ion remains unchanged. Again, this reaction is not an oxidation-reduction reaction.

Redox Reactions and Covalent Bonds

Both the synthesis of NaCl from its elements and the reaction between copper and nitric acid involve ionic bonding. Substances with covalent bonds also undergo redox reactions. An oxidation number, unlike an ionic charge, has no physical meaning. That is, the oxidation number assigned to a particular atom is based on its electronegativity relative to the other atoms to which it is bonded in a given molecule; it is not based on any real charge on the atom. For example, an ionic charge of 1− results from the complete gain of one electron by an atom or other neutral species, whereas an oxidation state of −1 means an increased attraction for a bonding electron. A change in oxidation number does not require a change in actual charge.

When hydrogen burns in chlorine, a covalent bond forms from the sharing of two electrons. The two bonding electrons in the hydrogen chloride molecule are not shared equally. Rather, the pair of electrons is more strongly attracted to the chlorine atom because of its higher electronegativity.

$$\overset{0}{H_2} + \overset{0}{Cl_2} \longrightarrow 2\overset{+1\;-1}{HCl}$$

As specified by Rule 3 in **Table 1,** chlorine in HCl is assigned an oxidation number of −1. Thus, the oxidation number for the chlorine atoms changes from 0, its oxidation number in the elemental state, to −1; chlorine atoms are reduced. As specified by Rule 1, the oxidation number of each hydrogen atom in the hydrogen molecule is 0. As specified by Rule 6, the oxidation state of the hydrogen atom in the HCl molecule is +1; the