spaces in the connector. When the current is turned off, the decrease in temperature causes the aluminum to contract, creating a small gap between it and the connector. Oxidation of the aluminum can now fill the gap created, further increasing the resistance of the connection. The temperature of the connection is slightly higher the next time current flows through the wire. This cycle can continue until either the connection burns out or surrounding building materials ignite. The aluminum oxidation problem is made worse if aluminum is in contact with copper or steel and trace amounts of moisture. Under these circumstances, aluminum corrodes even faster.

5.13 CASE STUDY: PIERCING PROBLEMS

CASE STUDY 5.13 QUESTIONS

(Page 419)

Understanding Concepts

1. Nickel allergies are difficult to overcome because metallic objects containing nickel are very common.
2. Metals such as silver and gold would not be affected by the acidity of skin because they are listed below hydrogen on the activity series.
3. A lower pH value indicates increased acidity. Perspiration with a lower pH increases the rate of release (oxidation) of nickel from a piercing.
4. Washing removes most of the electrolytes from your skin or the back of the watch. Reducing the concentration of electrolytes reduces the rate of corrosion.
5. Tongue piercing is riskier than earlobe piercing because the tongue is thicker and contains far more blood vessels than the earlobe, making the healing period for a tongue piercing much longer than that for an ear piercing. Longer healing times and increased blood flow also increase the risk of infection. Furthermore, since a tongue piercing is continually bathed by saliva, the risk of nickel being oxidized out of the piercing and ingested is greatly increased.

Making Connections

6. Wearing jewellery is a very ancient custom, with deep roots in many traditions. Jewellery can symbolize one's financial status, marital status, social affiliation, sexual orientation, etc. While wearing jewellery may make a person a target for theft, people wear jewellery to make a statement, to make themselves blend in with or stand out from the crowd, to show appreciation for a gift, to attract a partner, or for many other reasons.
   (Student evaluations of their own use of jewellery will vary, but should include some of the abovementioned considerations.)
7. Student answers will vary. However, most will agree that some standardization and formal training should be required, especially for practitioners who administer tongue piercings.
   Possible training requirements include:
   - training in antiseptic methods
   - screening clients for certain medical conditions or medications that may cause prolonged bleeding
   - screening clients who have compromised immune systems
   - providing appropriate client education on the risks of the procedure before proceeding, and screening clients who do not understand the potential risks
   - educating clients to follow appropriate oral hygiene practices
   - the importance of follow ups with medical professionals should complications arise
   - how to maintain a sterile environment where the procedure is performed

5.14 INVESTIGATION: FACTORS THAT AFFECT THE RATE OF CORROSION

(Pages 420–421)

Prediction

(a) **Part 1:** The corrosion of the nail in distilled water will be significantly less than in the solutions because distilled water contains no ions. Corrosion will probably occur fastest in the acidic solution, $HCl_{(aq)}$, and more slowly in the basic and neutral solutions, $NaOH_{(aq)}$ and $NaCl_{(aq)}$.

Part 2: The sealed test tube containing boiled water will show less corrosion than the open test tube of water because very little oxygen is available in the sealed tube. If a nail were exposed to dry air (oxygen but no water), its corrosion would be very slow also.

Part 3: Since zinc is a more reactive metal than iron, the nail in contact with zinc should show less corrosion. The nail in contact with copper will be even more corroded than the iron nail alone.

Part 4: The mechanically stressed nails should show more corrosion because mechanical stress can strain the metal, making it weaker in its ability to resist corrosion.

Procedure

(b)

Part 1

1. Add 10 mL of the following liquids to four labelled test tubes: distilled water (as a control), $NaCl_{(aq)}$, $HCl_{(aq)}$, and $NaOH_{(aq)}$.
2. Test the pH of each solution.
3. Add two to three drops of potassium hexacyanoferrate(III) indicator and one drop of phenolphthalein indicator to each test tube. Stopper and invert the test tubes to mix their contents. Remove the stoppers.
4. Add one nail to each test tube.
5. Store the test tubes until next class.
6. Dispose of the contents of the text tubes as follows: the acid solution can be neutralized with the base solution and then poured down the drain; the $NaCl_{(aq)}$ solution can be poured down the drain.

(c)

Part 2

1. Add 10 mL of tap water to one test tube (control). Fill the other test tube to the brim with freshly boiled tap water to eliminate oxygen from the test tube.
2. Add two to three drops of potassium hexacyanoferrate(III) indicator and one drop of phenolphthalein indicator to each test tube. Stopper and invert the test tubes to mix their contents. Remove the stoppers.
3. Add one nail to each test tube.
4. Add another nail to a dry, empty test tube.
5. Stopper all three test tubes.
6. Store the test tubes until next class.
7. Dispose of the liquid contents of the text tubes down the drain.

(d)

Part 3

1. Add 10 mL of the $NaCl_{(aq)}$ solution to three test tubes.
2. Add two to three drops of potassium hexacyanoferrate(III) indicator and one drop of phenolphthalein indicator to each test tube. Stopper and invert the test tubes to mix their contents. Remove the stoppers.
3. Wrap one nail tightly with copper wire. Place the wrapped nail into one of the test tubes.
4. Use the hammer to punch the second nail through a small zinc square. Place this nail into the second test tube.
5. Place a third nail (with no metals attached) into the third test tube (control).
6. Store the test tubes until next class.

(e)

Part 4

1. Use pliers to bend one nail into a tight U shape.
   Flatten one end of a second nail, using the hammer and block.
2. Add 10 mL of tap water to three test tubes.
3. Add two to three drops of potassium hexacyanoferrate(III) indicator and one drop of phenolphthalein indicator to each test tube. Stopper and invert the test tubes to mix their contents. Remove the stoppers.
4. Add the bent nail to one test tube, the hammered nail to a second test tube, and a straight “unstressed” nail (control) to the third test tube.
5. Store the test tubes until next class.

Observations

Part 1

Test tube	Evidence of corrosion
distilled water (control)	faint tinge of pink no blue evident
$NaCl_{(aq)}$	solution is pink blue deposits on the tip of the nail
$HCl_{(aq)}$	no pink plenty of blue deposits on the nail and at the bottom of the test tube
$NaOH_{(aq)}$	solution is pink no blue deposits no changes on the surface on the nail

Part 2

Test tube	Evidence of corrosion
tap water (control)	some blue, indicating the presence of $Fe^{2+}_{(aq)}$ solution is mostly pink
boiled water	solution is pink but less intensely coloured than tap water no blue deposits
air	no evidence of corrosion

Part 3

Test tube	Evidence of corrosion
nail and copper	blue deposits around the copper coils nail is badly corroded solution is pink
nail and zinc	little evidence of blue in solution solution is pink
nail (control)	some evidence of blue at the tip and head of the nail solution is pink

Part 4

Test tube	Evidence of corrosion
straight nail (control)	some blue deposits solution is pink
bent nail	numerous blue deposits, particularly near the bend and ends of the nail solution is pink
hammered nail	numerous blue deposits solution is pink

Analysis

(f) **Part 1:** The pH of the solution had a significant effect on the amount of corrosion observed in the test tube. The solution with the lowest pH (hydrochloric acid, pH = 2) had the greatest amount of corrosion. The solution with the highest pH ($NaOH_{(aq)}$, pH = 13) showed no evidence of corrosion.
Part 2: Oxygen and water are both required for corrosion to occur. This conclusion was reached because the nail in the open test tube was more corroded than the nail in the sealed test tube of boiled water. Furthermore, the nail exposed only to air showed no corrosion.

Part 3: Contact with less reactive metals like copper increased the rate of corrosion. However, the nail in contact with zinc, which is more reactive than iron, showed little evidence of corrosion.
Part 4: The nail that experienced mechanical stress showed more blue deposits, indicating sites of iron oxidation. Blue deposits were also seen at the head, tip, and spiral edges of the nail: places where the nail was mechanically stressed while it was being manufactured.

Evaluation

(g) Student answers will vary. The investigation was fairly successful: we were able to see the effects of all four factors. The pink colour of some test tube solutions was too intense to allow us to see the corrosion of the nails clearly. We left our test tubes over four days, which may have been too long. It made detailed observations difficult. If we were doing this investigation again, we should make observations every day for four days.
(h) Controls are useful in this experiment to show how the nail would have changed under "normal" conditions before experimental variables are manipulated.
(i) Assuming that the solutions are made correctly (not contaminated) and that the nails used are not corrosion-resistant, there are few experimental errors or uncertainties in this experiment.
Boiling the water in Part 2 may not have effectively removed all the oxygen from the water. The only problem was the length of time we left the nails under their experimental conditions.

5.15 PREVENTING CORROSION

SECTION 5.15 QUESTIONS

(Pages 425–426)

Understanding Concepts

1. Painting prevents corrosion by isolating the metal from contact with its environment.
2. (a) Since aluminum is higher on the activity series, it should oxidize more readily than iron.
   (b) Although aluminum is more reactive than iron, aluminum protects itself from corrosion by forming a protective oxide layer that adheres well to the underlying metal. The oxide that iron forms, however, flakes off easily, exposing fresh iron that can be oxidized.
3. (a) A sacrificial anode is a piece of relatively reactive metal that is placed in electrical contact with the metal object to be protected from corrosion. The use of a sacrificial anode is a form of cathodic protection. The electrons released from the oxidation of the sacrificial anode prevent the object from oxidizing.
   (b) Iron would be the best choice to protect copper because it is the only metal of the three given that is more reactive (e.g., higher on the activity series) than copper.
4. (a) Impressed current and sacrificial anodes are both forms of cathodic protection. Both methods provide corrosion protection by sending electrons into the metallic object to be protected, preventing the object from losing electrons and being oxidized by its environment.
   (b) The use of a sacrificial anode is a method that involves the consumption of another chemical. As long as the anode metal remains in electrical contact with the metal to be protected, and until it is all corroded away, the protection continues. Impressed current, on the other hand, is an electrical method that does not involve any other chemical substance. This method provides protection only while an external supply of electrical energy is maintained.
5. Physical properties: strong, stiff, have a good degree of springiness, and should resist being bent.
   Chemical properties: completely unreactive with any of the substances that could commonly enter the mouth.

Applying Inquiry Skills

6. (a) The nail stored in salt water without a coating of grease is badly corroded. The coated nail shows little evidence of corrosion.
   (b) This is an example of applying a protective coating to prevent corrosion.
   (c) This method provides corrosion protection by completely isolating the metal from its environment, which prevents the metal from reacting with oxygen and water.
   (d) The main disadvantage of a protective coating is that the metal remains protected only while the coating remains intact. A small crack or other imperfection in the coating could quickly become the site of corrosion.
7. (a) The nail with the zinc attached shows little evidence of corrosion, although the zinc has developed a pale-grey coating. The control nail (with no zinc) is visibly rusting.
   (b) This is an example of cathodic protection.