Aluminum Production by Electrolysis

Aluminum is the most abundant metal in Earth's crust. It is a relatively reactive metal; therefore, in nature, it is found as its oxide in an ore called *bauxite.* Aluminum is now very useful commercially, but it was not until 1886 that a process to obtain pure aluminum metal was discovered. Charles M. Hall (from the United States) and Paul Héroult (from France) simultaneously, but independently, determined a practical method for producing aluminum; it is an electrolytic process called the Hall-Héroult process.

Bauxite ore contains not only aluminum oxide (Al_2O_3), but oxides of iron, silicon, and titanium. Therefore, the aluminum oxide (called alumina) must first be separated from the other compounds in the ore. The pure hydrated alumina ($Al_2O_3 \cdot nH_2O$) is obtained by treating bauxite with sodium hydroxide, which dissolves the alumina but does not dissolve the other compounds in the ore. The alumina solution is then separated from the remaining solid compounds and reprecipitated to obtain pure alumina. The purified alumina is dissolved in molten cryolite, Na_3AlF_6, at 970°C in an electrochemical cell, and the aluminum ions are reduced to aluminum metal. The liquid aluminum is denser than the molten cryolite and alumina; therefore, the molten aluminum metal settles to the bottom of the cell and is drained off periodically.

The electrolytic solution contains a large number of aluminum-containing ions, and the chemistry of the electrochemical reaction is not completely understood. Scientists still debate the exact species that participate in the half-reactions; but the overall cell reaction is

$$2Al_2O_3(l) + 3C(s) \longrightarrow 4Al(l) + 3CO_2(g),$$

where carbon is the anode and steel is the cathode in the cell.

The aluminum metal produced in this process is 99.5% pure. The Hall-Héroult process made the production of aluminum economically feasible. However, this process is the largest single user of electrical energy in the United States—nearly 5% of the national total. Recycling aluminum saves almost 95% of the cost of production. Aluminum recycling is one of the most economically worthwhile recycling programs that has been developed.

Chemistry in Action

Sodium Production by Electrolysis

Sodium is such a reactive metal that preparing it through a chemical process can be dangerous. Today, sodium is produced mainly by the electrolysis of molten sodium chloride. The melting point of sodium chloride is about 800°C; but mixing it with solid calcium chloride lowers the melting point to around 600°C. This mixture is introduced into an electrolytic cell called the Downs Cell to retrieve the sodium metal, and the lower melting point allows the cell to use less electrical energy to run.

SECTION REVIEW

1. Describe an electrolytic cell.
2. Explain the process of electroplating.
3. What is a rechargeable cell?
4. Give an example of how electrolytic cells are used in industry.

Critical Thinking

5. **APPLYING CONCEPTS** Copper ore contains zinc metal, which is oxidized along with Cu during the electrolytic purification process. However, the Zn^{2+} ions are not then reduced when the Cu^{2+} ions are reduced to Cu at the cathode to obtain purified copper metal. Explain how Zn can be oxidized with Cu, but their ions not be reduced together.