

Redox Reactions

Key Words

oxidation number: number given to each atom in a chemical formula to show the number of electrons that might be gained, lost, or shared during bond formation.

redox reaction: short term for an oxidation-reduction reaction

KEY IDEAS

In a redox reaction, oxidation numbers change. These numbers are used to show the direction of electron movement in the reactions. When an atom loses electrons, its oxidation number increases. When an atom gains electrons, its oxidation number decreases.

Redox reactions that take place in the body can lead to disease and aging. Antioxidants can stop or slow down harmful redox reactions. For this reason, nurses and other health care workers need to know about antioxidants present in foods and medicines.

Finding Oxidation Numbers. Electrons are gained, lost, or shared when atoms bond together. Oxidation numbers are used to keep track of electrons during bonding. It is easy to find the **oxidation number** of an atom by using the following set of rules:

The oxidation number of a one-atom ion is equal to its charge. For example, the oxidation number of calcium in Ca^{2+} is +2. The oxidation number of sulfur in S^{2-} is -2.

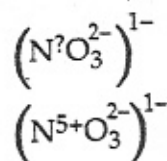
The oxidation number of an element is zero. An uncombined atom such as K or P has an oxidation number of zero. When atoms of the same element bond together, each atom also has an oxidation number of zero. Thus the oxygen atoms in O_2 and the oxygen atoms in ozone O_3 both have oxidation numbers of zero.

In compounds made up of only two elements, the more electronegative element has a negative oxidation number. The less electronegative element has a positive oxidation number. In PCl_3 , chlorine is more electronegative than phosphorus. Chlorine therefore has an oxidation number of -1. Phosphorus in PCl_3 is less electronegative than chlorine. Thus, phosphorus has a charge of +3.

In compounds, hydrogen usually has an oxidation number of +1. Oxygen usually has an oxidation number of -2. In HCl , the oxidation number of hydrogen is +1. In CaO , the oxidation number of oxygen is -2.

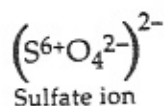
The sum of the oxidation numbers in an ion made up of many elements is equal to its charge. One example is the nitrate ion NO_3^- , shown in Fig. 41-1. In this ion, each oxygen atom has an oxidation number of -2 . Three oxygen atoms have an oxidation number of -6 , since $3(-2) = -6$. The sum of the oxidation numbers is the charge on the ion, which is -1 . That is, the oxidation number of nitrogen added to -6 should equal -1 . So the oxidation number of the nitrogen must be $+5$.

Fig. 41-1



In the sulfate ion SO_4^{2-} , the oxidation numbers add up to -2 . Look at Fig. 41-2. Each oxygen atom has an oxidation number of -2 . The oxidation number of sulfur is $+6$ because $(+6) + (4)(-2) = -2$.

Fig. 41-2



The sum of the oxidation numbers in a compound is zero. In water, the oxidation number of the oxygen is -2 . The oxidation number of each hydrogen is $+1$. The oxidation number of both hydrogens is $2(+1) = +2$. The sum of -2 for the oxygen and $+2$ for the hydrogens is zero. In nitric acid HNO_3 , the oxidation number of the hydrogen is $+1$, and the charge on the nitrate ion is -1 .

- ☒ 1. What is the oxidation number of a free element? _____
- ☒ 2. What is the usual oxidation number of oxygen? _____
- ☒ 3. What is the sum of the oxidation numbers in a compound? _____

Oxidation Numbers in Reactions. A redox reaction is an oxidation-reduction reaction. Look at the equation shown in Fig. 41-3.

Fig. 41-3



In this reaction, the oxidation number of the bromine changes from -1 to 0 . The oxidation number of the chlorine changes from 0 to -1 . Each bromine atom loses an electron, which is oxidation. Each chlorine atom gains an electron, which is reduction. Thus, the reaction shown is a redox reaction.

Now look at the equation in Fig. 41-4. In this reaction, no change of oxidation numbers occurs. If none of the oxidation numbers change, no redox reaction takes place.

Fig. 41-4



TAKE ANOTHER LOOK

Look at the redox reaction between sodium (Na) and sulfur (S) shown in Figs. 41-5 and 41-6. The diagrams show the movement of electrons during the same reaction in different ways. Notice that sodium loses electrons, which is oxidation. Sulfur gains electrons, which is reduction. The oxidation number of each sodium atom increases from 0 to +1. The oxidation number of the sulfur atom decreases from 0 to -2.

Fig. 41-5

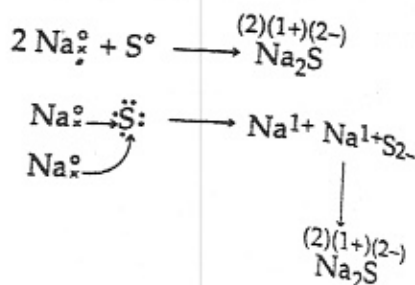
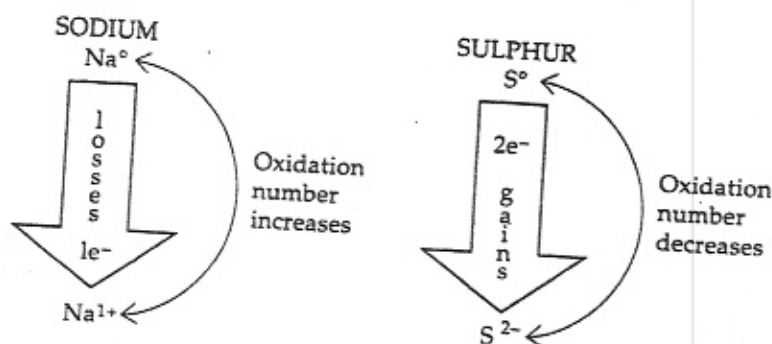


Fig. 41-6



Check Your Understanding

Fill in the blanks with the correct terms.

The rules for finding oxidation numbers are the following: The oxidation number of an ion equals (4) _____. The oxidation number of an element equals (5) _____. In two-element compounds, the more electronegative element has a (6) _____ charge, and the less electronegative element has a (7) _____ charge. Hydrogen usually has an oxidation number of (8) _____, and the oxidation number of oxygen is usually (9) _____. The sum of the oxidation numbers of an ion equals (10) _____. The sum of the oxidation numbers of a compound equals (11) _____.

Assign oxidation numbers to each element in the following unbalanced equation.



12. The oxidation number of the nitrogen changes from _____ to _____.
13. The oxidation number of the oxygen changes from _____ to _____.

What
Do You
Know?

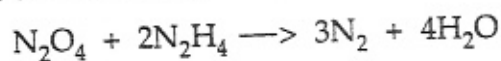
14. What is the oxidation number of each element in the following compounds?

- (a) HCl _____
- (b) H_2SO_4 _____
- (c) KMnO_4 _____
- (d) NO _____

15. Which of the following reactions are redox reactions? _____

- (a) $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$
- (b) $\text{NaCl} + \text{AgNO}_3 \rightarrow \text{AgCl} + \text{NaNO}_3$
- (c) $\text{Zn} + \text{CuSO}_4 \rightarrow \text{Cu} + \text{ZnSO}_4$
- (d) $2\text{HgO} \rightarrow 2\text{Hg} + \text{O}_2$

Dinitrogen tetroxide (N_2O_4) and hydrazine (N_2H_2) are used as rocket fuels. The reaction between these two compounds produces nitrogen and water, as shown below.



16. What two changes of oxidation number does the nitrogen undergo?

17. Does the oxidation number of the oxygen change? _____
