CORROSION OF METALS

The most commonly known metals to ancient civilizations were gold, silver, copper, tin, lead, iron, and mercury. Chronological dating suggests that the use of these metals and their alloys began in the period from 7000-6000 BCE and accounted for nearly all metal usage until the onset of modern metallurgy in the 1800's.[1] To date, thousands of metallic artifacts have been found around the world. They have been found in caves, tombs, shipwrecks, and various other environments above and below ground.

Archaeological metal objects are not only the valuable remains of cultures from the past (*e.g.* the Mesopotamians, Egyptians, Greeks, and Romans) but constitute our main information source regarding ancient metallurgy and the corrosion behaviour of metals buried for centuries.[2] Most often, metal objects excavated from archaeological sites cannot be studied immediately because the artifacts undergo changes which alter the entire structure of the metal and alloys.

Many archaeological metal objects are in severely corroded and unstable conditions due to corrosive agents in the environment. In fact, it can sometimes be difficult to distinguish the original shape of the artifact, where the original shape can only be revealed via radiography. Therefore, conservation and restoration treatment aims to protect and preserve archaeological objects to allow both investigation and public display.[2]

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From 1917-1922, British archeologists Howard Carter and Lord Carnarvon excavated Egypt's Valley of the Kings, searching for the tomb of King Tutankhamen. On November 26, 1922, Howard Carter and Lord Carnarvon stumbled upon the antechamber of King Tutankhamen's tomb. This began a monumental excavation process in which Carter uncovered an incredible collection of jewelry and gold, furniture, clothes, weapons, tools, ornaments, statuaries and numerous other objects that shed a brilliant light on the culture and history of ancient Egypt.

STUDENT INSTRUCTIONS

Re-excavation of King Tutankhamen's tomb led to the discovery of another hidden chamber. With its crowded contents, two small sarcophagi were discovered in opposite corners of the chamber – ***sarcophagus #1*** was found submerged in water, while ***sarcophagus #2*** was found leaned against the wall of the chamber. Both sarcophagi appeared to be corroded; however, both appeared differently with respect to corrosion. For the first sarcophagus, the entire exposed surface was corroded, leaving behind a deposit (i.e. rust). For the second sarcophagus, only portions of the surface were corroded. Both artefacts where brought to the Museum of Cairo for further investigation.

You are a metallurgist working for the Museum of Cairo and your job is to study the nature, structure, and the physical and chemical properties of metals. Upon receiving the metallic artifacts at the Museum of Cairo, you are tasked with identifying, conserving, and restoring the metallic portions of the artefacts.

POINTS OF DISCUSSION/QUESTIONS

1. Many metals are inherently unstable and have a strong tendency towards corrosion. Rank the following metals from most potential for corrosion to least potential for corrosion: Platinum, Nickel, Copper, Tin, Lead, Aluminum, Silver, Iron, and Zinc. What observations can you can conclude?

2. There are several different reasons for metal corrosion. Identify the types of corrosion and which type corresponds to each sarcophagus.

3. An electrochemical reaction must consist of an oxidation and reduction reaction. What is an oxidation reaction? What is a reduction reaction?

4. Experimental analysis indicates that the metal composition of ***sarcophagus #1*** is solely iron. Write the corresponding electrochemical reaction equation (i.e. half-reactions) for the oxidation of iron in water. Calculate the cell potential.

5. Experimental analysis indicates that the metal composition of ***sarcophagus #2*** consists of isolated regions of iron and zinc. If these two metals are immersed into an electrolyte, they form an electrochemical cell. Write the equation for each half-reaction that will occur. Draw a diagram of the cell.

6. A number of techniques are used to combat corrosion. Identify the types of techniques. As a metallurgist working for the Museum of Cairo which technique best aims to protect and preserve archaeological objects to allow for public display?

References:

[1] Johnson, A.B. & Francis, B. Durability of metals from archaeological objects, metal meteorites, and native metals. **1980.** DOI: 10.2172/5406419.

[2] Bertholon, R. Archaeological metal artefacts and conservation issues: Long-term corrosion studies. *Corrosion of Metallic Heritage Artefacts.* **2007,** 31.

[3] Image. Retrieved from https://www.foxnews.com/science/king-tut-tomb-mystery-experts-explain-strange-spots-on-burial-chambers-walls

CORROSION OF METALS LABORATORY

BACKGROUND

Metals played a significant role in past civilizations. To date, thousands of metallic artifacts have been found around the world; however, many metal objects excavated from archaeological sites are in corroded or unstable conditions due to environmental pollutants, microorganisms in the soil, vegetation, soil chemistry, land use, or the presence of water and air.[1]

For the metals to effectively survive in many harsh operating conditions, the metal surface is converted into coatings via a chemical or electrochemical process. These coatings are used for conservation and restoration treatment, corrosion protection, and increased surface hardness.[2]

OBJECTIVE

The primary objective of this experiment is to study the most common form of corrosion, which is found in wet or aqueous environments, and explore the effectiveness of the use of protective systems to prevent metals from corroding (*i.e.* methods used to slow its progression).

EXPERIMENT

Materials:

- Copper wire
- Zinc nails
- Iron nails
- Wires with alligator clips
- Beakers
- 1M Zinc(II) sulfate solution
- Batteries
- Iron indicator solution*

*This is a mildly corrosive solution which changes colour in the presence of Fe^{3+} ions.

Instructions: “wet corrosion” refers to metal corrosion occurring in an aqueous environment. This process occurs when two or more electrochemical reactions take place on the metal surface.[2] Explore what happens when iron (the least expensive and most widely used metal of all) is exposed to a corrosive aqueous environment. Develop a method to protect the iron metal from corroding using the materials given.

References:

[1] Selwyn, L. Corrosion of metal artifacts in buried environments. *ASM Handbook. Corrosion: Environments and Industries.* **2006,** 13C. DOI: https://doi.org/10.31399/asm.hb.v13c.9781627081849

[2] Zarras, P. & Stenger-Smith, J. Smart inorganic and organic pretreatment coatings for the inhibition of corrosion on metals/alloys. *Intelligent Coatings for Corrosion Control*. **2015,** 59-91.