This supplement to the CIBL Interactions of Matter/Chemistry science kit provides an opportunity to integrate engineering. This extension can work well at any time during your teaching of this unit. Before you begin teaching the unit, consider when you would like to use it. This supplement is packed with the CIBL Interactions of Matter/Chemistry kit, and it uses materials already in the kit or readily available at your school.

A student handout is at the back of the lesson in the black line master section.

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Detoxifying Waste Chemicals

In this 1 or 2 class period activity, students devise a way to neutralize waste products from an industrial process. When the two waste products are combined in proper proportions, they are suitable to dispose in the environment. The activity specifies an outcome but does not provide ways to achieve it. The challenge is for teams to puzzle through the problem on their own, as if they were chemical engineers. There is a solution, but it is not important for teams to find the exact, correct proportion. Teams’ reasoning and their approach to the problem are most important. Because of this, teams are asked to document what they do and why.

- a half gallon of washing soda solution (see preparation section)
- a supply of graduated 1-oz cups for measuring
- a supply of 1 oz cups to distribute solutions A and B
- 15 Chemplates
- a box of toothpicks
- a supply of graduated plastic pipettes (2 ml)
- a supply of pH paper strips and color comparison sheets for determining pH
- student handouts, one per team.

- a 1 oz. cup of solution A (vinegar)
- a 1 oz cup of solution B (washing soda and water)
- 2 pipettes
- a dozen toothpicks
- 1 graduated 1 oz. cup for measuring
- 8 strips of pH paper torn in half – 16 half strips
- a color comparison sheet for the pH paper
- Chemplate
- 1 Chemical Engineering Challenge handout.

1. Copy one Chemical Engineering Challenge sheet per team.

2. Solution A is pure white vinegar, undiluted. To make solution B, place one tablespoon of washing soda in a half-gallon jug full of water. Shake or swirl until most of the washing soda is dissolved.

3. Before class, distribute a set of cups labeled A and B to each team. Fill the A cups with the vinegar, and the B cups with the washing soda solution.
The company you work for produces two waste products (solutions A and B). The EPA has ruled that the two waste products are safe to put into the environment if their pH is 7. Luckily, when the solutions are mixed in proper proportions, the mixture has a pH of 7. You have been assigned the task of determining how much of each solution should be mixed together so that the pH is acceptable for release. Your company wants to mix as much as possible of the two waste products. Any waste products that they cannot treat by mixing must have further expensive treatment. Your company produces 10,000 gallons of solution A and 30,000 gallons of solution B each month.

**What is pH and why 7?**

In chemistry, pH measures how acidic or basic a solution is. Solutions with a pH lower than 7 are acidic. Solutions with a pH above 7 are basic. A pH of 7 is neither acidic nor basic, but neutral. Pure water has a pH of 7. The lower the pH, the more acidic the solution; the higher the pH, the more basic the solution. Some approximate pH values of foods include apple juice (pH 3), grapes (pH 4), white bread (pH 5-6), milk (pH 6.5), soft drinks (pH 3).

1. Briefly explain that the challenge is to figure out the proportion of each solution needed to make the solution neutral, as measured by pH paper. Give out BLM 1 and tell the class that you will not give them any further instructions about how to do this. There are, however, a few techniques that everyone will use. Explain (and demonstrate as needed) each of the following:

   a. When you mix the two solutions, stir them with a toothpick before testing.

   b. To test pH, dip the paper strip into the mixture and match the color (read results) within 2 seconds after wetting the strip. The strip is accurate immediately, then begins to change color after about 2 seconds. Once the end of a strip is wet, it is finished and cannot be used again.

   c. When you use pipettes to transfer solution, always use the same pipette with the same solution. Mixing up pipettes will change results and make the problem more difficult.

   d. Make a chart to record the amounts of each solution used and the resulting pH for each trial.

2. Give out materials, including the Chemical Engineering Challenge handout, and tell students to begin.

3. At this point, teams will begin to use pipettes, a Chemplate, and strips of pH paper, to determine a ratio for combining solutions A and B that results in pH 7. Check to be sure they are all keeping track of how they determine the ratio.

4. Once teams have determined a ratio of solutions A and B, they must apply that ratio to 10 ml of solution B. They will again use pH paper and modify until they can reproduce the result. They must start by pouring 10 ml of solution B into a clean 1-oz graduated (measuring) cup. The ratio might change slightly with larger amounts, and it is important that students record the new ratio if necessary.
Procedure

Continued

Answer Key

5. Write up a report for the waste management engineer. The report will specify how many gallons of waste solutions can be neutralized and how many gallons will remain and need further treatment. Remember your company produces 10,000 gallons of solution A and 30,000 gallons of solution B each month. The reports should include:

a. The ratio used to mix Solutions A and B that will result in a safe waste product, pH 7. Provide the procedure that you and your partner used to determined the ratio. Include any sources of error.

b. After each month, how many gallons of each solution, A and B will be neutralized?

c. After each month, how many gallons of solution A or B will remain and need further treatment?

Teams will find slightly different ratios because measuring instruments are crude and students’ techniques vary. Expect different answers. For example, a team might find that 13 drops of B and 3 drops of A produce a pH of 7, but they can still scale these numbers up to higher volumes. This activity is designed for teams to follow a reasonable line of thinking rather than to find a specific answer.

Here is one way to determine how many milliliters (ml) of solution A to mix with 10 milliliters of solution B. In this hypothetical example, 5 parts of B mixed with 1 part of A made a pH 7. A student could set it up as follows:

\[
\frac{X_{ml}}{A} \times \frac{1}{10 ml} = \frac{1}{5} \frac{A}{B}
\]

Cross multiplying,

\[
X_{ml} = 2 \ ml \ of \ A
\]

To apply this 5B:1A ratio to 30,000 gallons of solution B and 10,000 gallons of solution A, first determine which solution will have some left. In our hypothetical case, all 30,000 gallons of solution B can be neutralized with a fifth that amount of solution A, (6,000 gallons).

NOTE: The math is simple with ratio like 5B:1A. However, teams that have ratios like 13B:3A might need to estimate to determine which of the solutions will have some left over.

Using the 5B:1A example, all 10,000 gallons of A are not needed. Therefore, A will be the unknown in the formula. To determine how much of solution A will be used, a student might set it up as follows:

\[
X_{gal} \times \frac{1}{30,000 gal} = \frac{1}{5} \frac{A}{B}
\]

Cross multiplying,

\[
X_{gal} = 6,000 \ gal \ of \ A
\]

Since only 6,000 gallons of A are needed for the 30,000 gallons of B, and the company makes 10,000 gallons of A, there will be 4,000 gallons of A left over.
Scenario:
The company you work for produces two waste products (solutions A and B). The EPA has ruled that the two waste products are safe to put into the environment if their pH is 7. Luckily, when the solutions are mixed in proper proportions, the mixture has a pH of 7. You have been assigned the task of determining how much of each solution should be mixed together so that the pH is acceptable for release. Your company wants to mix as much as possible of the two waste products. Any waste products that they cannot treat by mixing must have further expensive treatment. Your company produces 10,000 gallons of solution A and 30,000 gallons of solution B each month.

What is pH and why 7? In chemistry, pH measures how acidic or basic a solution is. Solutions with a pH lower than 7 are acidic. Solutions with a pH above 7 are basic. A pH of 7 is neither acidic nor basic, but neutral. Pure water has a pH of 7. The lower the pH, the more acidic the solution; the higher the pH, the more basic the solution. Some approximate pH values of foods include apple juice (pH 3), grapes (pH 4), white bread (pH 5-6), milk (pH 6.5), soft drinks (pH 3).

Procedure:
You and a partner will be given a 1 oz. sample of each solution A and B, pH paper, pipettes, a Chemplate, toothpicks and graduated cups.

Here is your schedule:

1. Using pipettes, a Chemplate, toothpick stirrers, and strips of pH paper, determine a ratio for combining known amounts of solutions A and B to achieve pH 7. Keep a table of results and keep track of how you determine the ratio. Here are some testing guidelines:
   a. When you mix the two solutions, stir them with a toothpick before testing.
   b. To test pH, dip the paper strip into the mixture and match the color (read results) within 2 seconds after wetting the strip. The strip is accurate immediately, then begins to change color after about 2 seconds. Once the end of a strip is wet, it is finished and cannot be used again.
   c. When you use pipettes to transfer solution, always use the same pipette with the same solution. Mixing up pipettes will change results and make the problem difficult or impossible.

2. Test the ratio that you found in step 1 on a larger scale. Apply the ratio to 10ml of solution B. Modify the amounts if solution A that you add to 10 ml of solution B, and test with pH paper until the solution has a pH of 7.

3. Write up a report for the waste management engineer. Remember, your company produces 10,000 gallons of solution A and 30,000 gallons of solution B each month. Your report specifies how many gallons of waste can be neutralized and how many gallons of which waste product will remain and need further treatment. The reports should include:
   a. The ratio used to mix solutions A and B that will result in a safe waste product, pH 7. Describe the procedure that you and your partner used to determined the ratio. Include any sources of error.
   b. After each month, how many gallons of each solution A and B will be neutralized?
   c. After each month, how many gallons of solution A or B will remain and need further treatment?