Teacher Resources

Atoms and Nuclear Propulsion

INTRODUCTION

This unit is designed to use the topic of nuclear powered submarines to teach a unit on atomic structure. Students are first given some background information on nuclear submarines and then begin to learn about atomic structure, isotopes, and nuclear chemistry. When appropriate, specific examples that relate to nuclear submarines are given.

STATE/NATIONAL STANDARDS

National Science Education Standards

STRUCTURE OF THE ATOM

- Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.
- The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element.
- The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.

Science Common Core Standards

PS1.A: Structure and Properties of Matter

- *By the end of grade 12.* Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.

PS1.C: Nuclear Processes

- *By the end of grade 12.* Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. The total number of neutrons plus protons does not change in any nuclear process.

Virginia Standards of Learning

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

a) average atomic mass, mass number, and atomic number;
b) isotopes, half-lives, and radioactive decay;
c) mass and charge characteristics of subatomic particles

INTRODUCTORY ACTIVITY

Procedure

1. Have students read the handout **"A Brief History of Submarine Development in the United States."**
2. Show the US Navy You Tube Video "Life on a Sub (1:42)." http://www.youtube.com/watch?v=NFBQd6HQrZM
3. Have students discuss what they saw in the video. Lead the students to understand that using nuclear power as the source of energy to power the ship is what allows subs to operate away from land and underwater for extended periods of time.
4. Direct students to the "Submarine Power and Propulsion" page, tab 2, of the US Navy Museum Cold War Gallery site.
   http://www.usnavymuseum.org/Ex2_Power.asp
   Have them examine the diagram in Tab 2 watch the video "Reactor Operations" in Tab 3 which explains the diagram in more detail. Alternately, they can read the handout "**Nuclear Propulsion."**
5. Tell students they will learn how a nuclear reaction can produce heat to make steam.

STRUCTURE OF THE ATOM AND ISOTOPES

Teacher Preparation

1. Before class, prepare samples of "Beanium:"
   a. Obtain one bag each of dried lima beans, kidney beans, and black-eyed peas.
   b. To make up a sample, place some of each type of bean in a re-useable zipper storage bag. Students will be counting the number of each type of bean present so adjust the total number of beans accordingly.

Procedure

1. Review atomic structure: protons, neutrons, electrons; relative sizes and location of each; and the fact that elements are differentiated from each other by the number of protons in the nucleus.
2. Review the concepts of isotope and mass number as well as ways to notate specific isotopes of elements.
3. Tell students that uranium is used in the nuclear reactor. Uranium has three naturally occurring isotopes: U-238, U-235, and U-234. Ask students to identify the similarities and differences between these three isotopes. *(Similarities: same number of protons and electrons in the neutral isotope; differences: different number of neutrons, different mass numbers)*
4. Review the concept of atomic mass calculation from isotope percent abundance.
5. Have students complete the activity "**Bean Counting**."
6. Give the students the following percent abundance information about the naturally occurring isotopes of uranium:
   U-238: 99.2745% U-235: 0.72% U-234: 0.0055%
   a. Ask them to calculate the atomic mass of uranium based on this data (*237.98 amu*).
   b. Point out to students that the mass listed on the Periodic Table is 238.03. Ask them to come up with possible explanations for this discrepancy. (*The percent abundance data is*

given for naturally occurring isotopes only. Atomic mass calculations take into account both natural and man-made isotopes.)

c. As an extension, have students research other man-made elements. All elements of atomic number 95 and higher are man-made.

NUCLEAR REACTIONS

1. Tell students that nuclear reactors use nuclear reactions to generate heat.
2. Use the "**Nuclear Reactions**" PowerPoint to explain the difference between nuclear and chemical reactions.
3. Review the definition of radioactivity for students:
   The spontaneous emission of radiation, either directly from unstable atomic nuclei or as a consequence of a nuclear reaction.
4. Use the "**Nuclear Reactions**" PowerPoint to review the three types of naturally occurring radiation.
5. Use the "**Nuclear Reactions**" PowerPoint to illustrate alpha and beta decay. Be sure to point out to students that the sum of the mass numbers on the reactant side and product side are the same and that the sum of the atomic numbers on the reactant side and product side are the same. For example, in the equation

$$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$$

   The mass number is 226 on the reactant side and the sum of the mass numbers on the product side is 222 + 4 = 226. Likewise, the atomic number on the reactant side is 88 and the sum of the atomic numbers on the product side is 86 + 2 = 88. Point out that the symbol of the element should match the atomic number listed. Also, tell students that gamma radiation is always released during a nuclear reaction and therefore is often left out of a nuclear equation.
6. Have students practice balancing nuclear reactions using the questions on "**Nuclear Reaction"** PowerPoint slides 4 and 5.
7. Emphasize to students that what they just studied was nuclear <u>decay</u>. The process used to generate heat in a nuclear reaction is fission. A basic description of fission can be found in the "**Nuclear Propulsion**" handout.
8. Have students complete the "**Nuclear Fission Simulation**" activity. This activity uses a PhET simulation produced by the University of Colorado. Java is required to run the simulation. The simulation can either be run online or downloaded and run off-line.
9. If computers or an Internet connection are not available, have students complete the "**Falling Like Dominoes**" activity. To conduct this activity, each group of students will need 15 dominoes and a ruler.