The Autoclave and the Production of Heat and Acid

Elisabeth M. Price and Dana Sue Kimbal;
adaptation of method by Dr. Stanley Cavitt, Texas Operation Chemistry Team

KEY CONCEPT

The oxidation of sulfide ore in the autoclave produced heat and acid. The activity models these reactions in a small scale reaction of steel wool or sulfide ore that is monitored with probes.

SKILLS: ***Observing, Recording, Investigating, Modeling***
TIME: ***50 minutes***
AUDIENCE: ***Teachers and students, grades 5 - 8.***

OBJECTIVE

To understand that the reactions in the autoclave to oxidize the ore and release the gold for processing themselves provide the heat and acid required for the process. These same reactions happen naturally in the mine or geologically and may have environmental consequences.

SAFETY

Wear chemical splash goggles.

Background for teachers

CONTENT FOCUS

Gold that is mined must be available for separation from the rest of the rocks. Much gold is held in compounds that involve a metal and sulfur, for example pyrite, an iron sulfide. This gold held in the sulfide compound is not available for processing. However, if the sulfide compound is changed to an oxide, the gold is readily accessible. This process happens naturally over geologic time to produce the oxide ores. That same oxidation process can be speeded up to human time scales in an autoclave. The autoclave reactions produce the positive products of heat and acid required to keep the reactions going. These same products can cause environmental concerns, the treatment of which is included as a part of the mine plan.

In this activity, two model systems are used so the production of heat and the production of acid are readily observed. In the first model, steel wool (iron) is oxidized by hydrogen peroxide (H_2O_2) to produce measurable heat. Investigate the second model in which sulfide ore should be oxidized by hydrogen peroxide to produce acid and some heat according to the reaction below. If heat isn't measurable, what could be measured to show if the reaction is taking place?

The overall reactions of the iron oxidation model can be written:

$$2Fe_{(s)} + O_{2(aq)} + 2H_2O_{(l)} \rightarrow 2Fe^{+2}_{(aq)} + 4OH^-_{(aq)}$$

However, because the reaction of oxygen is hard to reproduce in the lab, so we can substitute hydrogen peroxide for the following reaction:

$$2Fe(s) + 2H_2O_{2(aq)} \rightarrow 2Fe^{+2}_{(aq)} + 4OH^-_{(aq)}$$

The natural reaction for the oxidation of pyrite (sulfide concentrate) can be written:

$$4FeS_{2(s)} + 15O_{2(aq)} + 14H_2O_{(l)} \rightarrow 4Fe(OH)_{3(s)} + 8SO_4^{2-}{}_{(aq)} + 16H^+_{(aq)}$$

The reaction with oxygen gas dissolved in water (aqueous) is hard to duplicate in the lab, so we use hydrogen peroxide as our source of oxidizing agent, modeling oxygen. This can be written:

$$4FeS_{2(s)} + 30H_2O_{2(aq)} \rightarrow 4Fe(OH)_{3(s)} + 8SO_4^{2-}{}_{(aq)} + 16H^+_{(aq)} + 16H_2O_{(l)}$$

ADVANCE PREPARATION

Prepare the sulfide concentrate. This is available at the mine site. Pyrite or other pulverized sulfide ore could be used instead. If finely ground activated carbon is not readily found, grind some of the activated carbon available in tropical fish stores. Calibrate and prepare the electronic probes as indicated in the operation manual.

TIPS

- For all the variables, run a control in which the component thought to make a difference is left out. For example, if the pH change produced by sulfide ore is to be studied, the control would include all the components except the sulfide ore.

- The reactions as written in the introduction show that iron alone produces OH^- ions while the sulfide ore produces H^+ ions. Make observations that reveal this reaction product.

- Study any other unexplained observations using chemical tests or other measuring devices (thermometers, probes).

The activity should be presented as an investigation; however, students have to have had the level of experience of seeing reactions and measuring products in order to begin to understand the reactions. To maximize learning from the activity, both in content and how to conduct an investigation, have the students explore the activity as a "cook book" activity in which the purpose is to make observations. From the observations, the students can begin to try to understand the reasons for the various reagents. The investigation can come into play in studying the part each reagent plays in the reaction. Students should propose ways to find out what each reagent does by running the experiment omitting the reagent in question and comparing the results with the reaction that has all reagents.

The Activity

MATERIALS

Oxidation of steel wool
For each student or small group:

- No. 0000 steel wool
- Sodium chloride (table salt)
- 3% hydrogen peroxide (H_2O_2), available at the pharmacy section of grocery stores
- Activated carbon, finely ground, available from pet stores for aquariums
- Quilted cotton squares, available in cosmetics areas of grocery stores
- Water
- Squirt bottle, measuring spoons, pipets, graduated cylinders for water
- Small plastic zipper closing bags, available in grocery store

Oxidation of sulfide ore
For each student or small group:

- Finely ground sulfide mineral (sulfide concentrate from a mine, pyrite, or finely ground sulfide ore)
- Sodium chloride (table salt)
- 3% hydrogen peroxide (H_2O_2), available at the pharmacy section of grocery stores
- Activated carbon, finely ground, available from pet stores for aquariums
- Quilted cotton squares, available in cosmetics areas of grocery stores
- Water
- Squirt bottle, measuring spoons, pipets, graduated cylinders for water
- Small plastic zipper closing bags, available in grocery store

PROCEDURE

Iron oxidation

Prepare a control by following the procedure but leave out the steel wool.

1. Place a 2” square or round cotton pad on the work place.
2. Flatten a piece of steel wool about the same size as the cotton pad and place it on top of the cotton pad.
3. Add one teaspoon of salt (NaCl) to the steel wool pad, then add about a quarter teaspoon of finely ground activated carbon onto the steel wool.
4. Place the other cotton pad on top. Squeeze the layers together to make a “sandwich.”
5. Place the sandwich of cotton pad, steel wool, and carbon plus salt into a small plastic bag. Add about two teaspoons of room temperature water to the pads. Knead the sandwich through the bag, gently so the ingredients are not lost but come into contact well.
6. After about 2 minutes, open the bag, add one teaspoon of 3% hydrogen peroxide.
7. Record observations in temperature, pH, appearance. Compare to those values for the control.

Sulfide Ore Oxidation

Prepare a control by following the procedure but leave out the steel wool.

1. Place a 2” square or round cotton pad on the work place.
2. Sprinkle about 2 teaspoons of sulfide concentrate onto the cotton pad.
3. Add one teaspoon of salt (NaCl) to the sulfide concentrate, then add about a quarter teaspoon of finely ground activated carbon onto the sulfide concentrate.
4. Place the other cotton pad on top. Squeeze the layers together to make a “sandwich.”
5. Place the sandwich of cotton pad, sulfide ore, and carbon plus salt into a small plastic bag. Add about two teaspoons of room temperature water to the pads. Knead the sandwich through the bag, gently so the ingredients are not lost but come into contact well.
6. After about 2 minutes, open the bag, add one teaspoon of 3% hydrogen peroxide.
7. Record observations in appearance, temperature, pH.
8. If changes are not observed, what could be changed in the system to make a reaction take place? (Consider the balanced equation for the reaction.)

EXTENSIONS

1. Carefully record and report observations of products. What products are useful? How can they be used?
2. What products might not be useful or even a problem? When could the product be a problem? How could the problem be controlled?
3. Study other variations of the oxidation system.
4. What are the products? Devise methods to analyze qualitatively.
5. What does each component of the system do? Check your ideas by proposing a test.

SUGGESTED FOLLOW-UP (DISCUSSION)

1. In what situations are these reactions observed in normal daily activities?
2. What are useful aspects of the reactions. What are negative aspects of the reactions?