RESEARCH TRIANGLE NANOTECHNOLOGY NETWORK

Capture that Phosphorus!

Overview

In this lesson, students will be presented with issues surrounding extracting and recycling phosphorus. They will be told that in order to recycle phosphorus, it has to bond with another element and precipitate out of solution. Students will search for the best element to bond with phosphorus, working in groups to analyze various options. Elements will be analyzed through academic and real-world lenses, looking at stability, accessibility, cost effectiveness, toxicity, environmental impacts, storage and transport restrictions, and solubility in water. From here, students will create a poster to share their evaluation with the class as to whether this element is a realistic contender. They will include a balanced chemical equation and a stoichiometry problem. As a class, students will decide which element(s) would best fit the current need.

Key Search Words

High School, Science, Chemistry, Physical Science, Bonding, Reactions, Periodic Table, Ionic, Covalent, Phosphorus, Precipitation, Recycling, Solubility, Elements, Stoichiometry, Dimensional Analysis, Conversions

Learning Objectives

Students will be able to use technology and their periodic table knowledge to gather and organize information related to various elements.
Students will be able to write and balance equations to use for stoichiometry problems.
Students will be able to analyze data to choose the best solution to a problem.

Curriculum Alignment

Chm.1.2.5 Compare the properties of ionic, covalent, metallic, and network compounds.
Chm.1.3.2 Infer the physical properties (atomic radius, metallic and nonmetallic characteristics) of an element based on its position on the Periodic Table.
Chm.2.2.3 Analyze the law of conservation of matter and how it applies to various types of chemical equations (synthesis, decomposition, single replacement, double replacement, and combustion).
Chm.2.2.4 Analyze the stoichiometric relationships inherent in a chemical reaction.

Classroom time required

This lesson is designed to take one 90 minute block or two 45-55 minute classes, with the option of extending further if needed for class presentations..

Materials & Technology

Students will need:

1. access to the internet (device, either per student, or per group).
2. a copy of the instruction sheet (printed or projected for all) (see appendix).
3. Poster paper, art supplies (markers, colored pencils, crayons, construction paper, glue, etc).

Safety

Teachers should be aware and conscious of appropriate internet usage by students.

Teacher Preparation for Activity

Before the lesson begins, the teacher should:

1. Prepare the materials listed.
2. Be familiar with the issues with phosphorus recycling.
    a. In short, Phosphorus is a limited resource that does not cycle like carbon or nitrogen. Much of it ends up in wastewater treatment centers; however, it is necessary in the development/maintenance of numerous species (including humans) and is vital to agriculture via fertilizers. Much research is focused on how to recover phosphorus from these waste sources and recycle it back to farmers as a responsible and sustainable fertilizer.
    b. For further information, conduct an internet search with phrases such as: “phosphorus recovery”, “phosphorus removal wastewater”, and “phosphorus water pollution”.

Student Preparation for Activity

In order to be set up for success in this activity, students will need basic understanding of the following topics: Periodic table, Bonding, Reactions, and Stoichiometry.

Procedure

After the teacher has prepared the materials and researched information pertaining to phosphorus recovery from wastewater treatment centers, the teacher will begin the activity:

1. Introduce the topic of recovering phosphorus from wastewater treatment plants.
    a. One might ask the students to briefly explain the carbon, nitrogen, or water cycle. The teacher would then emphasize the cyclical nature and explain not all substances work like this. For example, phosphorus is mined from the earth, primarily used as a fertilizer, before being collected in various forms of waste. Because there is only so much phosphorus to be mined, we have to figure out a way to get phosphorus out of the waste in a way that allows it to be recycled back as a fertilizer to be sold to farmers. One way that this is done is through precipitation reactions (ask them to remind you what that means…forming a solid that can then be collected; ask them to remind you the differences between ionic and covalent bonds, who is involved, what's happening with electrons, etc.)
2. Introduce the activity.
    a. Explain that we are going to find the best element to bond with phosphorus so we can recover the phosphorus from the wastewater.
3. Ask them what are some factors that should be considered when selecting an element to bind to phosphorus. For example, would arsenic be a good element to use? Why or why not? From here, have them list some factors to consider.
    a. They might mention (or the teacher will help lead them to consider the following):
        i. For the element in question:
            1. Is the element stable?
            2. Is it plentiful or easily accessible?
            3. Is it cost effective relative to other elements? (price per unit)
                a. This part might need some extra attention. Say they were looking at the cost of calcium. They won't be able to find plain calcium (ask them why this might be) because calcium is more stable in a bond like calcium carbonate.
                b. If they then look to see the cost of calcium carbonate, we have to report the cost in a way that is uniform across the class to make accurate comparisons. Perhaps your class decides to report the cost of 1 gram of calcium carbonate. Their research might say that 100g of calcium carbonate can be purchased for $60. Make sure they know how to report how much 1 gram of calcium carbonate would cost (100g/$60= $0.60 per gram)
        ii. For the element in question **and** resulting phosphorus compound:
            1. Is it toxic to humans? If so, how? Can realistic measures be taken to avoid toxicity?
            2. Is it environmentally friendly?
            3. What are the storage/transportation requirements?
            4. Is it soluble in water?
4. Once the class poses some possible factors to consider, explain that they will work in groups to look at various elements. Some elements might turn out to be great options, and others won't. Either way, it is important to know before attempting to recover the phosphorus. Groups will each look at one element and address some of the factors previously mentioned. Students will organize this information on a poster and give their element an overall grade related to its potential as a phosphorus recovery protocol. Each group will report their findings to the class before the class votes on the best element(s).
5. The teacher will then break students into groups, assign their element, give/project the instruction sheet (see appendix), have students get a device to use the internet, and give students poster materials.
6. The teacher should be available to move around the room, help groups get started, stay focused, and answer questions.
7. Once groups have finished, they will present their findings to the class and the class will vote on the best potential elements.

Differentiation

To maintain accountability in groups, the teacher can outline duties for each group member (stay engaged, contribute fairly, etc) or assign jobs (data gathering, data organizing, etc).

Assessment/Check for Understanding

Teachers may check for understanding through group observations during the activity and via their presentation to the class. This lesson ties in several previously cultivated skills (bonding, periodic table, reactions, and stoichiometry).

Author comments

If your kids need help with buy-in: Explain that this is common practice amongst scientists, collaborating with their research to find the best solution. Tell them to imagine themselves in lab coats, sitting around a boardroom, discussing these various options before selecting the best one.

Appendices

see below

Instructions for Phosphorus Recovery Research and Presentation:

1. **Begin with the Data Gathering Guide Table by addressing the Factors to Consider.** You will search for information for each factor for both your assigned element **and** the resulting compound made of your element and phosphorus. **You will give grades (out of 100) for each factor.** For example, if your element is super cheap and accessible you would give it a 95. If your element results in a toxic compound, you would give it a 25.
   You may use whatever reliable source you can find to collect data but I recommend you start with the following sites:

   a. First try PubChem: https://pubchem.ncbi.nlm.nih.gov/
      i. Type in the element or compound you wish to learn about in their search box.
   b. Then try EndMemo: http://endmemo.com/
      i. Type in the element or compound you wish to learn about in their search box.
   c. Then try google for reliable sources.

2. Once you have gathered information for each factor, assigned appropriate scores, and calculated averages, you will begin to **create the poster you will present to the class**. The poster must be neat, well organized and include:

   a. The information from the Data Gathering Guide.
      i. You may neatly copy the table on your poster if you wish or highlight major pros and cons.
   b. Total average grade (Take the average of all the overall averages. (add the overall averages and divide by the number of overall averages (9))).
      i. With this final grade, **indicate whether you think this element would be realistically successful in recovering phosphorus**. Think deeply here, if your average is high, but the element itself is highly toxic with no means of protection, it may not be a good bet after all.
   c. Write and balance the equation depicting your element reacting with phosphorus to yield the phosphorus compound.
   d. Solve this problem using the balanced equation and stoichiometry/dimensional analysis (fence post method):
      i. If a wastewater tank is estimated to have 400g of phosphorus, how many grams of your element would be needed to extract all the phosphorus?

Data Gathering Guide for element:_____ and element bonded with Phosphorus (*criss-cross charges!*):_____

Factors to Consider	Info for Element: _____	Grade for Element (out of 100)	Info for Resulting Phosphorus compound: _____	Grade for Phosphorus compound (out of 100)	Overall average of Two Grades
Is the element stable in nature?					
Is the element plentiful/easily accessible/renewable?					
Is the element able to be purchased/cost effective? (report in $ per gram)					
Is it toxic to humans? If so, how? Can realistic measures be taken to ensure safety?					
Is it environmentally friendly? If not, can realistic measures be taken to protect the environment?					
What are the storage and transportation requirements? Are these requirements realistic and cost effective?					
Is it soluble in water? (check your solubility rules)					
What is the average atomic mass?					
What kind of bond does the phosphorus compound make?					