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Teacher's Guide

Mystery Molecules: Identifying Materials with Nanoscale Characterization Tools

Grade Level: High school

Subject area(s): Chemistry; physical science

Time required: 2 hours class time; 1.5-2 hours remote access

Learning Objectives:

1. Students will be able to discuss limitations of macroscale observations in regards to identifying unknown compounds
2. Students will be able to describe and compare different nanoscale characterization techniques
3. Students will be able to explain what the characterization techniques can tell us about a molecule/material's structure
4. Students will be able to determine the type of data they will obtain with specific characterization techniques and relate this to a material's molecular structure

Summary: In this lesson plan, students will be given several similar looking materials and asked to identify them by observing them at the macro and micro-scale. They will then be exposed to different analytical tools and describe how they can be used to explore materials at the nanoscale. A unique component of the lesson plan is to access RTNN facilities at Duke, NC State, or UNC (remotely or by field trip (trip for NC schools)) to collect/analyze data with tools described in the lesson. To bring this technology into your classroom, contact RTNN at rtnanonetwork@ncsu.edu. Similar equipment can be accessed through the Remote Access Instrumentation for Nanotechnology (RAIN) network (http://nano4me.org/remoteaccess) or check with your local research university.

Lesson Background Information: Novel materials are currently being developed for numerous applications including medicine, textiles, and computers. These novel materials are being developed through nanotechnology which utilizes the unique properties materials often have at the nanoscale to create new materials and devices. A good introduction to nanotechnology that you may want your students to read can be found at National Nanotechnology Initiative's website (https://www.nano.gov/nanotech-101).

To test and characterize these materials, scientists use a number of different analytical tools. Many of these explore what is going on at the atomic level, which is on the nanoscale. Here they can see how different atoms are behaving and even look at what is going on in dynamic or changing environments. These same tools can also help to identify materials.

Listed below are several web-based resources that may be useful in explaining crystal formation and structure to your students.

- Crystal Structure: https://en.wikipedia.org/wiki/Crystal_structure

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- https://saylordotorg.github.io/text_general-chemistry-principles-patterns-and-applications- v1.0/s16-03-structures-of-simple-binary-co.html
- Crystal Structure Review: https://www.youtube.com/watch?v=iPb8vRtroLU

MIT Class: Introduction to Solid State Chemistry

- (http://ocw.mit.edu/courses/materials-science-and- engineering/3-091sc-introduction-to-solid-state-chemistry-fall-2010/)
- http://ocw.mit.edu/courses/materials-science-and-engineering/3-091sc-introduction-to-solid-state- chemistry-fall-2010/crystalline-materials/15-introduction-to-crystallography/
- http://ocw.mit.edu/courses/materials-science-and-engineering/3-091sc-introduction-to-solid-state- chemistry-fall-2010/crystalline-materials/16-crystallographic-notation-x-rays/
- http://ocw.mit.edu/courses/materials-science-and-engineering/3-091sc-introduction-to-solid-state- chemistry-fall-2010/crystalline-materials/17-x-ray-emission-absorption/
- http://ocw.mit.edu/courses/materials-science-and-engineering/3-091sc-introduction-to-solid-state- chemistry-fall-2010/crystalline-materials/18-x-ray-diffraction-techniques/

Information about the electromagnetic spectrum

- https://en.wikipedia.org/wiki/Electromagnetic_spectrum
- https://www.khanacademy.org/science/chemistry/electronic-structure-of-atoms/bohr-model- hydrogen/a/light-and-the-electromagnetic-spectrum

Links to other lesson plans:

There are several lesson plans that this lesson was modified from. Some of these could be paired with this lesson.

- http://www.middleschoolchemistry.com/lessonplans/chapter6/lesson6
- http://www.nsta.org/publications/news/story.aspx?id=48629
- https://www.uu.edu/books/greenchemistrylabs/pdf/lab11-st.pdf
- http://microscopy4kids.org/Making_and_Observing_Crystals

Pre-requisite Knowledge: Understanding of elements, molecules, bonding, and chemical composition of materials.

Materials:

- Magnifying glass and/or basic light microscope
- Salt
- Sugar (Sucrose)
- Epsom Salt (magnesium sulfate)
- MSG (monosodium glutamate)
- Other white powders that looks similar: like baking soda, baking powder, Splenda, etc.
- Printouts of molecular structures of various powders
- Handouts on different characterization techniques like scanning electron microscopy, transmission electron microscopy, X-ray diffraction, X-ray photoelectron spectroscopy, UV/Vis Spectroscopy, atomic force microscopy, and Raman spectroscopy

Safety Information: None

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Advance Preparation:
Schedule a remote session or field trip to an RTNN facility to see instruments in action and collect and analyze data. *Or* send samples to RTNN to get analyzed! Experts will run samples, provide data sets, and help analyze the data.

For RAIN, schedule your time in advance through the link provided. Determine from them how to prepare the samples.

Also, it is advised that you do a “test run” of the remote link prior to using it in class.

Suggested Teaching Strategies or Troubleshooting Tips
Check YouTube to ensure the videos will play correctly.

Directions for the Activity:
Part 1. (groups of 3-4 students)
Provide each group with different unknown white powders and chemical structures of potential molecules. Students then examine the powders at the macro level.
Ask the following questions and have students share responses with the class.

1. What differences do you see in the molecular structures (Bonding, elemental composition, bonds between elements, crystal structure)?
2. What differences can you see between the powders?
3. Can you make any connections between what you observe and the molecular structure?
4. Make a guess to what each powder is. Explain why you think so.

Part 2. (groups of 3-4 students)

1. Have groups look at powders under the microscope or magnifying glass.
2. Have groups answer the same questions as above.
3. Share responses with class.

Part 3.

1. Give each group a different analytical technique description and/or a link to a YouTube video with a short description. (Optional: students are assigned a technique and research it as a homework assignment.)
2. Each group will describe how they could use that technique to determine what the unknown powders are.
3. Answer questions:
    a. What kinds of information would this technique give you?
    b. How does this relate to the molecules’ structures?
    c. Would the information obtained be sufficient to determine the molecule or would you need to use other techniques?
    d. How would the data be used to differentiate between the different powders?

Part 4. (Optional) Conduct the remote access session.

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1. Connect to instruments remotely to learn more about how they work and what information they give you.
2. If possible, send white powder samples for analysis to generate data and discussion.

Part 5. (Optional) Once the remote session or field trip is complete, ask the students some follow up questions:

1. What would be some advantages and disadvantages of these analytical techniques?
2. How could these techniques be applied in real-world scenarios? What would they be used for?
3. Can you think of other ways that you might be able to distinguish between the mystery powders?

Next Generation Science Standards:

- HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

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