LESSON PLAN | **ADVANCED LEVEL**

Grades: High school (9–12)
Subjects: Science and visual arts
Time required: 1–3 class periods

Lesson Overview

Students study an ancient **bronze** statue, analyze its pose, and discover how **conservators** remove and prevent corrosion. They learn that the bronze used to make this sculpture is an **alloy** of **copper** and **tin** with small amounts of antimony, lead, iron, silver, nickel, and cobalt. They use the periodic table to research the chemical formulas of **compounds** used to make bronze. After learning about **oxidation-reduction reactions** that occurred in the statue, students speculate about the conservation techniques needed to conserve the bronze sculpture.

Learning Objectives

Students will:

- Observe and understand the changes that occur to **metals** when submerged in water.
- Analyze the pose of an ancient Greek sculpture.
- Use a periodic table to identify the **elements** that compose bronze and understand the process by which these elements combine to form bronze.
- Understand the oxidation-reduction reactions that occurred in a statue when it was made and then when it was exposed to seawater.

Materials

- Materials listed in the beginning-level lesson (p. 98)
- Video: *Conserving Bronze: The Lamp with Erotes from Vani,* www.getty.edu/art/gettyguide/videoDetails?segid=4386
- Digital projector with Internet access or a computer lab

Lesson Steps

1. Complete steps 1–5 of the beginning-level lesson and steps 2–3 of the intermediate-level lesson.

2. Explain to the class that some of the corrosion of *Victorious Youth* was caused by a **chemical reaction** between the bronze and the **oxygen** in the salt water. This chemical reaction resulted in an electron transfer known as **oxidation**. This means that the metal compound of bronze was combined chemically with the oxygen in the water to create an **oxide**. In this process, electrons were released at the **anode** (salt water) and taken up at the **cathode** (statue).

3. Have the class balance the oxidation-reduction reactions that occurred in the bronze when the statue was submerged in the ocean.
   - Electrochemical corrosion of copper alloy leads to the production of cuprous ions. Cuprous ions combine with the chloride in the seawater to form cuprous chloride, a major component of the corrosion layer:

     $Cu - e \rightarrow$

     Answer: $Cu - e \rightarrow Cu^{+}$

     $Cu^{+} + Cl^{-} \rightarrow$

     Answer: $Cu^{+} + Cl^{-} \rightarrow CuCl$
   - The statue now contains cuprous chlorides and is recovered and exposed to air. It continues to corrode when cuprous chlorides are combined with moisture and oxygen to hydrolyze and form hydrochloric acid and basic cupric chloride:

     $4CuCl + 4H_2O + O_2 \rightarrow$

     Answer: $4CuCl + 4H_2O + O_2 \rightarrow CuCl_2 \bullet 3Cu(OH)_2 + 2\ HCl$
   - The hydrochloric acid attacks the uncorroded metal to form more cuprous chloride:

     $2Cu + 2\ HCl \rightarrow$

     Answer: $2Cu + 2\ HCl \rightarrow 2CuCl + H_2$

   This process would have continued until no metal remained. Conservators had to scrape off the incrustation layers and find a way to stop the corrosion process.

4. Divide the class into working groups of four students. Explain that to stop the statue from corroding further, the conservators could have chosen among the following methods: electrolytic, electrochemical, sodium-sesquicarbonate, and sodium-sesquicarbonate/vacuum. Students can explore these treatments in detail in "Methods of Conserving Archaeological Material from Underwater Sites" on the Conservation Research Laboratory website, nautarch.tamu.edu/CRL/conservationmanual/. You may wish to note that the methods mentioned above are used to enhance salt extraction in archaeological metals and that, if the salt extraction is not completed, the reaction outlined in number 3 above would continue to occur.

5. Have groups come up with a combination of methods to conserve the bronze statue. Students should record findings in their journals. Groups will share their findings

with the class. Explain that the Getty conservators decided to use the sodium-sesquicarbonate/vacuum method to preserve the artwork. This method guaranteed that all unstable elements would regain stability without any loss to the original bronze or to the artistic qualities of the statue's surface. In addition, the statue is now kept in a humidity- and temperature-controlled room to prevent further corrosion. Compare students' recommendations to the actual treatment.

6. Return to the image of the sculpture and ask students to discuss the artistic qualities of the statue's surface. Which qualities do they think the **curators** were hoping to retain, and why would this be important?