Applications of Electrolysis

Industrial applications of electrolytic cells include the production of elements, the refining of metals, and the plating of metals onto the surface of an object.

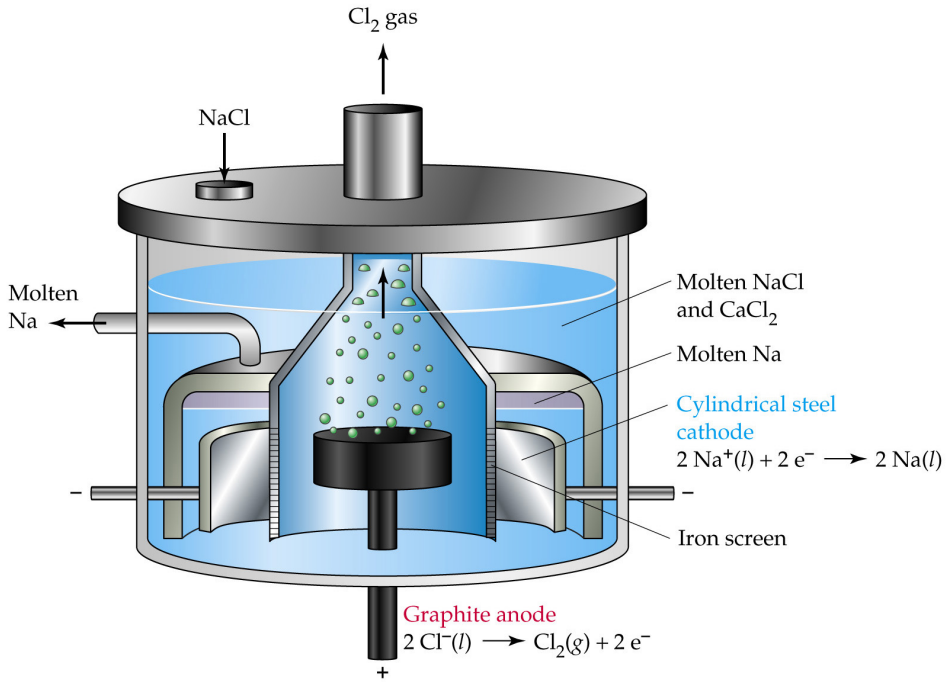
Production of Elements

Many elements can be produced by electrolysis of solutions of their ionic compounds, but two difficulties arise. First, many naturally occurring ionic compounds have low solubility in water. Second, water is a stronger oxidizing agent than active metal cations.

To overcome these difficulties, a cell design in which water is not present can be used. When an ionic compound is melted, the resulting molten ionic compound is a good conductor of electricity, and can function as the electrolyte in a cell.

The production of active metals (strong reducing agents) from their minerals typically involves the electrolysis of molten compounds of the metal. In the electrolysis of a molten ionic compound, only one oxidizing agent and one reducing agent are present.

The cell illustrated below is used in the electrolysis of molten sodium chloride. This process can be used to collect elemental sodium ($Na(s)$) and chlorine ($Cl_2(g)$).



Chloride ions undergo oxidation at the anode to produce chlorine gas. This gas rises out of the top of the cell and is collected.

$$2Cl^- \rightarrow Cl_2(g) + 2e^-$$

Sodium ions undergo reduction at the cathode to produce metallic sodium. The liquid sodium floats to the top of the molten sodium chloride and is collected via an outlet tube.

$$2Na^{+} + 2e^{-} \rightarrow 2Na(l)$$

The overall cell reaction is given below.

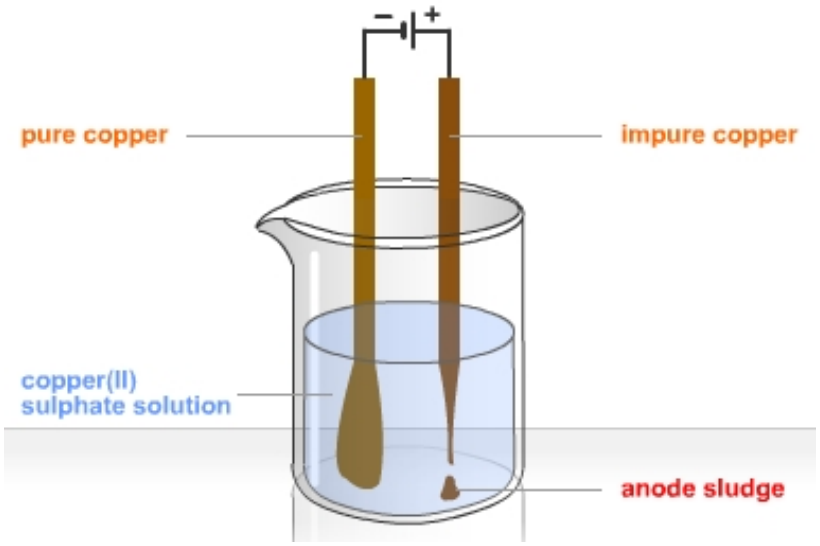
$$2Cl^{-} + 2Na^{+} \rightarrow Cl_2(g) + 2Na(l)$$

A similar apparatus can be used to produce pure supplies of other elements as well.

Refining of Metals

In the production of metals, the initial product is usually an impure metal. A common method of purifying a metal, known as electro-refining, uses an electrolytic cell to obtain high-grade metals at the cathode from an impure metal at the anode.

A good example is the electro-refining of copper. As shown below, a slab of impure copper is the anode of an electrolytic cell that contains copper(II) sulfate dissolved in sulfuric acid. The cathode is a thin sheet of very pure copper.



As the cell operates, copper and some of the other metals in the anode are oxidized, but only copper is reduced at the cathode. After the refining process is complete, the copper is about 99.98% pure. The half-reactions are:

cathode:	$Cu^{2+} + 2e^{-} \rightarrow Cu(s)$	reduction of copper
anode:	$Cu(s) \rightarrow Cu^{2+} + 2e^{-}$	oxidation of copper

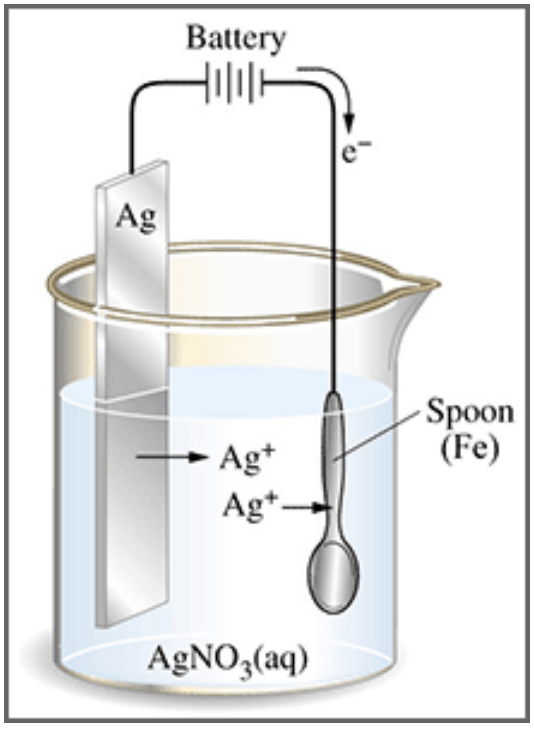
Electroplating

Several metals, such as silver, gold, zinc, and chromium, are valuable because of their resistance to corrosion. However, products made from these metals in their pure form are either too expensive or they lack suitable mechanical properties, such as strength and hardness.

To achieve the best compromise among price, mechanical properties, appearance, and corrosion resistance, utensils or jewelry may be made of a relatively inexpensive, yet strong, alloy such as steel, and then coated (plated) with another metal or alloy to improve appearance or corrosion resistance.

Plating a metal at the cathode of an electrolytic cell is called electroplating and is a common technology that is used to cover the surface of an object with a thin layer of the metal.

In the example shown below, a cell is constructed with an iron spoon at the cathode and a strip of metallic silver at the anode. The two are immersed in an electrolyte of silver nitrate.



At the anode, metallic silver is oxidized to form silver ions.

$$Ag(s) \rightarrow Ag^{+} + e^{-}$$

At the cathode, silver ions are reduced to form metallic silver. This metallic silver deposits on the outer surface of the iron spoon, forming a coating of silver.

$$Ag^{+} + e^{-} \rightarrow Ag(s)$$

A similar cell design could be used to electroplate objects with other metals, by simply replacing the silver anode and the silver nitrate solution with appropriate materials. For example, if you wanted to electroplate something with gold, you might use a gold anode and a solution of gold ions (usually in a compound such as gold cyanide).