



Chapter 11

Oxidations and Reductions

THE MAIN IDEA



Oxidation is the loss of electrons, and reduction is the gain of electrons.

11.1 [Losing and Gaining Electrons](#)

11.2 [Harnessing the Energy](#)

11.3 [Electricity from Batteries](#)

11.4 [Electricity from Fuel Cells](#)

11.5 [Energy from Photovoltaics](#)

11.6 **Electrolysis Produces Change**

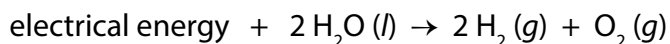
11.7 [Producing Metals](#)

11.8 [Corrosion and Combustion](#)

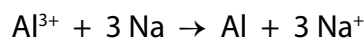


11.6 Electrolysis Produces Change

Electrolysis is the use of electrical energy to produce chemical change. The recharging of a car battery is an example of electrolysis. Another, shown in **Figure 11.22**, is passing an electric current through water, a process that breaks down the water into its elemental components:



Electrolysis is used to purify metals from metal ores. An example is aluminum, the third most abundant element in the Earth's crust. Aluminum occurs naturally bonded to oxygen in an ore called *bauxite*. Aluminum metal wasn't known until about 1827, when it was prepared by reacting bauxite with hydrochloric acid. This reaction gave the aluminum ion, Al^{3+} , which was reduced to aluminum metal, with sodium metal acting as the reducing agent:



This chemical process was expensive, which is why the initial price of aluminum was well beyond the means of the average person. Aluminum was thus considered a rare and precious metal. In 1855, aluminum dinnerware and other items were exhibited in Paris with the crown jewels of France. Then, in 1886, two men working independently, Charles Hall (1863–1914) in the United States and Paul Heroult (1863–1914) in France, almost simultaneously discovered a process whereby aluminum could be produced from aluminum oxide, Al_2O_3 , a main component of bauxite. In what is now known as the Hall–Heroult process, shown in **Figure 11.23**, a strong electric current is passed through a molten mixture of aluminum oxide and cryolite, Na_3AlF_6 , a naturally occurring mineral. The fluoride ions of the cryolite react



READING CHECK

What is electrolysis?

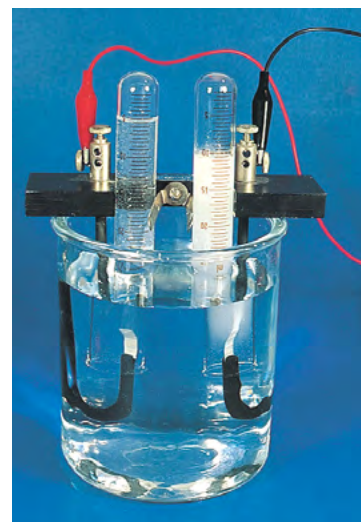
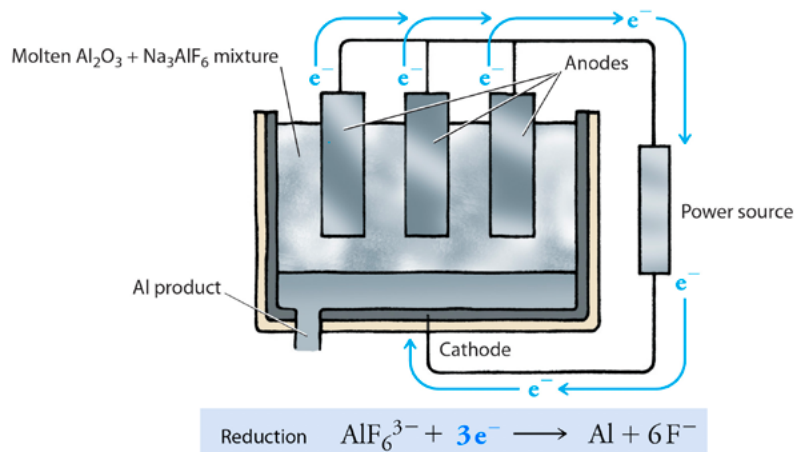
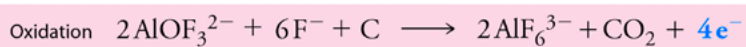


Figure 11.22

The electrolysis of water produces hydrogen gas and oxygen gas in a 2:1 ratio by volume, in accord with the chemical formula for water: H_2O . In order for this process to work, ions must be dissolved in the water so that electric charge can be conducted between the electrodes.



< **Figure 11.23**

The melting point of aluminum oxide (2030°C) is too high for efficiently electrolyzing it to aluminum metal. Aluminum oxide, however, dissolves in molten cryolite at a more reasonable 980°C. A strong electric current passed through the molten aluminum oxide–cryolite mixture generates aluminum metal at the cathode, where aluminum ions pick up electrons and are thus reduced to elemental aluminum.



FOR YOUR INFORMATION

Charles Hall and Paul Heroult not only invented the cryolite process at about the same time, but they were born and died in the same years. Hall lived 51 years and 21 days. Heroult lived 51 years and 29 days. Both became rich and famous for their inventions and held no grudges against the other. Hall won the U.S. patent for the process in great part because of the careful records kept by his sister, Julia Brainerd Hall, who assisted him in his work. To be considered, if none of these individuals had been born, how much longer would it have taken for the cryolite method to be discovered? In the race to be the first, there is usually only one winner.

with the aluminum oxide to form various aluminum fluoride ions, such as $\text{AlO}_2\text{F}_3^{2-}$, which are then oxidized to the aluminum hexafluoride ion, AlF_6^{3-} . The Al^{3+} in this ion is then reduced to elemental aluminum, which collects at the bottom of the reaction chamber. This process, which is still in use by manufacturers today, greatly facilitated mass production of aluminum metal, and by 1890, the price of aluminum had dropped to about \$2 per pound.

Today, worldwide production of aluminum is over 64 million metric tons annually. For each ton produced from ore, about 16,000 kilowatt-hours of electrical energy is required, as much as a typical American household consumes in 18 months. Processing recycled aluminum, on the other hand, consumes only about 700 kilowatt-hours for every ton. Thus, recycling aluminum not only reduces litter but also helps to reduce the load on power companies, which in turn reduces air pollution. Furthermore, reserves of high-quality aluminum oxide ores are already depleted in the United States. Recycling aluminum, therefore, also helps to minimize the need to develop new bauxite mines in foreign countries.

CONCEPT CHECK

Is the exothermic reaction in a hydrogen–oxygen fuel cell an example of electrolysis?

CHECK YOUR ANSWER No. During electrolysis, electrical energy is used to produce chemical change. In the hydrogen–oxygen fuel cell, chemical change is used to produce electrical energy.