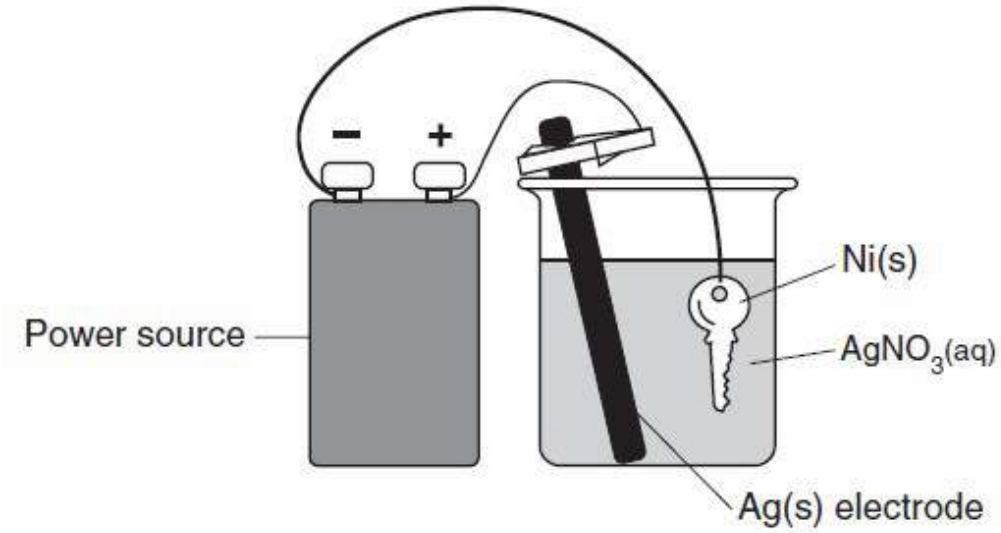
Figure 1

Base your answer to the question on the information below.

The diagram below represents an operating electrolytic cell used to plate silver onto a nickel key. As the cell operates, oxidation occurs at the silver electrode and the mass of the silver electrode decreases.



1. **[Refer to figure 1]**

Explain, in terms of Ag atoms and $Ag^+(aq)$ ions, why the mass of the silver electrode *decreases* as the cell operates.

Figure 2

Base your answer to the question on the information below and on your knowledge of chemistry.

A student develops the list shown below that includes laboratory equipment and materials for constructing a voltaic cell.

Laboratory Equipment and Materials

- a strip of zinc
- a strip of copper
- a 250-mL beaker containing 150 mL of 0.1 M zinc nitrate
- a 250-mL beaker containing 150 mL of 0.1 M copper(II) nitrate
- wires
- a voltmeter
- a switch
- a salt bridge

2. **[Refer to figure 2]**

Compare the activities of the two metals used by the student for constructing the voltaic cell.

Figure 3

Base your answer to the question on the information below and on your knowledge of chemistry.

Fossil fuels produce air pollution and may eventually be depleted. Scientists are researching ways to use hydrogen as an alternate fuel. A device called an artificial leaf was invented to produce hydrogen and oxygen using sunlight and water. The artificial leaf is an electrochemical cell. Equations 1 and 2 below represent the reactions taking place in the leaf. Equation 3 represents a reaction of hydrogen when used as fuel.

Equation 1: $2H_2O$ + energy from sunlight $\rightarrow O_2 + 4H^+ + 4e^-$

Equation 2: $4H^+ + 4e^- \rightarrow 2H_2$

Equation 3: $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ + energy

3. **[Refer to figure 3]**

State the change in oxidation number of oxygen during the reaction represented in equation 3.

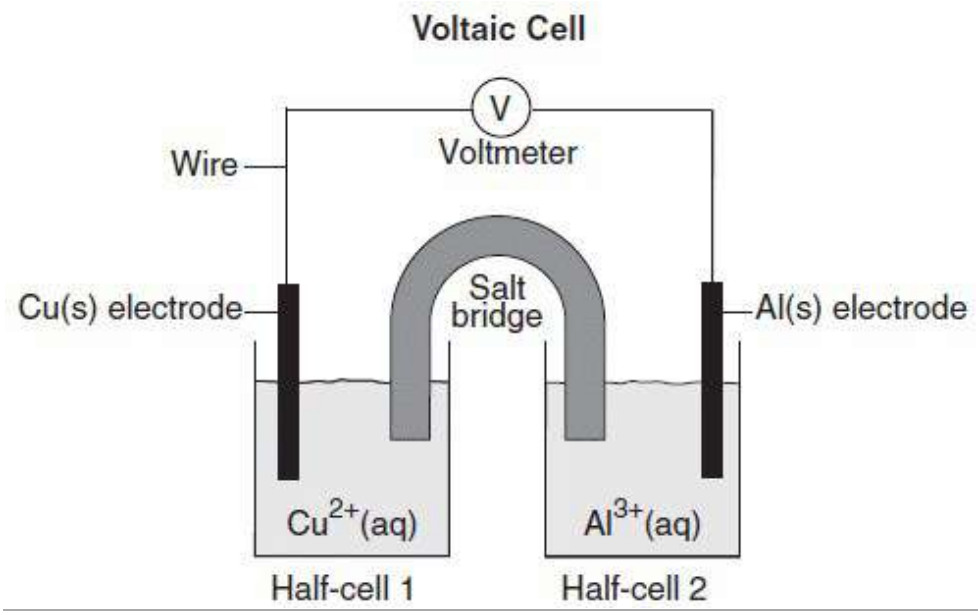
4. **[Refer to figure 2]**

Complete and balance the half-reaction equation for the oxidation of the Zn(s) that occurs in the voltaic cell.

Zn(s) $\rightarrow$ _____ + _____

Figure 4

Base your answer to the question on the diagram below. The diagram shows a voltaic cell with copper and aluminum electrodes immediately after the external circuit is completed.



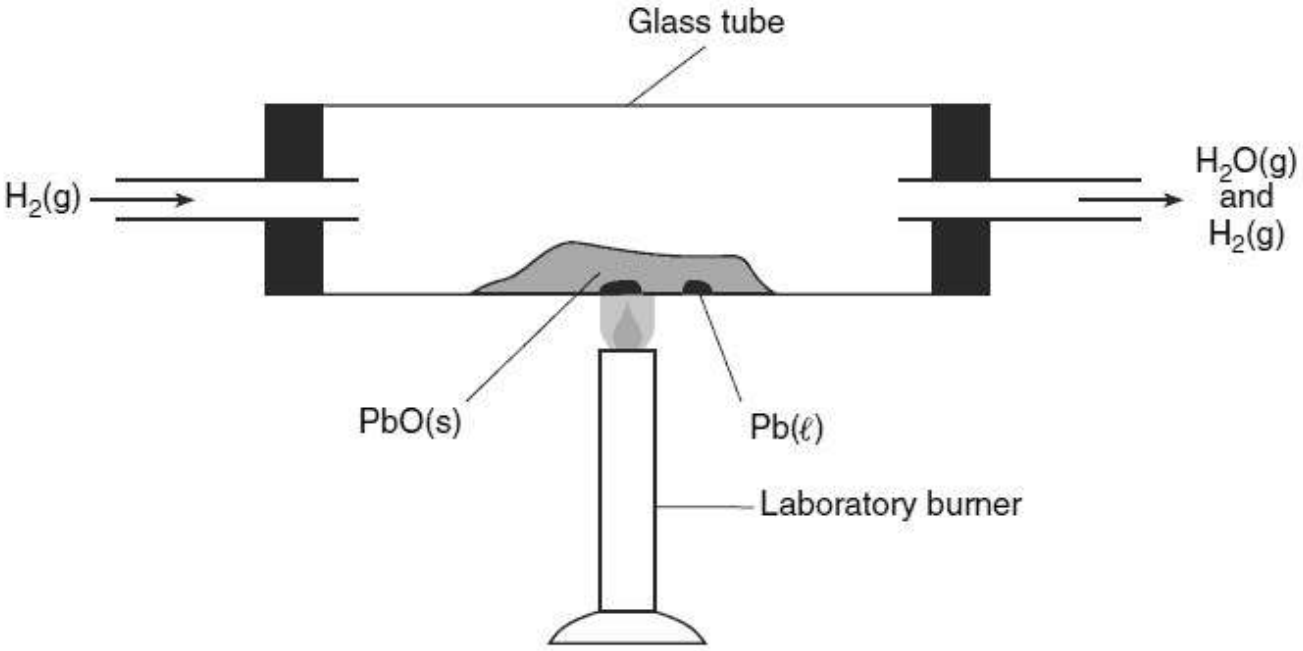
5. **[Refer to figure 4]**
Balance the redox equation using the smallest whole-number coefficients.

[ ] $Cu^{2+}(aq)$ + [ ] $Al(s) \rightarrow$ [ ] $Cu(s)$ + [ ] $Al^{3+}(aq)$

Figure 5

Base your answer to the question on the information below and on your knowledge of chemistry.

In a laboratory apparatus, a sample of lead(II) oxide reacts with hydrogen gas at high temperature. The products of this reaction are liquid lead and water vapor. As the reaction proceeds, water vapor and excess hydrogen gas leave the glass tube. The diagram and balanced equation below represent this reaction.



$$PbO(s) + H_2(g) + heat \longrightarrow Pb(\ell) + H_2O(g)$$

6. **[Refer to figure 5]**

Determine the change in oxidation number for the hydrogen that reacts.

Figure 6

Base your answer to the question on the information below and on your knowledge of chemistry.

Copper can be used for water pipes in homes. When the pipes corrode, copper atoms oxidize to form Cu^{2+} ions in the water.

A homeowner has a water quality report prepared for a sample of water taken from pipes in the home. According to the report, the 550.-gram sample contains 6.75×10^{-4} gram of dissolved Cu^{2+} ions.

7. **[Refer to figure 6]**

Write a balanced half-reaction equation for the corrosion that forms the Cu^{2+} ions.

8.

Base your answer on the following redox reaction, which occurs spontaneously in an electrochemical cell.

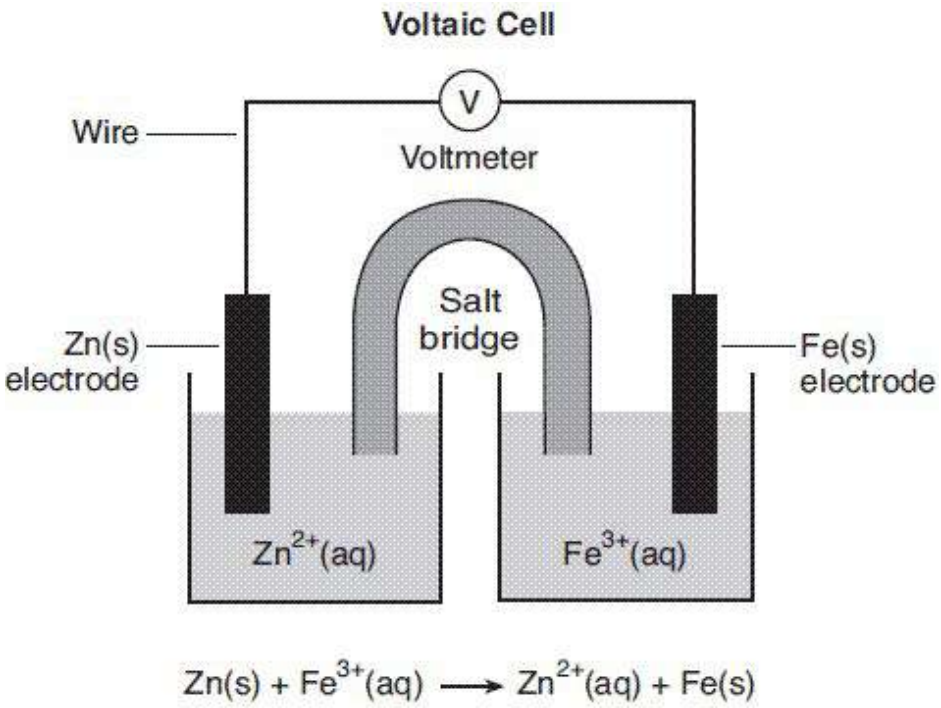
$$Zn + Cr^{3+} \rightarrow Zn^{2+} + Cr$$

State what happens to the number of protons in a Zn atom when it changes to Zn^{2+} as the redox reaction occurs.

Figure 7

Base your answer to the question on the information below and on your knowledge of chemistry.

An operating voltaic cell has zinc and iron electrodes. The cell and the unbalanced ionic equation representing the reaction that occurs in the cell are shown below.



9. **[Refer to figure 7]**

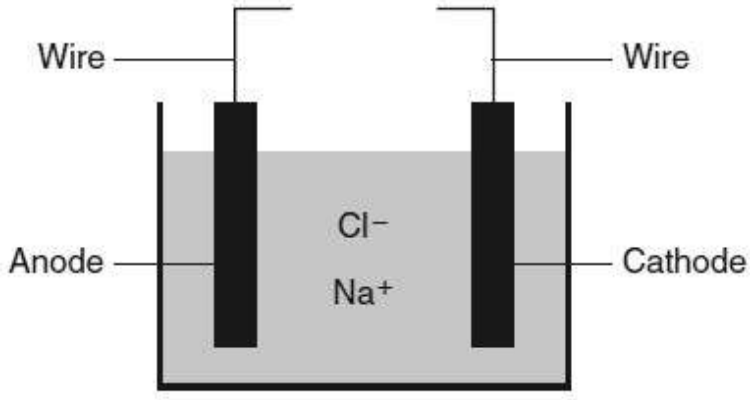
Explain, in terms of Zn atoms and Zn ions, why the mass of the Zn electrode *decreases* as the cell operates.

Figure 8

Base your answer to the question on the information below.

Metallic elements are obtained from their ores by reduction. Some metals, such as zinc, lead, iron, and copper, can be obtained by heating their oxides with carbon.

More active metals, such as aluminum, magnesium, and sodium, can *not* be reduced by carbon. These metals can be obtained by the electrolysis of their molten (melted) ores. The diagram below represents an incomplete cell for the electrolysis of molten NaCl. The equation below represents the reaction that occurs when the completed cell operates.



$$2NaCl(\ell) \rightarrow 2Na(\ell) + Cl_2(g)$$

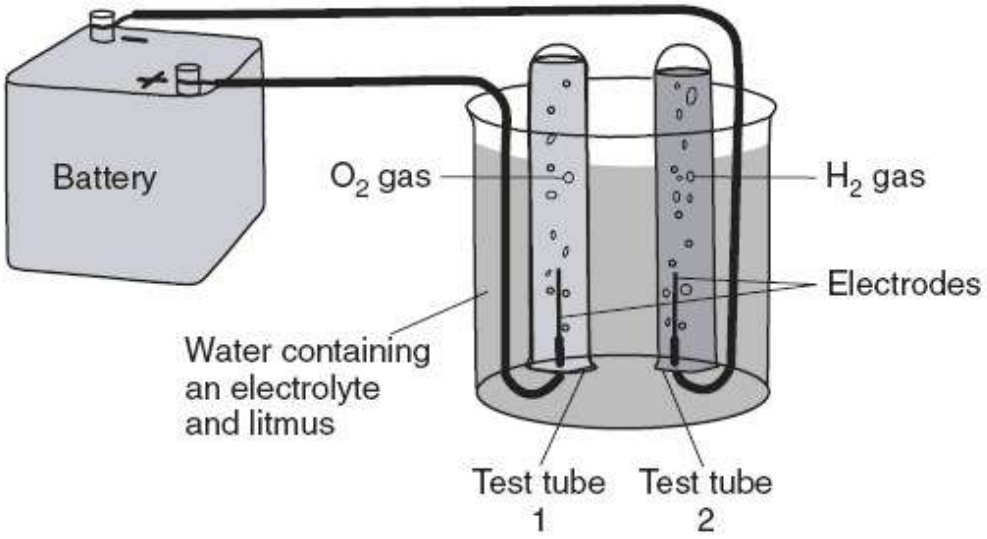
10. **[Refer to figure 8]**

Identify the component required for the electrolysis of molten NaCl that is missing from the cell diagram.

Figure 9

Base your answer to this question on the information below.

The diagram below shows a system in which water is being decomposed into oxygen gas and hydrogen gas. Litmus is used as an indicator in the water. The litmus turns red in test tube 1 and blue in test tube 2.



The oxidation and reduction occurring in the test tubes are represented by the balanced equations below.

Test tube 1: $2H_2O(\ell) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

Test tube 2: $4H_2O(\ell) + 4e^- \rightarrow 2H_2(g) + 4OH^-(aq)$

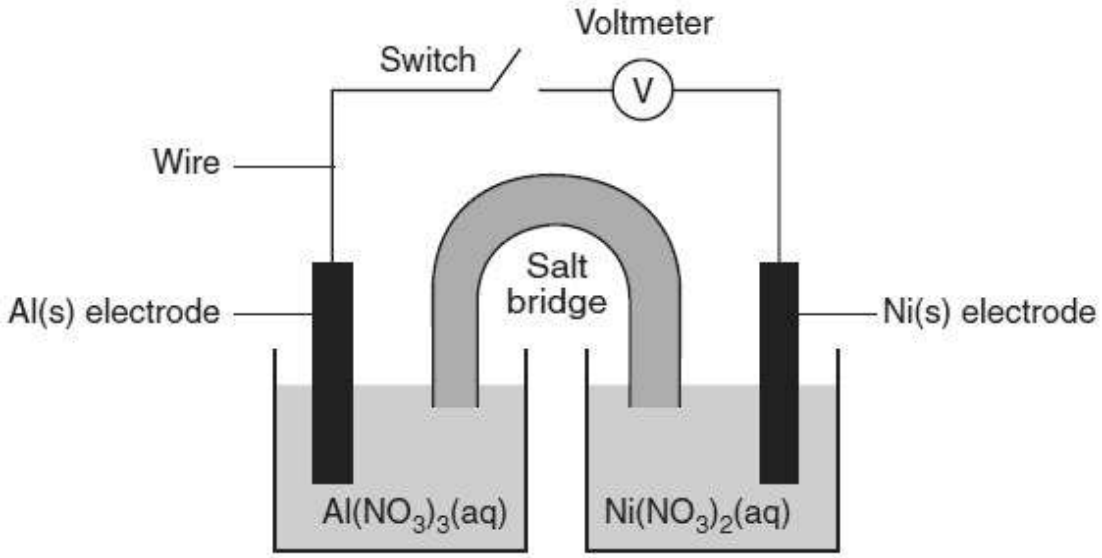
11. **[Refer to figure 9]**
Determine the change in oxidation number of oxygen during the reaction in test tube 1.

Answer: From [ ] to [ ]

Figure 10

Base your answer to the question on the information below.

A student constructs an electrochemical cell during a laboratory investigation. When the switch is closed, electrons flow through the external circuit. The diagram and equation below represent this cell and the reaction that occurs.



$$2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$$

12. **[Refer to figure 10]**

State the direction of electron flow through the wire when the switch is closed.

Figure 11

Base your answer to the question on the information below and on your knowledge of chemistry.

One type of voltaic cell, called a mercury battery, uses zinc and mercury(II) oxide to generate an electric current. Mercury batteries were used because of their miniature size, even though mercury is toxic. The overall reaction for a mercury battery is given in the equation below.

$$Zn(s) + HgO(s) \rightarrow ZnO(s) + Hg(\ell)$$

13. **[Refer to figure 11]**

Using information in the passage, state one risk and one benefit of using a mercury battery.

Figure 12

Base your answer to the question on the information below and on your knowledge of chemistry.

Stamping an identification number into the steel frame of a bicycle compresses the crystal structure of the metal. If the number is filed off, there are scientific ways to reveal the number.

One method is to apply aqueous copper(II) chloride to the number area. The Cu^{2+} ions react with some iron atoms in the steel frame, producing copper atoms that show the pattern of the number. The ionic equation below represents this reaction.

$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$

Another method is to apply hydrochloric acid to the number area. The acid reacts with the iron, producing bubbles of hydrogen gas. The bubbles form faster where the metal was compressed, so the number becomes visible. The equation below represents this reaction.

$$2HCl(aq) + Fe(s) \rightarrow FeCl_2(aq) + H_2(g)$$

14. **[Refer to figure 12]**

Write a balanced half-reaction equation for the reduction of the hydrogen ions to hydrogen gas.

Figure 13

Base your answer to the question on the information below and on your knowledge of chemistry.

Early scientists defined oxidation as a chemical reaction in which oxygen combined with another element to produce an oxide of the element. An example of oxidation based on this definition is the combustion of methane. This reaction is represented by the balanced equation below.

Equation 1: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

The definition of oxidation has since been expanded to include many reactions that do not involve oxygen. An example of oxidation based on this expanded definition is the reaction between magnesium ribbon and powdered sulfur when heated in a crucible. This reaction is represented by the balanced equation below.

Equation 2: $Mg(s) + S(s) \rightarrow MgS(s)$

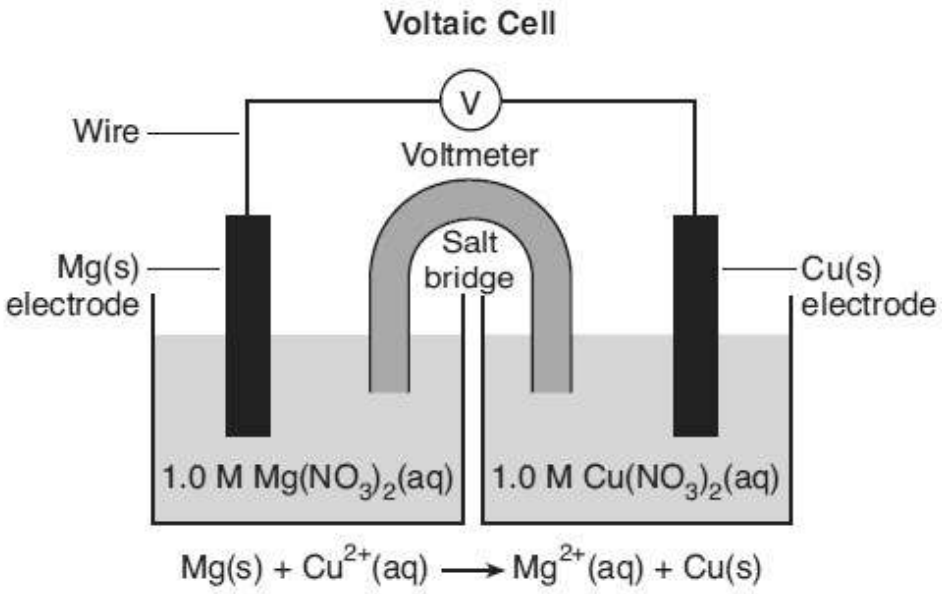
15. **[Refer to figure 13]**

State why early scientists classified the reaction represented by equation 1 as oxidation.

Figure 14

Base your answer to the question on the information below and on your knowledge of chemistry.

The diagram and balanced ionic equation below represent two half cells connected to produce an operating voltaic cell in a laboratory investigation. The half-cells are connected by a salt bridge.



16. **[Refer to figure 14]**

Determine the oxidation number of nitrogen in the negative ion in the aqueous solutions.

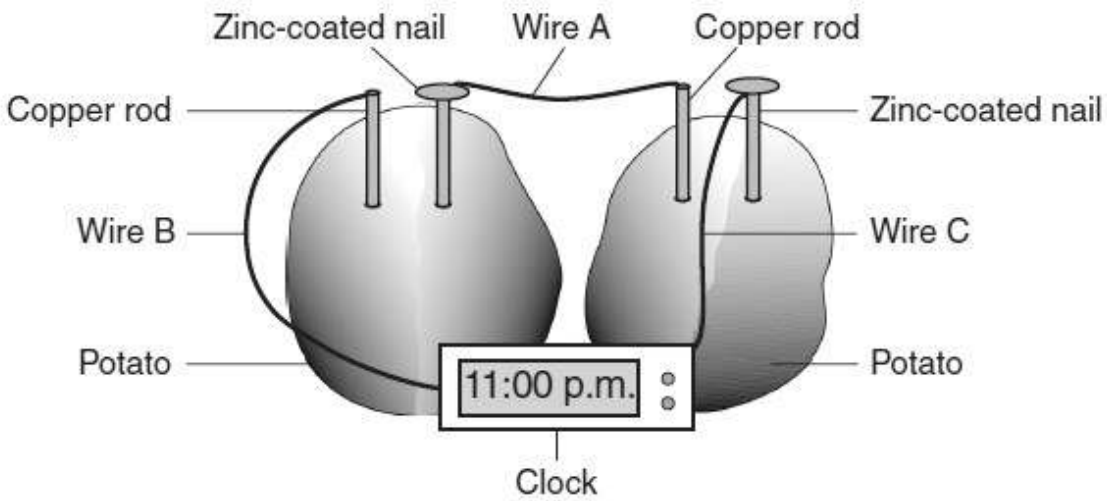
17. **[Refer to figure 12]**

Explain why the Fe atoms in the bicycle frame react with the Cu^{2+} ions.

Figure 15

Base your answer to the question on the information below and on your knowledge of chemistry.

A small digital clock can be powered by a battery made from two potatoes and some household materials. The "potato clock" battery consists of two cells connected in a way to produce enough electricity to allow the clock to operate. In each cell, zinc atoms react to form zinc ions. Hydrogen ions from phosphoric acid in the potatoes react to form hydrogen gas. The labeled diagram and balanced ionic equation below show the reaction, the materials, and connections necessary to make a "potato clock" battery.



$$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$$

18. **[Refer to figure 15]**

Write a balanced half-reaction equation for the oxidation that occurs in the "potato clock" battery.

Figure 16

Base your answer to the question on the information below and on your knowledge of chemistry.

The nuts, bolts, and hinges that attach some gates to a playground fence can be made of iron. The iron can react with oxygen in the air. The unbalanced equation representing this reaction is shown below.

$$Fe(s) + O_2(g) \rightarrow Fe_2O_3(s)$$

19. **[Refer to figure 16]**

Determine the change in oxidation state for oxygen in this reaction.

Figure 17

Base your answer to this question on the information below.

In a laboratory investigation, a student constructs a voltaic cell with iron and copper electrodes. Another student constructs a voltaic cell with zinc and iron electrodes. Testing the cells during operation enables the students to write the balanced ionic equations below.

Cell with iron and copper electrodes: $Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$

Cell with zinc and iron electrodes: $Fe^{2+}(aq) + Zn(s) \rightarrow Fe(s) + Zn^{2+}(aq)$

20. **[Refer to figure 17]**

Identify the particles transferred between Fe^{2+} and Zn during the reaction in the cell with zinc and iron electrodes.