Isotopes

Strand	Atomic Structure and Periodic Relationships	
Topic	Investigating atomic structure	
Primary SOL	CH.2	The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of b) isotopes, half-lives, and radioactive decay; c) mass and charge characteristics of subatomic particles; d) families or groups; e) periods; f) trends including atomic radii, electronegativity, shielding effect, and ionization energy; g) electron configurations, valence electrons, and oxidation numbers; h) chemical and physical properties; and i) historical and quantum models.
Related SOL	CH.1	The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include i) construction and defense of a scientific viewpoint.

Background Information

A simple classroom model for atomic structure can be assembled by using a magnetic white board and poker chips with small disc magnets glued to them to represent protons, neutrons, and electrons. Use the model to review the location, charge, and relative mass of protons, neutrons and electrons. It is not necessary for students to understand electron configurations at this point; simply model an electron cloud around and some distance away from the nucleus.

Each of the 16 cells on the student tic-tac-toe card identifies a specific atom by giving the element's name and the mass number of the isotope and providing space to list the numbers of protons, neutrons, and electrons in the atom. The cells also include information on percent relative abundance for naturally occurring elements or information on half-life and decay for radioactive isotopes. See example at right.

Lithium-6
of protons:__
of neutrons:__
of electrons:__
% abundance: 8%

Before undertaking the activity, make "particle poker chips" from construction paper by marking them as follows: **+** on blue chips (representing protons), **–** on red chips (representing electrons), and no mark on white chips (representing neutrons).

Student pairs become "certified experts" in modeling the structure of a particular atom. The expert pairs then check other students' work as those students work individually to describe and model the structure of selected atoms while completing a game of tic-tac-toe. The student tic-tac-toe cards then provide the basis for calculating relative atomic masses as well as for introducing radioactive decay.

Materials

- Colored “particle poker chips” with disc magnets attached to them
- 16-cell tic-tac-toe card for each student
- Magnetic white board
- Periodic table of the elements for each student
- Colored pencils or crayons

Vocabulary

half-life, isotope, radioactive, relative atomic mass

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Introduction

1. Distribute “particle poker chips,” periodic tables, and tic-tac-toe cards. Select one of the cells on the card to complete as a class. Let students make models at their desks, and then ask them to check for accuracy by comparing their model to the classroom model. Have students draw a representation of the model in their data books.
2. Refer to other cells on the tic-tac-toe card to introduce or review the term *isotope*. Explain that the relative atomic masses shown on the periodic table of the elements are determined from the percent abundances of that element’s isotopes as they exist on Earth. Point out that the isotopic ratios can be strongly affected by the source of the element and that the elemental isotopic abundances elsewhere in the universe are different.
3. Ask students to identify the isotopes on the card for which percent abundance information is given. Then point out the radioactive isotopes, and direct students to use a yellow pencil or crayon to shade each of the cells containing a radioactive isotope.

Procedure

1. Certifying “expert” teams: Assign an isotope to each team, and direct students to complete that isotope’s information in the cell and make a poker-chip model of it. As the teams work, move from team to team, checking their work for accuracy. Initial the completed cell on each student’s card to “certify” him/her as an “expert.”
2. Have students draw a representation of their certified accurate model in their data books so they will have it available for checking other students’ work during the tic-tac-toe game. For classes of fewer than 32 students, you will be the expert for the remaining isotopes.
3. Playing tic-tac-toe: Have each student work individually to complete a vertical, horizontal, or diagonal tic-tac-toe by filling in information for an isotope on the card, making a model, and getting a signature from one of the isotope’s experts to verify the accuracy of the work. Have students make a record of each of their models in their data books.

Observations and Conclusions

1. Have students calculate the relative atomic mass of elements, using the percent abundance data on the cards, and compare the calculated masses to the atomic masses on the periodic table.
2. Explain that half-life must be determined experimentally by following the decay of a radionuclide over time, and that databases may include more than one value for the half-life of a particular isotope based on the reported results of different experiments.

3. Ask students to list the radioactive isotopes on their cards in order of decreasing half-life, and discuss the range of half-life periods. Point out that because some of the radioisotopes decay so fast, they are not found in nature although they can be observed as the product of some nuclear reactions. You may wish to have students construct decay curves for some of the radioisotopes, based on their half-lives.
4. Direct students to list the different types of radioactive decay shown on the cards: alpha decay, beta decay, and electron capture. Students can use poker chips to demonstrate radioactive decay if they modify their poker-chip models by using a proton chip and an electron chip stacked on top of each other to represent a neutron. Examples include:
   - Hydrogen-3 decays by the conversion of a neutron to a proton and emission of an electron, forming helium-3.
   - The nucleus of an atom with too few neutrons may gain one more neutron by capturing one of the negatively charged electrons orbiting about the nucleus. This effectively cancels the positive charge on one of the protons, turning it into a neutron. An example of this kind of radioactivity is the decay of beryllium-7 to form lithium-7.
   - Boron-8 decays to form helium-4 by electron capture and alpha emission.
5. Describe penetrating power and shielding of alpha and beta emissions. Explain that after a nuclear decay, the nucleus may still have excess energy to shed. This energy can be given off in the form of a pulse of electromagnetic radiation, called "gamma radiation," with no change in mass or charge. Compare the penetrating power and shielding of gamma radiation to alpha and beta emissions.

Assessment

- **Questions**
  - How is half-life determined experimentally?
  - Why is understanding half-life important?
- **Journal/Writing Prompts**
  - Describe the difference between alpha and beta decay.
- **Other**
  - Give students new isotopes, as in the examples shown below, and assess their ability to
    - determine the number of protons, neutrons, and electrons in the atom;
    - model the structure of the atom;
    - calculate the relative atomic mass of the atom;
    - model radioactive decay of the atom; and
    - construct a decay curve for the atom.

Nitrogen-14	**Nitrogen-15**	**Nitrogen-16**	**Nitrogen-17**
# of protons:__	# of protons:__	# of protons:__	# of protons:__
# of neutrons:__	# of neutrons:__	# of neutrons:__	# of neutrons:__
# of electrons:__	# of electrons:__	# of electrons:__	# of electrons:__
% abundance: 99.6%	% abundance: 0.04%	Half-life: 7.13 s	Half-life: 4.75 s

Extensions and Connections (for all students)

The relative masses of atoms are measured using a mass spectrometer. The history of mass spectrometry clearly illustrates the emergence of modern theories based on historical development. The first mass spectrometer was invented in J. J. Thomson's lab at Cambridge at the end of the 19th century. Mass spectrometry was used to discover the existence of isotopes of nonradioactive elements. Modern radiometric dating employs accelerator mass spectrometers that can count each particle of a sample and separate all the isotopes, making them useful in radiometric dating. In this connection, you may have students do one or more of the following:

- Investigate the contributions of Democritus and John Dalton to the atomic model that Thomson used.
- Relate Rutherford's discovery of the proton, Moseley's arrangement of the elements on Mendeleev's periodic table by atomic number, and Bohr's planetary model to an explanation of the basis for mass spectrometry.
- Research the relationship between Thomson's discovery of the electron and his contribution to invention of the mass spectrometer as well as the contribution of Millikan to clarifying the relationship.
- Describe insights regarding electron structure that have emerged as the principles and applications of mass spectrometry have evolved.
- Have students make posters describing the work of one or more of these scientists and showing the model that they used to visualize the atom. Posters can be displayed chronologically to form a timeline on the classroom wall, thus illustrating the historical development of a model for atomic structure from the ancient Greeks to the present.

Strategies for Differentiation

- Have students use graphic organizer software to create a web of vocabulary terms showing their interconnectedness.
- Have students create an electronic slide presentation about the life of one of the principal scientists discussed.
- Have students use vocabulary word cards to manipulate and form graphic organizer webs showing the interconnectedness of the terms listed in vocabulary.
- Have students explore various ways radiation is used in everyday life and in industry (e.g., smoke detectors, food industry, carbon dating for archaeological finds) and create a brief presentation of this material.