Drexel-SDP GK-12 ACTIVITY

Subject Area
Algebra, Chemistry, Physical Science

Activity Title
"Optimizing a chemical reaction"

Grade Level
11-12

Time Required
3 hours

Group Size
3 students per group

Summary
In this activity students perform a single replacement redox reaction of zinc and hydrochloric acid to produce hydrogen gas. They learn the importance of balancing a chemical equation for determining the concentrations needed for a reaction to efficiently occur. Students will also learn how to maximize the amount of hydrogen gas they can produce by keeping a budget.

Engineering Connection
Chemical engineers often have to figure out how to get the most out of their supplies by maximing the number of experiments they can perform within a budget. Additionally, engineers frequently have to model an experiment with equations they develop. By graphing the equations they can determine parameters needed for to optimize an experiment.

Keywords
Chemistry, limiting reagent

Educational Standards
- Science: 3.4.12.A
- Science: 3.4.12.B
- Math: 2.8.11.D
- Math: 2.8.11.H

Pre-Requisite Knowledge
- Understand molar concentrations
- Know how to balance chemical equations

Learning Objectives
After this lesson, students will be able to:
- Calculate the cost per mole of a chemical compound when given the total amount and price of a bottle.
- Convert from grams to moles from the quantity on a bottle using the molar mass of the compound.
- Convert from moles to grams after reading values from the intercept point on a graph.

Materials List
Each group needs:
- Graph paper
- Zinc
- HCl
- 10-mL graduated cylinder
- 500 mL beaker
- 100 mL beaker
- Spatula/Scooper

Introduction / Motivation
Zinc can be very reactive when placed in hydrochloric acid, if too much is added there could be a large explosion. Scientists must be very careful when mixing acids with bases so this does not occur. Additionally, chemicals can be very expensive so engineers must carefully think about their procedure so they do not waste chemicals unnecessarily. Careful calculations enable scientists and engineers to conduct experiments safely and resourcefully. In this activity each group must calculate the maximum amount of hydrogen gas they can produce with a budget of only $2.

Vocabulary / Definitions

Word	Definition
Redox reaction	Formally known as an oxidation-reduction reaction in which a transfer of electrons takes placed. Oxidation refers to a loss of electrons and reduction refers to gain of electrons.
Single replacement reaction	Occurs in a chemical reaction when one element replaces another element in a compound. For example A + BX → AX + B

Procedure

Background

One way to produce hydrogen gas is to react Zn with HCl. This type of reaction is known as a single replacement reaction. In this case the Zn replaced the H ions and the hydrogen is free to escape. However the reaction occurs fairly fast so you need a way to collect the gas before it diffuses into the air.

$$Zn + HCl \rightarrow ZnCl_2 + H_2$$
$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Before the Activity

Look up the prices of your supplies of Zn and HCl from a company such as Fisher Scientific. At the time this lesson was developed, Zn costs $22.50 for a 100 gram bottle and (38%) HCl cost $72.90 for 2.5 Liters. You must be confident in the mathematical procedure before letting the students attempt this so it is wise to practice the problem a few times.

First change the Zinc to moles:
1 mol = grams of compound / molecular weight of compound
(100 g) / (65.4 g/mol) = 1.53 mol of Zn costs $22.50
Thus, 1 mol of Zn costs $14.70

Now change the liters of HCl into moles:
(12 mol/ L) * (2.5 L) = 30 moles (this costs $72.90)
Thus, 1 mol of HCl costs $2.43

Derive an equation that relates the two compounds to your budget:
If we consider,
x = the number of moles of Zn
y = the number of moles of HCl

then we have:

$$\$14.7x + \$2.43y = \$2.00 \quad (1)$$

Additionally, from the balanced equation we have:

$$2x = y \qquad (2)$$

The graph of the two equations is shown below. The intersection point of the two equations gives the corresponding concentrations for both chemicals to produce the most hydrogen gas.

Another method to solve for the two is by inserting equation (2) into (1) we get:
14.7x + 4.86x = 2.00
19.56x = 2.00
x = 0.102 moles of Zn
y = 0.204 moles of HCl

We can convert this back to grams and milliliters:
6.67 g of Zn
17 mL of HCl

With the Students

1. Balance the equation
2. Find price of Zn and HCl per mole
3. Write an equation relating the number of moles of Zn to the number of moles of HCl to consume all of the materials.
4. Write an equation to calculate how many moles of Zn and HCl you can buy with a spending limit of one dollar.
5. On a piece of paper, draw a graph with the two equations you found from #3 and #4.
6. Find the intersection point
7. Convert the values you found from the graph from moles into grams for Zn and milliliters for HCl and then have the teacher check your answers
8. If you values are correct continue to perform the experiment.
9. Place calculated amount of Zn in beaker.
10. Fill container half way with water and then place water filled beaker with water upside down in container so there is only a minimum of air trapped in the beaker.
11. Connect one side of the tube to the Erlenmeyer flask and the other end feed to the bottom of the beaker.
12. Pour HCl into Erlenmeyer flask and watch it react with Zn
13. All hydrogen gas that is produced by the reaction will travel to the upside down beaker.
14. Once the beaker is full of air (you will see this because the hydrogen gas will push the water out of the beaker) take a piece of glass and cover the top of the beaker so no gas escapes.
15. Calculate the volume of gas produced based on the volume of beaker filled with gas.
16. Uncover beaker and quickly light a match over it.

Troubleshooting Tips
All students should rinse supplies out with distilled water to make sure there is no residue in the glassware.
Although the recipe will not produce a large flame, make sure students stand back when bringing the lit match to the trapped gas.
When working with HCl it is important students wear gloves and goggles.

Investigating Questions
1. Which compound is your limiting reagent?
2. What steps would you take to produce more gas?
3.

Assessment
Pre-Activity Assessment
Title: Class exercise
Have students develop two formulas that would help them calculate the number of hot dogs they could make if they were only given $100 and had to purchase the buns and the sausages.

Activity Embedded Assessment
Title: Checkpoint
Make sure students can calculate the grams and milliliters they will need to use for each chemical compound.

Post-Activity Assessment
Title: Experiment
From their calculated values have students perform the experiment described above and record how much hydrogen gas they were able to make. Have them relate this volume to the moles they needed to yield the gas.

Activity Scaling
For a more advanced class do not give the students the guided questions, instead only give provide the prompt question, “Calculate the maximum amount of hydrogen gas that can be produced from a Zn-HCl reaction with a budget of only $2.

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