



Figure 4.14 This plant processes seawater to extract magnesium.

Magnesium Mining from Seawater

Many metals, such as copper, zinc, and gold, are extracted from solid ores. Although magnesium is abundant in Earth's crust, it is extracted from seawater, not rocks. As a result, plants that produce magnesium, such as the one shown in **Figure 4.14**, are usually located on the coast. Magnesium ions are the second most abundant cations found in seawater, with only sodium ions in greater abundance. The process of producing metallic magnesium requires several chemical reactions.

Steps in the Process of Magnesium Mining

Figure 4.15 shows the main steps in extracting magnesium from seawater. The steps in the flowchart match the reactions described below.

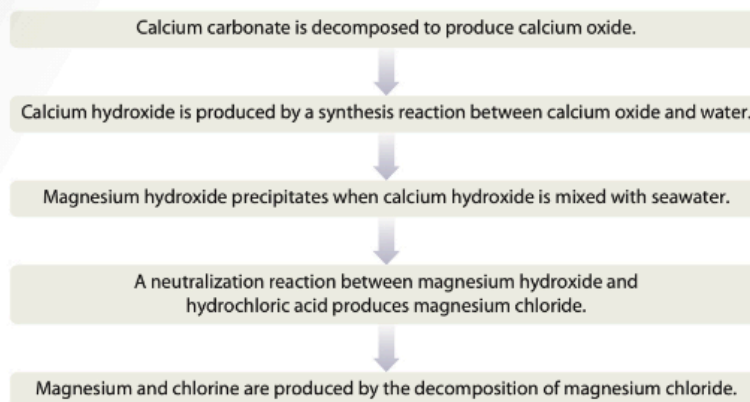
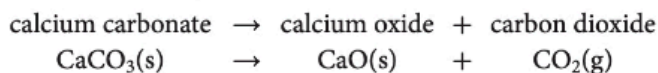


Figure 4.15 Use this flowchart to help you understand the sequence of chemical reactions used in the extraction of magnesium from seawater.

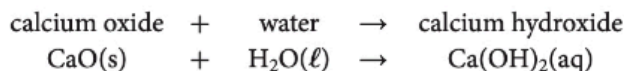
Decomposition of Calcium Carbonate

First, calcium carbonate from seashells is decomposed to produce calcium oxide. Recall, from Chapter 3, that carbon dioxide is a product when a metal carbonate decomposes. The chemical equation is



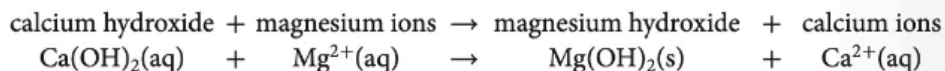
Synthesis of Calcium Hydroxide

The calcium oxide undergoes a synthesis reaction to form calcium hydroxide:



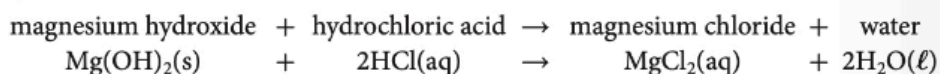
Double Displacement between Calcium Hydroxide and Magnesium Compounds

The calcium hydroxide reacts with the magnesium ions in seawater in a double displacement reaction. The magnesium ions are separated from the other ions in seawater, such as sodium, chloride, and bromide ions, as the precipitate magnesium hydroxide:



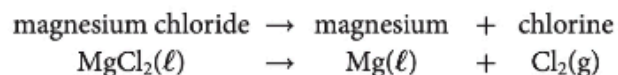
Neutralization of Magnesium Hydroxide

The solid magnesium hydroxide is filtered out and undergoes neutralization with hydrochloric acid:



Decomposition of Magnesium Chloride

The magnesium chloride is dried, melted, and then decomposed through electrolysis to form magnesium metal:



Industrial Uses of Magnesium

The main industrial use for magnesium is in the manufacturing of aluminum-magnesium alloys. An *alloy* is a mixture of two or more metals. Because magnesium is a less dense metal than aluminum, their alloys are lighter in weight than pure aluminum. In addition, the alloys are stronger and more resistant to corrosion than pure aluminum. Beverage cans are often made of aluminum to which a small amount of magnesium has been added, making the metal stronger and easier to shape. Magnesium is also commonly used in electronic devices because of its light weight and its electrical properties. The kayak shown in **Figure 4.16** is made, in part, of an alloy of aluminum and magnesium.



Figure 4.16 The frame of this kayak is constructed using tubing that is made from an alloy of aluminum and magnesium.

Infer What properties of aluminum-magnesium tubing make it suitable for constructing a kayak?

Extracting Metals from Ores

Gold and copper are important metals for Canada's economy. Several different methods are used for extracting these metals. Each method combines physical processes, such as grinding and filtering, and chemical processes to obtain the desired product.

Copper Smelting

A smelter is a facility that uses heat to extract metal from ore. **Figure 4.17** shows a smelter that is used to refine copper at the Kidd Creek copper and zinc mine in Timmins, Ontario. An important part of the design of this type of smelter is the different heights of the furnaces. Molten products flow from one furnace continuously into the next furnace because of the height difference, reducing the need for large buckets and transfer equipment.

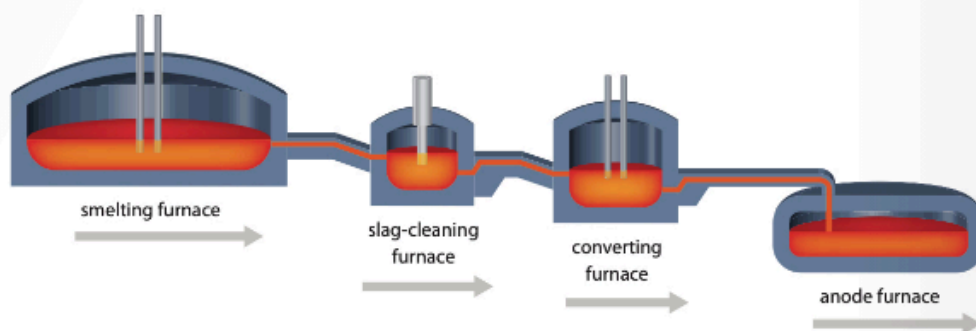


Figure 4.17 These furnaces produce increasingly pure copper through a series of reactions.

Identify how the construction of the smelter allows gravity to move the material from one furnace to the next.

Smelting Furnace

The smelting furnace is the first stage of copper production. An impure copper sulfide **matte**, $\text{Cu}_2\text{S}(\ell)$, forms. Oxygen is used to separate the iron from the copper in the mineral chalcopyrite, $\text{CuFeS}_2(\text{s})$, ore according to this overall reaction:



The iron(II) oxide is reacted with sand and limestone to convert it into a low density compound called *slag* which floats to the top of the molten mixture. The copper matte is more dense and sinks to the bottom.

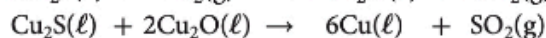
The sulfur dioxide gas that is produced in these reactions and in later steps of the process is collected and sent to a plant that produces sulfuric acid. This prevents the release of large amounts of pollutants that contribute to the formation of acid precipitation.

Slag-Cleaning Furnace

The products of the smelting furnace move to the slag-cleaning furnace, where they separate due to differences in density. The matte flows into the converting furnace, while the undesired material, called *slag*, is sent to storage.

Converting Furnace and Anode Furnace

In the next step, matte is purified further, to about 99 percent, in the converting furnace through further displacement reactions. Air is blown through the molten mixture and oxygen in the air reacts with the copper matte in a two step reaction. First, some copper(I) sulfide is converted to copper(I) oxide. The copper(I) oxide then reacts with more copper(I) sulfide to form metallic copper and sulfur dioxide.



As in the earlier furnaces, the sulfur dioxide gas is collected, so it can be sent to a plant that produces sulfuric acid. The small furnaces make it easier to recover the gases and provide a steady stream of sulfur dioxide to the acid plant. Meanwhile, the copper undergoes a final purification step in the anode furnace.

Because copper is an excellent conductor of electricity, a major use of copper is in electrical wiring. Copper is also melted with other metals to make alloys. For example, bronze is mainly an alloy of copper and tin, and brass is mainly an alloy of copper and zinc.

Gold and Cyanide Leaching

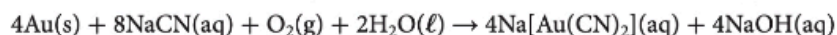
Gold is a relatively non-reactive metal. As a result, it can be found in nature in its uncombined form. As shown in **Figure 4.18**, however, most gold is mixed into the rock that surrounds it and must be separated. The most cost-effective method for removing the gold involves treating the crushed rock with a sodium cyanide solution to dissolve the gold.

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Figure 4.18 Much of the rock mined as gold ore contains particles of gold that are too tiny to be seen without a microscope. Some rocks, however, such as the one shown here, contain visible particles of gold.

Leaching is the process of converting a metal to a soluble form to extract the metal. A commonly used process for the extraction of gold from ore is to react it with a solution of sodium cyanide, $\text{NaCN}(\text{aq})$, to form sodium dicyanoaurate(I), $\text{Na}[\text{Au}(\text{CN})_2](\text{aq})$, and sodium hydroxide. The overall reaction for leaching gold is



The gold is recovered from the solution through displacement by zinc, according to the following equation:



The cyanide solution can be recycled and used again to convert gold to a soluble form in an aqueous solution.

In industry, the most important use of gold is in the manufacture of electronics components. Gold is an excellent conductor of electricity and is resistant to corrosion, so it is used in small amounts in electronic devices, including cell phones and computers. Gold is also an ingredient in some medications. In addition, it is used to fill cavities in teeth and to make crowns to cover and protect teeth. Gold is highly suited to such uses because it does not corrode, it does not trigger allergic reactions, and it is easy to shape into the desired form. Gold coins have been used for many centuries as currency. Other uses of gold include the production of jewellery, watches, and art objects.

leaching a process that is used to extract a metal by dissolving the metal in an aqueous solution