MATERIALS™ EXPLORERS

SMARTPHONES

If you're like a lot of people today, you just can't imagine life without your smartphone. But have you ever thought about what it takes to make the device that never leaves your side? In this module you'll learn about the materials that make smartphones possible and explore the implications of using rare materials in such a common item.

In this module students will be able to:

- Identify the materials used to create a smartphone
- Test the chemical and physical properties of some of the metals used to create smartphones
- Write an evidence-based conclusion identifying each metal based on the physical and chemical properties
- Explore the uses of rare earth metals and the challenges created by a reliance on them
- Illustrate a metallic bond and explain how the bonding arrangement affects physical properties

MATERIALS™ EXPLORERS

Class Activity

THE MATERIALS THAT MAKE UP SMARTPHONES

Background:
According to the Minerals Education Coalition©, each baby born in the U.S. will use 3.188 million pounds of minerals, metals, and fuels in their lifetime. The 3.188 million pounds include 968 pounds of copper, 419 pounds of zinc, 828 pounds of lead, and 48,856 pounds of other minerals and metals. Many of the minerals and metals are utilized in technological devices such as smartphones. Smartphones are composed of about 40% metals (including copper, silver, gold, platinum, and tungsten), 40% plastics, and 20% ceramics. Most phones use lithium-ion batteries, which are generally composed of lithium cobalt oxide, although other metals, such as manganese, are sometimes used in place of cobalt.

Cellular phones also contain many **rare earth elements** such as neodymium, terbium, and dysprosium which provide phones with the power to vibrate. This heavy reliance on rare earth elements poses a challenge to future smartphone development since there is a limited supply of these elements and no suitable substitutions. Rare earth elements are essential for miniaturization of products like computers and smartphones. Without them, computers would still be the size of a classroom, instead of a pocket. Rare earth elements are also valuable because of their magnetic and conductive properties. These properties allow technological devices to be faster, stronger, lighter, and more efficient.

Problem

Your school is organizing a recycling initiative around discarded smartphones. In order to send materials to the right recycling facilities, your class must first identify the types of materials used in various components.

Task:
Using the directions provided, you will test four unknown samples and record your observations of their physical and chemical properties in order to determine the materials being tested.

Requirements:
1. Safety goggles and an apron must be worn at all times.
2. Hair must be pulled back.
3. No loose or baggy clothing is permitted and closed-toe shoes must be worn.

Class Activity

4. Do not stare directly at burning samples.
5. Physical properties being examined should include appearance, mass, volume, and magnetism.
6. Chemical properties being examined should include reactivity with room temperature water, reactivity with hydrochloric acid, and reactivity with oxygen.
7. Samples should be tested using the following procedures and observations should be recorded in the data tables provided:

Complete each of the required tests for a sample before moving on to the next.

NOTE: The reaction with oxygen is performed only on samples A and D.

i. **Appearance:** Observe the chemical and record your observations.

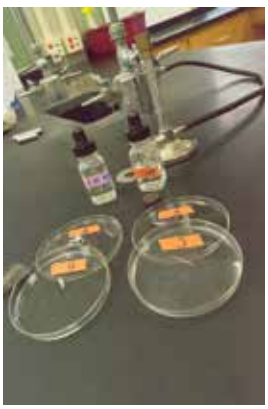
ii. **Volume and Density:** Determine volume and density via the water displacement method.

iii. **Magnetism:** Slowly wave the magnet over the sample and record any reaction.

iv. **Ability to React with Water:** Place a "pea-sized" amount of the sample in a petri dish and apply 15 drops of water. Look for evidence of a chemical change. If there is evidence, cite evidence. If there is no evidence, record "no evidence of a chemical change."

v. **Ability to react with an acid:** Place a "pea-sized" amount of the sample on a clean watch glass and add a few drops of acid. Look for evidence of a chemical change. If there is evidence, cite evidence. If there is no evidence, record "no evidence of a chemical change."

vi. **Reaction with Oxygen (with heat):** PERFORM THIS TEST ONLY ON SAMPLES A AND D. Light and adjust the burner. Use crucible tongs to burn a piece of Sample A while looking for evidence of a chemical change. Turn off the flame. If there is evidence, cite evidence. If there is no evidence, record "no evidence of a chemical change."
Repeat this procedure for Sample D but begin by vigorously rubbing the sample with steel wool to remove surface (oxide) impurities.



Class Activity

Questions

1. **Fill out the following data tables with your observations from the experiments above.**

Data Table: Samples A-D				
	Sample A	**Sample B**	**Sample C**	**Sample D**
Appearance				
Mass				
Volume	Initial: Final: Difference:	Initial: Final: Difference:	Initial: Final: Difference:	Initial: Final: Difference:
Calculated Density				
Magnetism Is sample magnetic?	Yes or No Evidence:	Yes or No Evidence:	Yes or No Evidence:	Yes or No Evidence:

Class Activity

Reaction with Water Does sample react?	Yes or No Evidence:	Yes or No Evidence:	Yes or No Evidence:	Yes or No Evidence:
Reaction with Acid Does sample react?	Yes or No Evidence:	Yes or No Evidence:	Yes or No Evidence:	Yes or No Evidence:
Reaction with Oxygen Does sample react?	Yes or No Evidence:	DO NOT PERFORM TEST ON SAMPLE B	DO NOT PERFORM TEST ON SAMPLE C	Yes or No Evidence:

2. **Write a response (including a claim, evidence, and reasoning) identifying Samples A through D based on their physical and chemical properties.**

3. **Sixteen out of the seventeen rare earth elements are used in cell phones. Select one of the sixteen elements and design a poster about the advantages and challenges of utilizing that rare earth element. Include information about how that element can be recycled or reused, or if there is a potential substitute for it. Be sure to include other uses of the element apart from smartphones.**

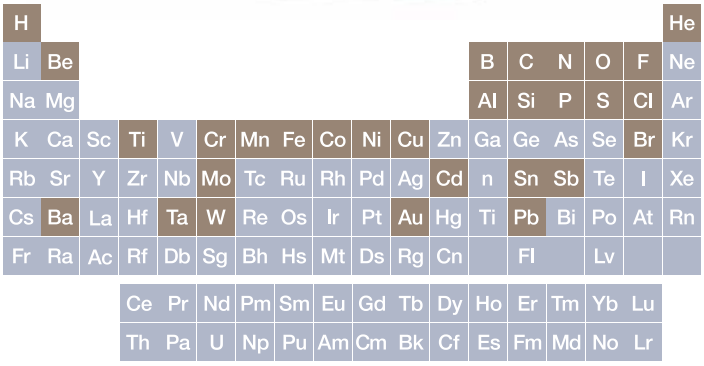
Activity Grading Rubric

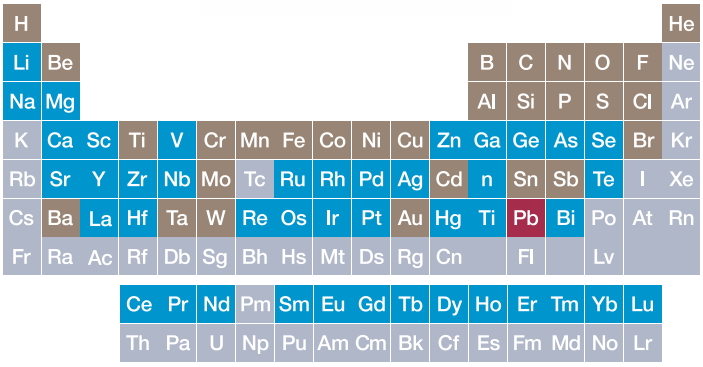
Rare Earth Elements

Rare earth elements, or rare earth metals, refers to a set of seventeen elements which includes the fifteen lanthanides plus scandium and yttrium. Despite their name, most of these elements are not particularly rare but they are difficult to economically extract and process.

Extension Activity

WHAT'S IN YOUR POCKET?





Original Cell Phone Elements Additional Elements Required for Smartphones Elements that are no longer used.

Motorola DynaTAC 8000X

1. Released in 1983, this was the world's first commercial cell phone.
2. It weighed 1.75 pounds, stood 13 inches high, stored 30 phone numbers, and took 10 hours to recharge to support 30 minutes of talk time.

30 Elements

Smartphone

Today's smartphone uses exponentially more elements than early mobile devices to support numerous functions and digital features, more storage capacity, and an extended battery life in a lighter, smaller body.

75 Elements

CMI Critical Materials Institute

(Chart reproduced with permission from the Critical Materials Institute, The Ames Laboratory, U.S. Department of Energy)

Questions

1. **Today's smartphones are dependent on a much wider variety of elements than early cellular phones. What are some of the major challenges that result from this?**

2. **The chart above indicates that only one element that was used in early mobile phones is no longer used in smartphones. Identify the element and suggest possible reasons why its use was discontinued.**

3. **Select one element used in the circuit board of both a smartphone and traditional cellular phone and discuss its importance to the phone's functioning.**

4. **Select one interesting feature of a smartphone and research some of the materials that make it possible. You may choose to discuss touchscreens, batteries, or vibration.**

Materials Explorers™ is a STEM educational outreach initiative of The Minerals, Metals & Materials Society (TMS). TMS is non-profit, international professional society with a mission to promote the global science and engineering professions concerned with minerals, metals, and materials.

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