Teacher Preparatory Guide
Lesson 1: Save the Dinosaurs with Copper and Zinc!

Overview: To produce nanowires, electrolysis can be used to plate metal ions into the pores of an anodisc (an inorganic membrane used in lab filtrations; has a precise and small pore structure which allows for high quality filtration). At a high school level, the wires can be made using a AA battery supplying approximately 1.5 V. The following activity allows students to learn about oxidation and reduction in an electrolytic cell using a similar set-up before working towards more advanced applications in Lesson 2. The following lab procedure will have students plate copper and zinc metal onto small plastic dinosaurs (or similar objects). Once plated, the dinosaurs' new "armor" can be tested in a bath of hydrochloric acid. This is a great way to reinforce the activity series as the copper plated dinosaur should be the only one which does not react.

Purpose: This lab is designed to introduce students to the applications of forcing a chemical reaction using an electrical current. Students will discover how a flow of electrons allows cations in solution to revert to a solid state while plating an object. Students will become familiar with the process which allows the ions of the plating solution to be replenished, and how this results in a loss of mass for the solid metal electrode.

Time required: Two 45 minute class periods or one 90 minutes block period. One to perform the actual lab activity and one for remaining questions and discussion on relation to the activity series, and how voltage forces the reaction to occur.

Level: High School Chemistry

Materials per two student group:
- Safety glasses
- Gloves
- Two 250 mL beakers
- One petri dish (or clean, plastic surface)
- Two small paint brushes
- Electrical tape
- Tweezers and stirring rod
- One volt meter
- One strip of zinc foil
- One strip of copper foil
- One 1 cm x 6 cm copper strip
- One 1 cm x 6 cm zinc strip
- Two AA batteries with holders and +/- leads
- Four wires with alligator clips
- Two small dinosaur toys (~6 cm long, other plastic objects will work)
- Rio Grande Midas conductive paint

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- 150 mL Rio Grande Midas Bright Electro-forming Copper Solution (copper sulfate)
- 150 mL 1 M zinc sulfate
- 300 mL 1 M HCl

Safety Information: Safety glasses should be worn at all times. The conductive paint contains butyl acetate. Use ventilation (fume hood if possible, otherwise open windows), keep away from open flames, and avoid contact with skin (wear gloves). The copper solution contains acid which may cause eye, skin, or respiratory irritation. Avoid contact with eyes, skin, and clothing. If eye contact is made, flush eyes with large amounts of water for 15 minutes and seek medical attention. Wash thoroughly with soap and cool water if contact is made with skin. If available, safety aprons can be worn to protect clothing.

Advance Preparation: If the Zinc Sulfate or a similar plating solution can not be purchased, it can be prepared using zinc metal and sulfuric acid.

Where to buy supplies:

Midas Silver conductive paint – Rio Grande, Item number 335068
Midas Bright electroforming copper solution - Rio Grande, Item number 335074
http://www.riogrande.com/

Teacher Background (additional information can be found in texts listed below):

Redox Reactions

Chemical reactions in which both oxidation (loss of electrons) and reduction (gain of electrons) occur. (ex. $H_2 + F_2 \rightarrow 2\ HF$ Hydrogen is oxidized and Fluorine is reduced)

Faraday's Laws of Electrolysis

1st Law of Electrolysis - The mass of a substance altered at an electrode during electrolysis is directly proportional to the quantity of electricity transferred at that electrode.
2nd Law of Electrolysis - For a given quantity of electricity (electric charge), the mass of an elemental material altered at an electrode is directly proportional to the element's equivalent weight. The equivalent weight of a substance is its molar mass divided by an integer that depends on the reaction undergone by the material.

Electrolytic Cells

There are three key components in an electrolytic cell: an electrolyte and two electrodes (a cathode and an anode). The electrolyte is usually a solution of water or other solvents in which ions are dissolved. An external voltage is applied to the electrodes, and the electrolyte provides ions that flow to and from the electrodes. A redox reaction takes place forming a solid at the cathode, while the mass of the anode decreases as metal atoms lose electrons and become ions in solution.

Activity Series

A list of metals organized based on reactivity, with the most reactive metals at the top and the least reactive metals at the bottom. Using this series one can determine whether or not a single displacement reaction involving the metals can take place.

Single Displacement Reactions

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A redox reaction in which an element replaces or displaces another from a compound. In these reactions, the element which replaces that which is in a compound is always oxidized. The element being displaced, is always reduced. The reaction shown below would occur if A is more reactive than B.

$$A + BX \rightarrow AX + B$$

Teaching Strategies This lab should be performed in groups of two students since there will be two dinosaurs painted and plated with metal. Redox reactions must be covered before the lab is started for students to understand what is actually happening at the cathode and anode. Types of reactions (specifically, single displacement) should be covered so that the students understand what is happening to the dinosaurs with metal plating.

Teacher Resources: You may wish to use these resources as background information for the lesson preceding the lab activity.

Site	**Topics**
Finishing.com http://www.finishing.com/faqs/howworks.html	Defines and describes the electroplating process Provides alternative plating activities
Britannica Encylopedia http://www.britannica.com/EBchecked/topic/183990/electroplating	Explains why battery is important to plating Explains electrolytic cells and includes diagrams Provides historical context

<u>Additional resources</u>

The following textbooks were used as resources in the preparation of this lesson as they include information along with pictures and diagrams of the electrolysis process. They are a good place to start, but any high school/college level chemistry text should have the necessary background information.

1. Krimsley, V. S.; *Introductory Chemistry*, Second Edition; Brooks/Cole Publishing Company: California, 1995; 505-510

2. McQuarrie, D. A.; Rock, P. A. *General Chemistry*, Third Edition; W. H. Freeman and Company: New York, 1987; 812-840

3. Zumdahl, S. S.; *Introductory Chemistry: A Foundation*, Fourth Edition; Houghton Mifflin Company: Boston, 2000; 550-574

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Lesson 1, Day 1 – Instructional Procedure
Save the Dinosaurs with Copper, Nickel, and Zinc!

Time (minutes)	Instructional Activity
10	Students will review the procedure, obtain necessary lab materials, and perform the activity series test in section A.
10	Students will paint dinosaurs and allow five minutes for drying. While drying students will prepare the plating solutions and electrolysis set up.
10	Students will perform both the copper and zinc plating simultaneously and record their observations. They should stop both processes at the same time for a proper comparison.
10	Students will place their dinosaurs in a bath of HCl and record observations.
5	Students will clean up their lab station, and answer any remaining questions.

Lesson 1, Day 2 – Instructional Procedure
Save the Dinosaurs with Copper, Nickel, and Zinc!

Time (minutes)	Instructional Activity: DAY 2
20	After submission of the lab notebook, the teacher should allow for a class discussion on the results and significance of the lab. If something from the procedure did not work, ask why? Have the students think about what could be changed in the procedure. If they painted a design onto the dinosaur would it only plate onto the design? Would nothing plate at all since the entire surface wasn't covered? If an interesting proposal is given, allow the students time to test their theory. Be sure to explain why a voltage is necessary for this reaction to occur.
10	Discuss the actual reaction that took place when the zinc coating was not sufficient. Make sure students understand what was being produced (hydrogen gas). Ask them what happened to the zinc metal. Ask the students (based on the activity series) which metals they believe would also work as a protective coating for acid. Economics can be brought into play. Would it be better to coat an object with copper or gold if both are effective for a certain purpose?
15	Expand into applications for plating in the real world. In the teacher resource section there is information on how electroplating has been used throughout history. Try to connect to something the students may have experienced. Connecting to economics again, why it may be more cost effective to electroplate a spoon with gold as opposed to buying a golden spoon.

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Name____________________________ Date________________ Class____________________

Save the Dinosaurs with Copper and Zinc!
Student Worksheet (*with answers*)

Introduction

QuickTime™ and a decompressor are needed to see this picture.

Sid is your neighborhood bully and he enjoys mutilating toys. Up until now he has been satisfied using rockets to blast spacemen and cowboy toys into orbit, but this time he has gone too far! He has threatened to dissolve your little brother's dinosaur collection in a bath of Hydrochloric Acid (HCl). Why such a malicious child was given access to such a dangerous chemical is unclear, but it is up to you to save your brother's toys. Being a clever chemist, you remember hearing about the reactivity of certain metals, and that some are less reactive than the Hydrogen in HCl, but you don't remember which ones. Using an electroplating solution to cover dinosaurs with copper or zinc, you will try to find out which would provide the best armor against Sid's devious actions.

Purpose

1. To study redox reactions involving zinc and copper species, while discovering why a reaction does or does not occur.
2. To construct an electrolytic cell capable of plating copper, nickel, and zinc onto an object (plastic dinosaurs) to protect them from hydrochloric acid.
3. To use the armored dinosaurs to study the reactivity of different metals in acid.

Question

1. How do the properties (in this case, reactivity) effect the potential applications of certain materials?

Hypothesis Develop a hypothesis to answer the question listed above.
We will assume that based on the activity series, copper will be the better armor since it is less reactive than zinc, and should not react with the hydrogen in HCl.

Key Terms

Oxidation: *A reaction in which the atoms in an element lose electrons and the valence of the element is correspondingly increased (postitive).*

Reduction: *A reaction in which the atoms in an element gain electrons and the valence of the element is correspondingly decreased (negative).*

Redox Reaction: *A reaction which combines oxidation and reduction half-reactions where one atom is gaining the electrons which another atom has lost.*

Electroplating: *To coat with metal by electrolysis. A metal in its ionic state is stimulated with electrons to a non-ionic coating.*

Voltage: *The electromotive force or potential difference expressed in volts.*

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Conductor: *A material through which an electrical current can pass. Metals are good conductors.*

Activity Series*:* *A list of substances ranked in order of relative reactivity.*

Materials per Student Group

- Safety glasses
- Gloves
- Two 250 mL beakers
- One petri dish (or clean, plastic surface)
- Two small paint brushes
- Electrical tape
- Tweezers and stirring rod
- One volt meter
- One strip of zinc foil
- One strip of copper foil
- One 1 cm x 6 cm copper strip
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- Two AA batteries with holders and +/- leads
- Four wires with alligator clips
- Two small dinosaur toys (~6 cm long, other plastic objects will work)
- Rio Grande Midas conductive paint
- 150 mL Rio Grande Midas Bright Electro-forming Copper Solution (copper sulfate)
- 150 mL 1 M zinc sulfate
- 300 mL 1 M HCl

Procedure

A. Exploring the activity series

1) Clean your Petri dish (or plastic reaction surface) with distilled water and dry.

2) User tweezers to place pieces of zinc and copper foil at least 2 cm apart on the reaction surface.

3) Using a pipette place 2 drops of 1 M $CuSO_4$ onto the top of the piece of zinc.

4) Using a pipette place 2 drops of 1 M $ZnSO_4$ onto the top of the piece of copper.

5) Study each set and record your observations in your lab notebook, and answer the following questions for each metal strip. If needed, the drop can be removed with a cotton swab for an easier observation.

   a. Did a reaction occur? *A reaction occurred when the $CuSO_4$ was placed on the piece of zinc.*
   If you think a reaction occurred, explain why. *You can tell that a reaction occurred because of the bubbles. A gas was produced.*

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b. If a reaction did occur, what was the reaction that took place? Include the reaction in both words (ex. Water → Hydrogen + Oxygen) and symbols (ex. $2H_2O \rightarrow 2H_2 + O_2$)
Copper Sulfate + Zinc → Copper + Zinc Sulfate
$CuSO_{4(aq)} + Zn_{(s)} \text{ ---> } ZnSO_{4(aq)} + Cu_{(s)}$

B. Creating a protective coating

1) Using a small paint brush with conductive paint in a fume hood, paint the surface of two dinosaurs. While allowing the dinosaurs to dry for 5-10 minutes, proceed to steps 2 and 3.

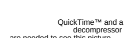
2) Prepare two 250 mL beakers with 150 mL of plating solutions in each (one for copper, and one for zinc). Use electrical tape to secure a copper strip to the side of the beaker in the copper plating solution, and a zinc strip in the zinc plating solution.

3) Obtain a battery with battery holder and test the voltage using a volt meter. The battery should produce at least 1.3 V. Answer the following in your lab notebook.

   a. Why do you think a voltage is necessary for the electroplating to occur? *(The voltage forces electrons to move towards the cathode where they will combine with metal ions from solution to form solid metal on the dinosaur.)*

4) Wrap a copper wire around the neck of each dinosaur leaving enough slack to wrap around a stirring rod. The dinosaur should have enough wire to remain submerged in the solution while the stirring rod rests on the top of the beaker.

5) Put one dinosaur in each solution.



Connect the negative lead to the wire around the dinosaurs' neck, and the positive lead to the metal electrode taped to the side of the beaker. Be sure that the dinosaur is not touching the metal electrode.

Figure 1: A completed dinosaur plating set-up for copper

When this step is complete, answer the following question.

   a. Is the dinosaur the cathode or anode? How do you know?
   The dinosaur is the cathode because that is where reduction is taking place. Reduction takes place at the cathode in an electrolytic cell.

6) Allow the dinosaurs to accumulate their armor for 10 minutes. While waiting think about the following questions, and record the answers in your lab notebook.

   a. Where is the metal which is plating onto the dinosaur coming from?
   The metal is coming from the metal ions in solution, which are being reduced by the electrons supplied by the battery.

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b. Is the solution being permanently depleted of metal ions?
The metal ions which are being reduced at the cathode are replaced by the cations created at the anode. The mass of the anode should decrease over time.

7) When the dinosaurs are covered remove them from solution and allow them to dry on a paper towel. Remove the batteries from the set up, and take the metal electrodes out of the solution. Dry them off using a paper towel. Ask your teacher about disposal of the plating solutions, as they will most likely be reused, but should not be put back with the stock solution. Clean beakers using soap and water.

C. Will the armor be enough to save your dinosaur?

1) Pour 100 mL of 1 M hydrochloric acid (HCl) into each clean beaker.

2) Use your wire and stirring rod to suspend each dinosaur in the HCl bath. Allow the dinosaur to soak for 5 minutes, and record your observations.

QuickTime™ and a decompressor are needed to see this picture.

Figure 2: Mendeleev has been successfully coated with copper, but will it work?

3) Then take out the dinosaur and rinse it off with distilled water, and lay on a paper towel to dry. Then answer the following questions

a. Which (if any) of the dinosaurs still have their protective coating?
The copper dinosaur should still be coated with metal.

b. Why would one coating be better protection against HCl?
Based on the activity series, Zinc metal is much more reactive than Hydrogen and will react with acid. Copper is less reactive than Hydrogen and will not react with acid.

c. If a reaction did occur, what was the reaction that took place? Include the reaction in both words (ex. Water → Hydrogen + Oxygen) and symbols (ex. $2H_2O \rightarrow 2H_2 + O_2$)
Zinc + Hydrochloric Acid → Zinc Chloride + Hydrogen
$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$

Cleanup: Plating solutions are replenished through the metal wire or strips connected to the positive end of the battery, so they can be used indefinitely. Collect the solutions from the students in separate bottles or containers (separate from the stock solutiona), just in case there is a contamination. This will prevent the loss of the stock solution if a procedural error was performed resulting in depletion of ions in solution. The metal strips can be reused. Emory cloth can be used to clean the surface and provide better contact. If the HCl is concentrated, it should be neutralized using base (ex. NaOH which would produce salt water) before disposal.

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Assessment

Assessments *for* Learning:

Following the lab, students will submit their lab notebook for grading. The teacher should then allow for a class discussion on the results and the significance of the lab. Allow students to ask questions that were not addressed during the lab. For example, what would happen if the dinosaur was not completely coated with conductive paint? Would the metal armor still form on the entire dinosaur? Would none form at all? Write all of these questions up on the board, and then go through each one together as a class. If a question arises to which you do not know the answer, use the opportunity to allow students to develop their own procedure to find the answer. Be sure to ask the students your own questions regarding electroplating. For example, why might one want to plate an object with a certain type of metal in the real world? Connect this idea of electroplating with economics. Would it be less costly to plate gold onto a spoon than to create a spoon entirely of gold?

Assessments *of* Learning:

Description	What is Assessed	Feedback
The students will perform the lab for the electroplating of copper and zinc. The lab requires students to define key terms, answer questions about the process, and keep their notes organized in a lab notebook. While there is no data or graphs to analyze, students must rely on their previous knowledge involving multiple concepts to form conclusions.	The students' notebooks allow for assessment regarding their organization of thoughts and ideas. The lesson itself assesses the students' ability to understand and make connections between concepts including the activity series, stoichiometry, electrolytic cells, conduction, and acids/bases.	Students receive a score according to the completeness and accuracy of their answers, and the organization of their notes. They also receive comments when the wrong answer or explanation is provided which both challenges the misconception, and provides further explanation of the correct concept.

National Science Content Standard: Level 9-12

A. Science as Inquiry

- Identify questions that can be answered through scientific investigations
- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations
- Communicate scientific procedures and explanations

B. Physical Science – Structure and Property of Matter section

- Structure and properties of matter

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- Chemical reactions
- Interactions of energy and matter

E. Science and Technology – Abilities of Technological Design section

- Identify appropriate problems for technological design
- Design a solution or product
- Implement a proposed design
- Evaluate completed technological designs or products
- Communicate the process of technological design

Pennsylvania Science Education Standards

3.2 Inquiry and Design

10 A. Apply knowledge and understanding about the nature of scientific and technological knowledge.

- Know that science uses both direct and indirect observation means to study the world and the universe
- Describe various types of chemical reactions by applying the laws of conservation of mass and energy

3.4 Physical Science, Chemistry, and Physics

10 B. Apply process knowledge and organize scientific and technological phenomena in varied ways.

- Use knowledge of chemical reactions to generate an electrical current
- Explain resistance, current and electro-motive force (Ohm's Law)

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