Structure of the Atom

Reference Guide

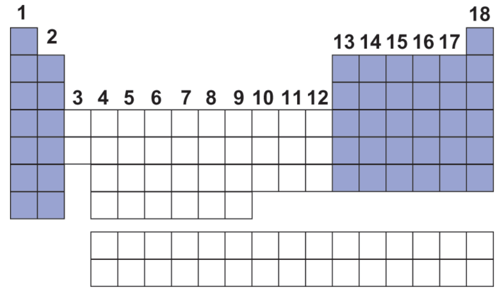
Equipment Setup

Investigation Guides

B-2 Nuclear Reactions Game

Key Question: How are elements organized on the periodic table?

Students discover how atomic structure is related to the placement of elements on the periodic table. Students use their knowledge to play a game called Nuclear Reactions using the Atom Building Game. By playing this game, students simulate nuclear reactions. Students learn the difference between fusion and fission, and the meaning of the term radioactivity.



Preparation

This Investigation provides students with an opportunity to use their knowledge of atomic structure in a game called Nuclear Reactions. The game is played with the Atom Building Game which provides hands-on reinforcement of concepts that students often have trouble grasping when they only hear or read about them.

A short reading and introduction to the Investigation will help students get involved in the Investigation quickly. For example, you might want to have a discussion about why atoms are radioactive in terms of atomic forces that hold atoms together (see Investigation B-1 Comparing Atoms). The periodic table that comes with the Atom Building Game is useful for guiding an introduction of the Investigation and the terms that the students will encounter.

Setup and Materials

Students work in groups of four at tables.

Each group should have:

- One Atom Building Game with a complete set of marbles.
- Four copies of the periodic table that comes with the Atom Building Game.

The Investigation

Time

One class period

Leading Questions

- How is atomic structure related to the placement of elements on the periodic table?
- What are nuclear reactions?

Learning Goals

In this Investigation, students will:

- Relate atomic structure to the placement of an element on the periodic table.
- Explain why atoms undergo nuclear reactions.

Key Vocabulary

atomic number, isotope, mass number, radioactive, strong nuclear force, ion, fusion, fission

1

Student responses are not required in part 1.

B-2 Nuclear Reactions Game

B-2

Question: How are elements organized on the periodic table?

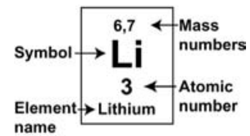
In this Investigation, you will:

1. Describe how atomic structure is related to the placement of elements on the periodic table.
2. Use your understanding atomic structure to play a game called Nuclear Reactions.
3. Discuss what happens during nuclear reactions.

In this Investigation, you will play a game called Nuclear Reactions using the Atom Building Game and the periodic table that comes with the game. By playing this game, you will learn about the organization of the periodic table.

For example, the elements on the periodic table are arranged by **atomic number**, from lowest to highest. The atomic number equals the number of protons in the nucleus of an atom. The atomic number also indicates the number of electrons in an atom. Each element has a unique atomic number.

Isotopes are atoms with the same number of protons, but different numbers of neutrons. Isotopes of an element have a different **mass numbers**. The mass number of an isotope indicates how many protons and neutrons are in the nucleus of the isotope. The periodic table shows the mass numbers of the stable isotopes of each element.



Playing Nuclear Reactions involves simulating nuclear reactions. To win the game, you will need to quickly figure out which nuclear reactions will make real atoms. The game is similar to the processes by which the elements of the periodic table were created inside stars. At the center of a star, nuclear reactions combine atoms to make new elements. We believe all the elements of the periodic table that are heavier than lithium were created inside stars through nuclear reactions. The process gives off a huge amount of energy that we experience as sunshine. The energy from nuclear reactions in the sun is what makes life on Earth possible.

1 Introduction to Nuclear Reactions

If you were to add one, two, or four more neutrons to lithium-7 you would have created lithium-8, lithium-9, and lithium-11, respectively. Each of these isotopes of lithium is **radioactive**, which means that the atomic force in the nucleus (called **strong nuclear force**) is not strong enough to hold these atoms together. The nuclei of these atoms fly apart.

The goal of Nuclear Reactions is to earn points by creating atoms that are stable (not radioactive) and neutrally charged (not ions). Remember that **ions** are atoms that have different numbers of protons and electrons and so have a charge.

Each player starts with 8 protons, 8 electrons, and 8 neutrons in his or her pocket of the Atomic Building Game board. The game will last for about half an hour. The first player to gain 20 points wins.

2 Playing Nuclear Reactions

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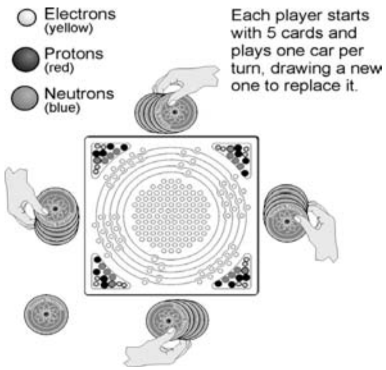
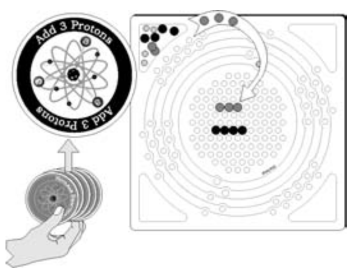
To begin, each player is dealt five cards from the deck of Nuclear Reactions cards. These are held and not shown to anyone else.

Players take turns, choosing which card to play each turn, and adding or subtracting particles from the atom as instructed on the card. For example, playing an "Add 2 Electrons" card would mean you place two yellow marbles in the atom.

Subatomic particles that are added or subtracted from the atom must come from or be placed in your own pocket. You may not play a card for which you do not have the right marbles. For example, a player with only 2 protons left cannot play an “Add 3 Protons” card.

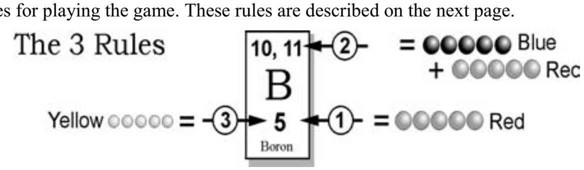




Each time you play a card, draw a new card from the deck so that you always have five. Played cards can be shuffled and reused as needed.

3 Scoring points

1. Points are scored depending on the atom you create. You will need to use the periodic table to determine your strategy and points earned. In particular, it is useful to know which cards to play to get to stable atoms, neutral atoms, or stable and neutral atoms. The diagram below illustrates the three rules for playing the game. These rules are described on the next page.



2 3

Student responses are not required in parts 2 and 3.

4

Student responses are not required in part 4.

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Rule #1: The number of protons (red marbles) matches the atomic number.
Rule #2: The number of protons (red marbles) plus the number of neutrons (blue marbles) equals one of the correct mass numbers for the element of Rule #1. This move creates a stable atom.
Rule #3: The number of electrons (yellow marbles) equals the number of protons (red marbles). This move creates a neutral atom.

You score 1 point if your move creates or leaves a stable atom. For example, you score 1 point by adding a neutron to a nucleus with 6 protons and 5 neutrons. The resulting atom is carbon-12 which is stable. The next player can also score a point by adding another neutron, making carbon-13. To get the nucleus right you need to satisfy rules #1 and #2.

You score 1 point for adding or taking electrons or protons from the atom if your move creates or leaves a neutral atom. A neutral atom has the same number of electrons and protons. Getting the electrons and protons to balance satisfies rule #3.

You score 3 points (the best move) when you add or take particles from the atom and your move creates a stable and neutral atom. For example, taking a neutron from a stable, neutral carbon-13 atom leaves a stable, neutral carbon-12 atom, scoring 3 points. In other words, you get 3 points if your turn makes an atom that meets all three rules.

4 Additional rules

Taking a turn
When it is your turn, you must either play a card and add or subtract marbles from the atom, or trade in your cards for a new set of five.

Trading in cards
You may trade in all your cards at any time by forfeiting a turn. You have to trade all your cards in at once. Shuffle the deck before taking new cards.

Using the periodic table
All players should use a periodic table to play the game.

The marble bank
You may choose to play two versions of the marble bank. In version 1, players take marbles from the bank at any time so that they have enough to play the game. In version 2, players must lose a turn to draw marbles from the bank, and may draw no more than 5 total marbles (of any colors) in one turn.

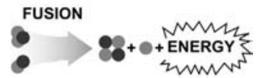
B-2

5 Nuclear reactions

There are two kinds of nuclear reactions, **fusion** and **fission**. These kinds of reactions only involve the nuclei of atoms. The word nuclei is the plural form of the word nucleus.

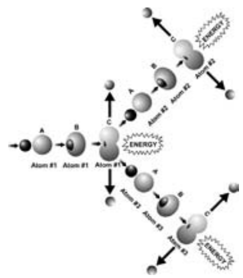
Fusion involves the combination of two elements with small mass numbers to make an element with a larger mass number.

In the diagram to the right, nuclei are fused, a particle is emitted, and a lot of energy is released. The reaction in the diagram involves the fusion of hydrogen-3 (1 proton + 2 neutrons) with hydrogen-2 (1 proton + 1 neutron) to make a helium-4, a neutron, and energy. In the diagram, the dark green dots are protons; the lighter green dots are neutrons.



Fission involves the splitting of an element with a large mass number into elements with smaller mass numbers. Both nuclear reactions release energy.

The diagram to the right shows a nuclear fission chain reaction. Nuclear fission can be started when a neutron (dark ball) bombards a nucleus (green ball). A chain reaction results. A free neutron (step A) bombards a nucleus (step B) and the nucleus splits into nuclei with smaller mass numbers. More neutrons are also released (step C). These neutrons then bombard other nuclei. Nuclear reactors control fission (and energy production) by capturing neutrons to start, slow, or stop the chain reaction.



The questions below will help you better understand fission and fusion. Use the Atom Building Game to work through the questions.

a. Demonstrate the fusion reaction diagram using the Atom Building Game board. Collect enough marbles (protons, neutrons, and electrons) to build a hydrogen-3 atom (this is a radioactive isotope). Then collect enough marbles to build a hydrogen-2 atom. Place all these marbles in the correct places on the Atom Building Game board. Remove one neutron and hold it in your hand. What element is represented on the board? Why was it important to take away one neutron?

b. Collect enough marbles (protons, neutrons, and electrons) to build lithium-6. Then collect enough marbles to build boron-11. Place all these marbles in the correct places on the Atom Building Game board. What element is represented on the board? Was this activity an example of fusion or fission?

c. Is the atom that results from the combination of lithium-6 and boron-11 a stable or a radioactive isotope? Is the atom an ion or neutral?

d. Now build boron-10 on the Atom Building Game board. How many protons, neutrons, and electrons did you need to add to the board to make fluorine-19? If you were to add these subatomic particles to boron-10, would this represent fusion or fission?

e. Suppose you split a uranium-238 atom. If you have to break it into two pieces, name two elements that could be formed. Be sure that your two elements use up all the neutrons and protons in the uranium. Is either of your two elements a stable isotope or is one (or are both) radioactive?

4

5

5a. Helium-4. When hydrogen-3 is combined with hydrogen-2, you get a helium atom with a mass number of 5. This is not a stable isotope of helium. By taking away the extra neutron, helium-4, a stable isotope, is formed.

5b. Fusion of lithium-6 and boron-11 makes oxygen-17.

$${}^{6}_{3}Li + {}^{11}_{5}B \Rightarrow {}^{17}_{8}O$$

5c. Oxygen-17 is a stable, neutral isotope of oxygen.

5d. You need to add four protons, five neutrons, and four electrons to boron-10 to make a neutral, fluorine-19 atom. Fusion.

5e. Answers will vary. Example answer: Uranium-238 can split into thorium-234 and helium-4. Thorium-234 is a radioactive isotope. Helium-4 is a stable isotope.

$${}^{238}_{144}U \Rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + energy$$

1. Answers are:
    a. Copper.
    b. Chromium and iron.
    c. Sulfur, chromium, iron, strontium, and lead.
    d. Terbium.
    e. Lithium.
2. The periodic table looks like a chart. Atoms are arranged in the order of their atomic number from left to right in rows. This organization helps you find an element quickly if you know its atomic number. The mass numbers also increase from left to right and in rows. You can use the atomic number and mass number of an element to find out how many protons, neutrons, and electrons it has. It is harder to find an atom by name because the symbols and the names are not in alphabetical order.
3. A radioactive isotope has a nucleus that is not stable. This means that the nucleus falls apart easily. Atoms with an atomic number greater than 83 (and a mass number greater than 209) are radioactive because the nuclei are too big for strong nuclear force to hold them together.
4. The first board is set up to represent potassium-41. This isotope is stable, but has a positive charge of +1. It is an ion. The second board is set up to represent technetium. All isotopes of technetium are radioactive.
5. Both fusion and fission reactions involve the nuclei of atoms. A lot of energy is also produced in these reactions. A fusion reaction involves two atoms with relatively small mass numbers combining to form a nucleus with a larger mass number. A fission reaction involves the splitting of an atom with a large mass number into two atoms with smaller mass numbers.
6. Protons and neutrons participate in nuclear reactions. Electrons participate in chemical reactions.
7. Answers will vary. Example answers are:
    a. Add one electron to make hydrogen-2; earn 3 points.
    b. Remove one neutron to make helium-3; earn 3 points.
    c. Add one proton to make lithium-6; earn 3 points.
    d. Add one proton to make boron-10 with a +1 charge; earn 1 point.
    e. Add one proton to make hydrogen-1 with a +1 charge; earn 1 point.
    f. Add one neutron to make silicon-29; earn 3 points.
    g. Remove one electron to make fluorine-19; 3 points.

Curriculum Resource Guide: Atom Building Game

Credits

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