JCE Classroom Activity #111: Redox Reactions in Three Representations

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ABSTRACT: This activity introduces students to the concept of reduction—oxidation (redox) reactions. To help students obtain a thorough understanding of redox reactions, the concept is explored at three levels: macroscopic, submicroscopic, and symbolic. In this activity, students perform hands-on investigations of the three levels as they work at different stations that support examination and discovery of the general ideas in redox reactions, including oxidizing and reducing agents, and the stoichiometry of a reaction.


FEATURE: JCE Classroom Activity

BACKGROUND
A reduction—oxidation (redox) reaction involves transfer of electrons among the chemical species in the reaction. Examples of redox reactions include corrosion of metals1,2 and combustion of fuels.3,4 In addition, biological processes such as cellular respiration5,6 involve oxidation of glucose to carbon dioxide and reduction of oxygen to water. To obtain a deep understanding of a chemical concept, like redox, students should be exposed to the three levels of representation in chemistry:7−10 macroscopic, submicroscopic, and symbolic. The macroscopic representation deals with phenomena as experienced with the senses, such as changes in color, and formation of precipitates in chemical reactions. The submicroscopic representation provides descriptions at the particulate level, such as atoms and molecules. The symbolic representation involves chemical symbols, drawings, and mathematical expressions used to represent chemical situations. Students generally memorize, repeat chemical equations, and solve problems in an algorithmic fashion without conceptually comprehending or connecting the macroscopic, submicroscopic, and symbolic levels.11−15 Learning scientific concepts using multiple representations could help students become better in transferring between different levels16 and improve their reasoning and problem-solving skills. Although the use of the threefold representation has been implemented before in the classroom,17 more activities are needed in different topics. In this Activity, students investigate the copper(II) sulfate and zinc reaction, Zn(s) + CuSO₄(aq) → ZnSO₄(aq) + Cu(s), by performing hands-on exploration as they work at three different stations, each incorporating a different representation. During the reaction, zinc solid is oxidized to zinc(II) ion by transferring two electrons to copper(II) ion, reducing the latter to copper solid, as shown in eq 1.

INTEGRATING THE ACTIVITY INTO THE CURRICULUM
This Activity serves to provide connections between three levels of representation in chemical reactions. It can be used as a hands-on reinforcement after the redox concept has been taught. For students to perform the activity successfully, prior knowledge of reduction and oxidation, ionic compounds, nomenclature, and stoichiometry is recommended. This Activity can be used as an introduction to other activities, such as building a battery18 and electroplating.19
ABOUT THE ACTIVITY

Each group (2–4 students) is initially assigned to one of three stations labeled macroscopic, submicroscopic, and symbolic. After all groups complete the task in the first station, they move to the next station in the sequence and so forth, until all groups have participated in all three stations. Students will need approximately 10 min to complete the tasks at each station. The instructor should prepare multiple stations of each level to accommodate varying class sizes. The chemistry involved in the copper(II) sulfate and zinc solid redox reaction is not explained in the Student Activity because the main purpose of this activity is for the students to describe the reaction using the information gathered from participating in the activities of all three stations.

Macroscopic

At this station, students are given two pieces of zinc solid and 5 mL of 1 M copper(II) sulfate solution in a 10 mL glass vial or glass test tube. (See Figure 1.) The 1 M copper(II) sulfate solution (#C0246) is available from Flinn Scientific. The cost of 500 mL is ~$7.00, sufficient for 100 iterations of the station’s activity. Alternatively, a 1 M CuSO4·5H2O solution can be prepared in advance: Dissolve 50 g of copper(II) sulfate pentahydrate in 200 mL of distilled water. Copper(II) sulfate pentahydrate, CuSO4·5H2O (#C0102) is available from Flinn Scientific, at a cost of ~$8.50 for 100 g. This makes 400 mL of solution, sufficient for 80 iterations of the station’s activity.

Also, copper(II) sulfate pentahydrate can be found in hardware stores as root killer. The zinc solid (zinc metal shot, #Z0021) can be ordered from Flinn Scientific at ~$16.00 for 100 g, sufficient for approximately 500–1000 iterations of the station’s activity. The instructor should make the setup ahead of time. (See Figure 2.) Using the white and black hook-and-loop fastener dots. The balls and fasteners can be obtained in most sporting goods stores and fabric stores, respectively. The instructor should make the setup ahead of time. (See Figure 2.) Using the

Submicroscopic

In this station, students will work on a model to explore the redox reaction at the submicroscopic level. For the setup, the instructor will need a beaker (400 mL or larger) or a container, white and orange ping-pong balls, a permanent marker, and adhesive white and black hook-and-loop fastener dots. The balls and fasteners can be obtained in most sporting goods stores and fabric stores, respectively. The instructor should make the setup ahead of time. (See Figure 2.) Using the

Figure 1. (Left) Macroscopic station setup. Vial with copper(II) sulfate solution and two pieces of zinc shot. (Right) Formation of copper on the surface of the shot after several minutes.

Figure 2. Submicroscopic station setup.

Figure 3. Ping-pong balls prepared for the submicroscopic station with hook-and-loop fasteners. (Left) Copper, represented by orange balls with white fasteners. (Right) Zinc, represented by white balls with black fasteners.

marker, label the white balls as “Zn” and the orange balls as “Cu”. Apply two of the white hook fasteners to opposite sides of each orange ball. (See Figure 3, left.) Repeat this procedure with the black hook fasteners and the white balls. Connect the black loops to the black hooks on the white balls. (See Figure 3, right.) To avoid having the sticky part of the loops exposed, the instructor can apply the loops to a piece of paper and cut them. Place the balls inside the beaker using the same number of white and orange balls to ensure the stoichiometry of the reaction (1:1). Instructors can use 2 or 3 ping-pong balls of each color per station. The orange and white balls represent copper(II) ion and zinc solid, respectively. The two hook-and-loop fasteners on the white balls correspond to the two valence electrons in zinc, and the two hook fasteners in the orange balls represent two available energy sublevels in copper(II) ion. The instructor should make the setup ahead of time. (See Figure 2.) Using the

Students will place two zinc solids in the copper(II) sulfate solution and record their observations. The reaction results in the formation of copper solid. (See Figure 1, right.) After the activity, instructors should collect all the solutions and solids separately in glass bottles, label them accordingly, and dispose according to local regulations.

Submicroscopic

In this station, students will work on a model to explore the redox reaction at the submicroscopic level. For the setup, the instructor will need a beaker (400 mL or larger) or a container, white and orange ping-pong balls, a permanent marker, and
Symbolic

In this station, students will read and discuss the half ionic and molecular redox equations provided on a card or paper. (A template for this is available to instructors in the online Supporting Information.) Students will use the information on the card (Figure 4) to explain the chemical equation. After observations are made in the three stations, students will apply the information gathered in each station to explain the copper(II) sulfate and zinc redox reaction by interconnecting the macroscopic properties observed with the transfer of electrons at the submicroscopic level, and will learn how to write the chemical equation using symbols.

### ASSOCIATED CONTENT

- **Supporting Information**
  - Student activity worksheet; answers to questions for students; template of the half ionic and molecular redox equations for the symbolic station. This material is available via the Internet at http://pubs.acs.org.

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### REFERENCES