NAVIGATING™ NUCLEAR
Energizing Our World

Classroom Lesson

Topic
Decoding Decay

LEARNING OUTCOMES

- How can the periodic table be used as a tool to predict a nuclide's properties?
- How do we determine if a nuclide is stable?
- How is the stability of a nuclide related to nuclear energy?

Overview

In this activity, students will learn to use the periodic table as a tool to predict a nuclide's properties. After a quick vocabulary refresher, students will engage in an interactive "Heads Up" game, working in groups to use the periodic table to correctly guess the term shown on a card. Next, students will watch a Nuclear Line of Stability video and apply their knowledge during a Line of Stability Kahoot game in which they use the graph to answer critical thinking questions. As an extension, students will "build' atoms and test their properties using an online interactive simulation.

Grade level

9–12

Timing

- **Preparation**

  Up to one hour to gather materials, prepare suggested videos.

- **Activity**

  1 or 2 class periods, depending on class length and activities included.

Performance Expectation(s)

Students that understand the concept are able to:

HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

NGSS Standards

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Developing and Using Models • Analyzing and Interpreting Data	**PS1.A Structure and Properties of Matter** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. • The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. • The total number of neutrons plus protons does not change in any nuclear process.	• Patterns • Scale, Proportion, and Quantity • Stability and Change

Essential questions:

- How can the periodic table be used as a tool to predict a nuclide's properties?
- How do we determine if a nuclide is stable?
- How is the stability of a nuclide related to nuclear energy?

Learning outcomes

- Students will gain an understanding of the structure and reactivity of elements, unstable nuclei, ions, and isotopes.
- Students will learn how to use the periodic table as a tool to predict a nuclide's properties.

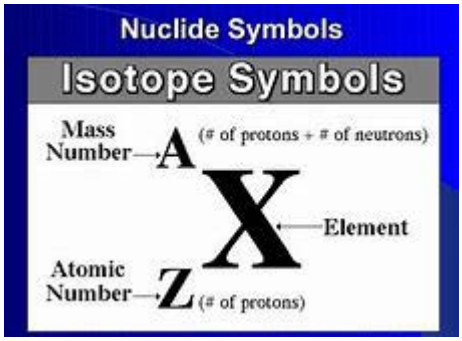
Prior Student Knowledge

Prior to beginning the lesson, students should be familiar with atomic structure of an atom—proton, neutron, and electron and the concept that radioactive isotopes decay. Any material containing unstable nuclei is considered radioactive. The process by which an unstable atomic nucleus loses energy by emitting radiation is known as radioactive decay. See ANS's Radiation Basics educational module for instructional tools.

Lesson Plan

1. Introduce students to nuclide symbols using an academic vocabulary strategy like the one below or by making online vocabulary study flashcards with a tool such as Quizlet.
    - Guide individual students to use a scrap piece of paper and rip it into ten pieces.
    - Ask them to write a vocabulary word on each piece: atomic number, mass number, protons, neutrons, electrons, elements, isotopes, ions, nuclide, and periodic table. Students should then be directed to mix them up.
    - In small groups of 3–4, have students discuss which words are familiar and share their understanding of the meanings.
    - As a whole group, briefly have students share and review the words and their meanings.
    - Next, invite students to work as partners to place the vocabulary words in order as they hear them in the following video.
    - Play the video. https://tinyurl.com/y5hp6eyl. Be sure to point out the following two errors:
        - At the three-minute mark, the host states that the atomic mass is the average of the atomic masses of all isotopes of that element. That is incorrect. The atomic mass is the average of the atomic masses of all **naturally occurring** isotopes of that element.
        - At the 3:20 mark, a statement is made that Chlorine can be either Cl-35 or Cl-37. Point out that Cl-36 also exists. We know that it has a long half-life, is found in trace amounts on earth, and is used for geologic dating far beyond carbon-14.
    - After the video segment concludes, have students discuss the sequence of topics from the segment, using the order identified for the vocabulary words. Then, ask them to discuss how the terms and concepts might be used in today's lesson.
2. Review the following vocabulary terms before moving on to the next part of the lesson:
    - **Atomic number**—the number of protons in the nucleus of an atom. The atomic number defines the atom.
    - **Mass number**—the total number of protons and neutrons in the atomic nucleus*
    - **Ion**—an atom or a group of atoms that has a net positive or negative charge; atoms that gain one or more electrons become negative ions (anions); atoms that lose one or more electrons become positive ions (cations).
    - **Nuclide**—the general term applied to each unique atom; represented by:

Image source: www.nuclear-powered.net



- **Isotopes**—atoms of the same element (the same number of protons) with different numbers of neutrons. They have identical atomic numbers but different mass numbers, and therefore a different mass. Isotopes of the same element have varying mass with the same chemical properties.
- **Protons**—positively charged particles in an atomic nucleus.
- **Electrons**—a stable subatomic particle with a charge of negative electricity, found in all atoms and acting as the primary carrier of electricity in solids.
- **Neutrons**—particles in the atomic nucleus with mass virtually equal to the proton's but with no charge.
- *Note: The reason the protons and neutrons make up the mass number is that the electrons are so tiny in relation to the neutron and proton that they are negligible. The mass number really is the mass of the atom (not just the nucleus) due to the combined mass of the protons and neutrons.

3. Next, tell students that they will work in groups to use the periodic table to correctly guess the symbol shown on a card. Describe the procedure and hand out the materials for the "Heads Up" game:

Materials (Teacher prepares these in advance):

- Index cards (20 or more, depending on time) Write the symbols of various chemical species (elements, ions, isotopes) on the index cards. Make a set of symbol cards for each group or pair of students. See examples below.
- Copies of the Periodic Table of the Elements for each student: https://periodic.lanl.gov/images/periodictable-3-13-17.pdf Countdown clock or hour glass timer

Below are some examples of what can be written on the cards. When coming up with additional symbols, try to choose a combination of elements, ions, and isotopes.

- U-235
- U-238
- $N3^-$
- $O2^-$
- Pu
- Rb+
- Th-230
- I-131
- Cd
- Ra-226
- Po-210
- Pb
- F
- Kr-85
- $Cd2^+$
- $Sr2^+$
- $Al3^+$
- $S2^-$
- I^-
- C-12

Procedure

- Break students into pairs or small groups.
- Pass out the index card sets (one set per group or pair of students) and periodic tables (one per student).
- Have students decide who will be the clue giver(s) and who will be the guesser for the first round. The guesser will randomly select an index card to hold up against his or her forehead with the answer facing out.
- The clue giver(s) will provide hints to get the guesser to correctly guess as many correct answers as they can before the time (60 seconds) winds down. The clue giver cannot use the name of the element/ion/isotope, but they can refer to other aspects from the periodic table, such as the number of protons and neutrons. For example, for the isotope C-12 the clue giver would say "six protons and six neutrons" based on the periodic table. Generalized groups and periodic trends in reactivity also may be used. For instance, in the metals, reactivity increases as you move down a group, and to the left approaching Francium (the most reactive metal). For nonmetals, the opposite is true. The most reactive nonmetal is Fluorine, so the reactivity of nonmetals increases as you go up a group and to the right. The least reactive (most stable) metals are the precious metals, such as copper, gold, silver, and platinum.
- Then, have students switch roles so every student in a group or pair gets a chance to be the guesser.
- Wrap up the game by asking for students to volunteer their observations about the periodic table. *What kinds of clues were most helpful? Which symbols were the toughest to get a partner to guess?* This is also a great time to review subatomic particles, ions and isotopes. Ask students which particle made it easier to guess—why?
- (Optional) Small prizes or bonus points can be awarded for the groups that have the most correct guesses after the final round is complete.

  Note: As an online alternative, use a tool such as Quizlet for this activity.

4. Before moving on to the next activity, it is important for students to understand isotope stability. Any or all parts of the following resource will help students make the connection between the composition of nuclei and isotope stability: https://www.ausetute.com.au/istability.html

   Give students time to review the resource online and ask questions before moving on to the Kahoot game.

5. Next, tell students that they will play a Line of Stability Kahoot game to make Nuclear Decay Predictions.

   Materials needed:

   - Computer connected to the Internet for projecting the Kahoot game
   - Cell phones or laptop/tablets for students to submit their responses
   - Copies of the Line of Stability Graph (one per student): http://nuclearpowertraining.tpub.com/h1019v1/img/h1019v1_52_1.jpg
   - Copies of the Periodic Table of the Elements (students can use their copies from the "Heads Up" activity)

Procedure

- Teachers will need to access the Kahoot game using the following link: https://create.kahoot.it/share/15c9ae0c-d7f5-4986-b765-7683a893df73

Students may play the game in "Player vs. Player" mode if using 1:1 devices. Alternatively, the game may be played in "Team Mode" if using shared devices.

- Instruct the students to access the following link, enter the game pin, and type in an **appropriate** nickname (Note: You can change the settings before playing to require the system to select nicknames for players if students are apt to select inappropriate nicknames): https://kahoot.it
- Play the game. After playing, have students discuss what they learned as a result. Also, relate the game questions back to periodic trends and reinforce concepts from earlier in the lesson. Some key points to emphasize include:
    - The numbers of neutrons and protons in a nucleus are related to its stability with respect to radioactive decay.
    - Radioactive decay occurs in unstable atomic nuclei—that is, ones that don't have enough binding energy to hold the nucleus together due to an excess of either protons or neutrons.
    - All nuclides with 84 or more protons are unstable with respect to radioactive decay.
    - Light nuclides are usually stable when the neutron-to-proton ratio is 1:1. One exception to this rule is the nuclide Be-8. However, for heavier elements the neutron-to-proton ratio required for stability is greater than 1 and increases with the atomic number (Z).
    - Certain combinations of protons and neutrons seem to confer special stability. For example, nuclides with even numbers of protons and neutrons are more often stable than those with odd numbers.

6. Extend the learning
    - Students can build an atom out of protons, neutrons, and electrons, and see how the element, charge, and mass change. Then, they play a game to test their ideas!
    - https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html
    - Students can also learn about radioisotope use in medicine using the following resource from the World Nuclear Association: https://tinyurl.com/y2cq8bak
7. Evaluate the learning with either of the following:
    - An online quiz on nuclear chemistry, https://tinyurl.com/chou4ln and/or
    - A quiz on the Line of Stability, https://tinyurl.com/y59g6dfp

Line Stability Graph

STUDENT HANDOUT