SAM Teachers Guide
Atomic Structure

Overview

In this activity students explore the structure and properties of atoms. They construct models of atoms with properties of particular mass and charge; create models of atoms with different stabilities by adding or subtracting neutrons, protons, and electrons; and determine that the same element may exist with different numbers of neutrons (called isotopes).

Learning Objectives

Students will be able to:

- Explore the probabilistic electron orbital model to help explain where electrons are most likely to be found.
- Explain that all atoms have similar structure, differing only in the number of protons, neutrons, and electrons.
- Build models of atoms and ions and identify patterns in numbers of protons and neutrons in stable nuclei and ions.
- Describe simple patterns in the periodic table.

Possible Student Pre/Misconceptions

- Students hold onto notions regarding earlier models of the atom. For example, electrons circle the nucleus in a set orbit, like planets around the sun.
- Orbitals tell you exactly where any electron is located at a given point in time.
- Physicists currently have a complete and "right" model of the atom.
- Electrons, protons and neutrons are all the same size and have the same mass.
- Atoms are small solid spheres.

Models to Highlight and Possible Discussion Questions

After completion of Part 1 of the activity:

Models to Highlight:

- Page 2 – Current Model of the Atom
  - Highlight the key differences between the current model of the atom and Bohr's model. In addition, use this as a chance for discussion regarding whether we know all there is to know about atomic structure.
- Page 4 – Atomic Model Building
  - Clarify what defines an **ion** and use examples to review.
  - Link to other SAM activities: **Chemical Bonding**. Students need to understand the structure of the atom to understand chemical bonding and reactions in the atomic world.

- Page 5 – Atomic Model Building
    - Clarify what defines an **isotope** and use examples to review.

Possible Discussion Questions:

- What subatomic particle (proton, neutron, electron) defines the element? Why?
- By looking at the numbers of protons, neutrons and electrons, can you determine if an atom is neutral or an ion? How?
- Which subatomic particles make up the mass number of an atom? What does this tell you about the mass of electrons relative to that of protons and neutrons?
- What is an isotope? What do you know about isotopes that are radioactive?

After completion of Part 2 of the activity:

Models to Highlight:

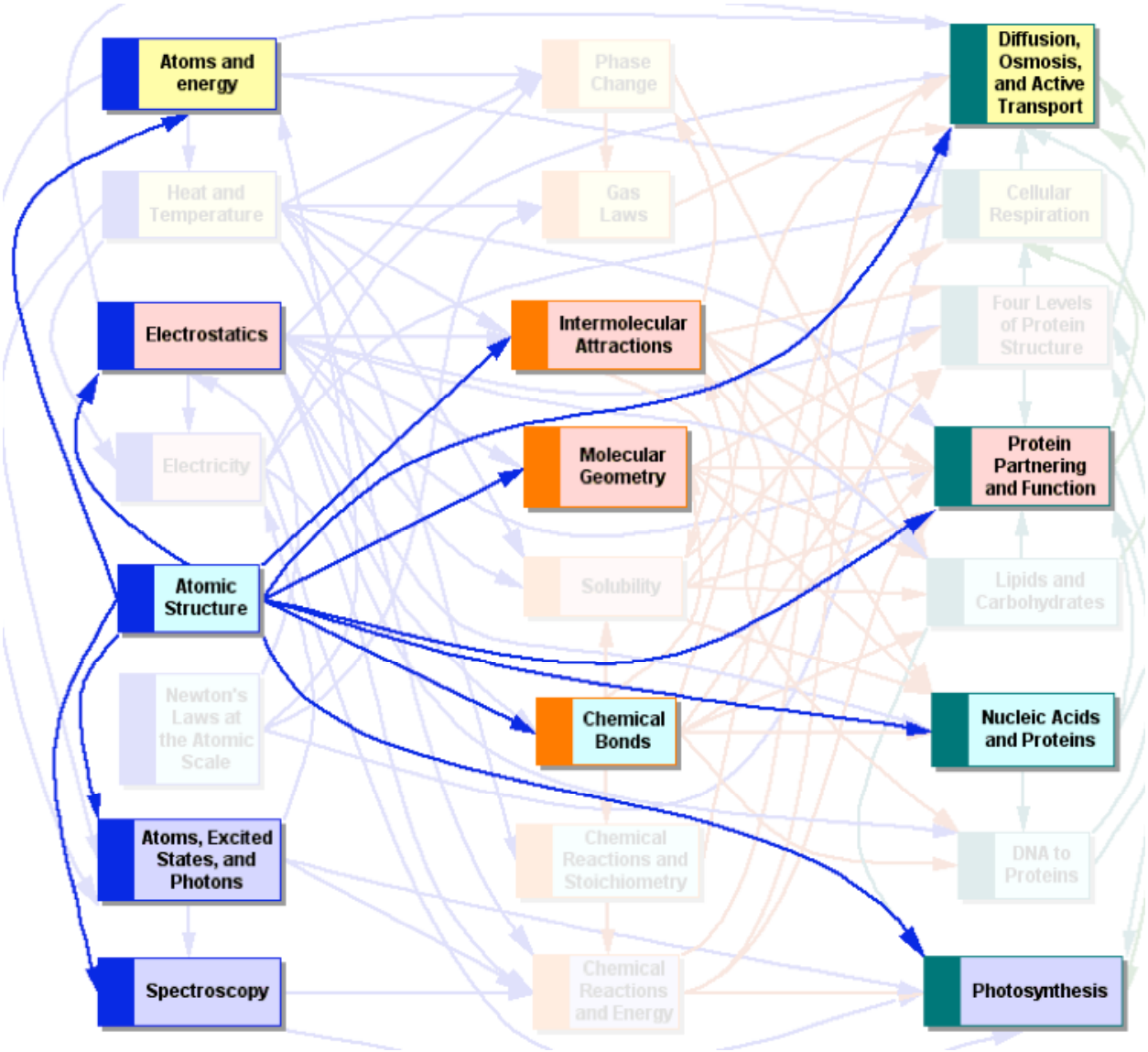
- Page 7 – Models of Boron Atom
    - Review how electrons are placed into orbitals. Reiterate that an orbital is actually a 3D area with a shape and volume where electrons are *likely* to be found. Discuss which shapes are characteristic of the s, p, and d orbitals and which best determines an atom's size.
    - Link to other SAM activities: **Excited States and Photons**. Students will need to understand the energy of electrons in orbitals to understand the emission and absorption of discrete amounts of energy.
- There are also many opportunities to link to future chemistry SAM activities. Use this as an opportunity to discuss the link between electrons and chemical bonding, polarity, van der Waals attractions and chemical reactions.

Possible Discussion Questions:

- Refer to page 6 and make connection back to **Atoms and Energy**. The location of electrons in an atom is dependent on the electron's energy.
- Refer to the periodic table trends on page 8.
    - Why does the size of atoms generally decrease as you move from left to right across a period? How does this relate to the orbitals where electrons are found?
    - What other properties do you think might follow trends either across a period or down a column?

- How does ionization energy relate to chemical bonding? How can you predict how atoms will be likely to behave when they interact with other atoms?

Connections to Other SAM Activities



Atomic Structure is considered a foundational activity. Everything is made from atoms. Atoms themselves are made from subatomic particles, such as positively charged protons and negatively charged electrons. The notion that everything is "sticky" at the atomic level because of atomic attractions stems from an understanding of atomic structure.

This activity is not directly supported by any other SAM activities because it is so fundamental. However, it supports many other SAM activities. First, to understand **Electrostatics** — the attraction and repulsion of atoms — students need to make the connection that atoms carry a charge when the number of protons and electrons is

uneven. Polarity is also a result of the uneven sharing of negative charge around nuclei. The **Atoms and Energy** unit is supported by **Atomic Structure** so students can better understand why attraction and repulsion exist. Both **Excited States and Photons** and **Spectroscopy** are also supported by an understanding of **Atomic Structure.** Students will understand at a deeper level that atoms in their excited states are really atoms whose electrons are in higher energy levels.

In order for students to understand **Chemical Bonds**, they must learn that atoms are a positively charged nucleus with a surrounding cloud of negative charge. The way in which electrons are shared or pulled will influence the type of chemical bond created. The structure of an atom explains how/why there are positive and negative charges involved in **Intermolecular Attractions.** The true shape of molecules is influenced by electrons involved in chemical bonds as well as unshared pairs of electrons. Students will gain a deeper understanding of **Molecular Geometry** by appreciating the behavior of these negative charges within an atom.

In addition, any activity that discusses ions relates back to the understanding of **Atomic Structure**. Ion formation is the result of uneven numbers of protons and electrons. In the activity **Diffusion, Osmosis, and Active Transport** understanding ions will help to understand what types of molecules can cross cell membranes and why. In **Four Levels of Protein Structure** and **Nucleic Acids and Proteins** students determine that the properties of the amino acids are determined by the atoms and their charges**.** Finally, in **Photosynthesis**, ions flow through reactions in a nerve impulse and in the electron transport chain.

Activity Answer Guide

Page 1:

1. Now imagine that some random person walks up and throws one dart at the board. Based on the pattern of holes you've seen from previous players, where will this dart most likely land? (b)

2. Explain the reasoning behind your prediction:

Even though there is no way to know exactly where that one dart will land, close to the center is the best guess. If the center gets you the most points, then you are most "attracted" to trying to get your throw close to there. In addition, when you highlight the previous hits, the greatest frequency of hits is closest to the center.

Page 2:

1. Explain why the color of the orbital gets lighter as you move further from the nucleus (see completed orbital above and to the right):

The color gets lighter because you are less likely to find electrons that far from the nucleus. When you trace the electrons in the model above you can see that there are more blue dots closer to the center and fewer as you get farther away.

2. If you had to bet on where you are most likely to find an electron at any particular point in time, where would it be? (a)

Page 3:

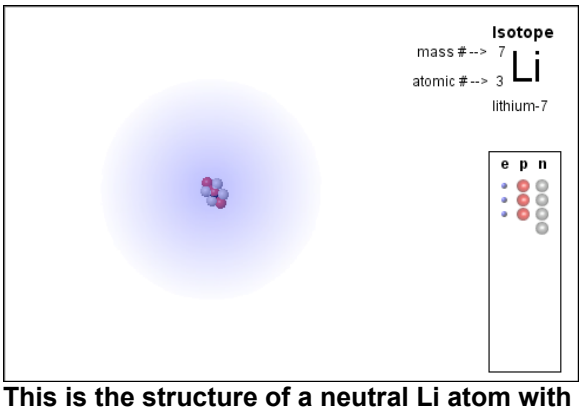
1. Which sub-atomic particle defines the kind of element an atom will be? (b)

2. Which number defines the kind of element an atom will be? (b)

3. Explain how you can predict the atomic number and the mass number by using an atom's number of protons and/or neutrons.

The atomic number is by definition the number of protons in an atom's nucleus. If you change the number of protons, the atomic number changes, too. The number of neutrons in the nucleus is the mass number minus the number of protons.

4. Put a snapshot of your lithium atom here.



This is the structure of a neutral Li atom with three protons, three electrons, and four neutrons.

Page 4:

1. What would be the charge on an atom with 7 protons and 4 electrons? +3

2. What would be the charge on an atom with 7 protons and 8 electrons? -1

3. An atom is NOT an ion when: (e)

4. Explain how you can predict the overall charge by knowing an atom's number of protons and electrons.

If you know the difference between the number of protons and electrons, you can predict the charge. If there are more protons than electrons, the charge will be POSITIVE and the magnitude of the charge will be equal to the difference. If there are more electrons than protons, the charge will be NEGATIVE and the magnitude will be equal to the difference.

Page 5:

1. What is different and what is the same between these carbon isotopes? (Check all that apply.) (b) (c) (e) (h)

2. Scientists use the fact that living things have a lot of carbon in them. When they die

the radioactive isotope breaks down over time, turning into other elements. By seeing how much of the radioactive carbon is left you can tell how old something is. Which one of these isotopes of carbon is radioactive, and can be used for carbon dating? (c)

3. Try making several stable and radioactive forms of other elements. What is the general rule for creating an atom with a stable nucleus (one that is NOT radioactive)?

The general rule is that the number of protons needs to equal the number of neutrons for the element to be stable.

Page 6:

1. Click on the energy diagram to determine which orbital this is, and record the name of the orbital below: 3d orbital

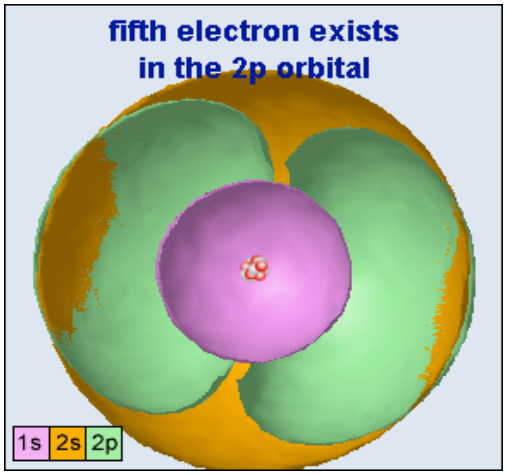
2. Electron orbitals (choose all that are correct): (a)

Page 7:

1. In what order do electrons form boron's orbitals? (a)

2. Which orbital is the one that would give the best estimate of the size of this atom? (b)

3. Take a snapshot of the boron atom showing all the overlapping orbitals.

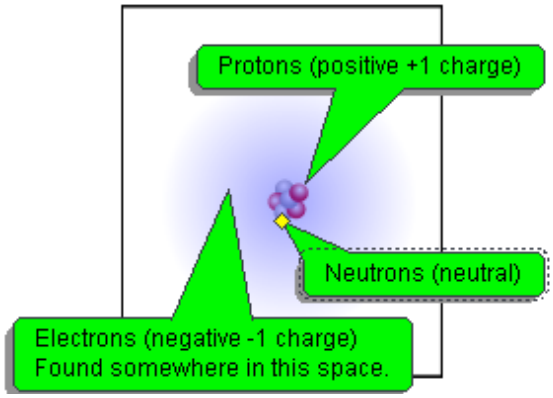


Page 8:

1. What happens to the size of an atom as you go across the table from left to right? Pick a row (also called a period) and click on each atom, starting from the left. (b)

2. What happens to the size of an atom as you go down a column? Pick a column (also called a group) and click on each atom, starting from the top. (a)

Page 9:



Labeled Model of an Atom

1. What is an orbital? Describe in detail.

An orbital is a region of 3D space around the nucleus of an atom where electrons are likely to be found.

2. What would be the charge of an ion with 10 protons and 12 electrons? (c)

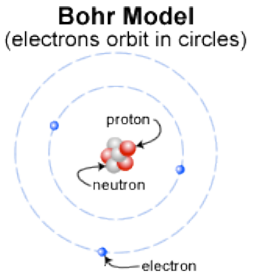
3. What is true when comparing these two isotopes? (Check all that apply.) (b) (d)

4. To the right you see part of a periodic table that shows the sizes of the atoms. Describe why it makes sense to start a new row with Li, and then another with Na:

The size of the atoms decrease across a row until the orbital is filled and then there is an increase in size as you jump to the next row.

SAM HOMEWORK QUESTIONS
Atomic Structure

Directions: After completing the unit, answer the following questions to review.



1. Many people think of the Bohr Model when they picture an atom. (See picture.) Explain why the Bohr Model is incorrect.

2. Draw and label a diagram that illustrates the current model of an atom.

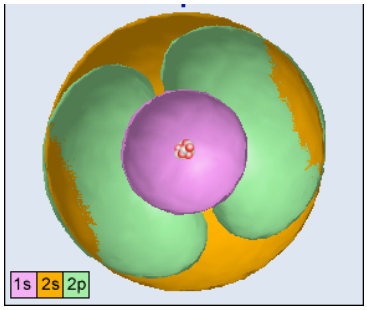
3. Which subatomic particle is responsible for determining the identity of the atom?

4. Which two subatomic particles make up most of an atom's mass?

5. Atoms that have lost or gained electrons have a net positive or negative charge. What are these atoms called?

6. Which subatomic particle differs in isotopes of the same element? For example, what is different about carbon-12 versus carbon-14?

7. Below is a cross-section of a boron atom. What is being shown in the areas of different shapes around the nucleus? What does this tell you about a boron atom?

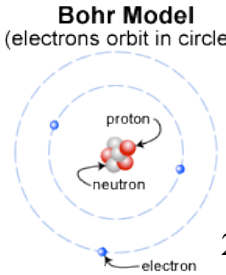


8. Explain one trend in how atoms are arranged on the periodic table.

9. **Career connection:** Scientists currently predict new elements based on computer models. Find information about the most recently discovered element.

SAM HOMEWORK QUESTIONS
Atomic Structure - With Suggested Answers for Teachers

Directions: After completing the unit, answer the following questions to review.



1. Many people think of the Bohr Model when they picture an atom. (See picture.) Explain why the Bohr Model is incorrect.

Electrons do not orbit the nucleus in specific paths. The best we can do is to describe the region of space where an electron is likely to be found.

2. Draw and label a diagram that illustrates the current model of an atom.

Student drawings should show the nucleus in the center with a cloud surrounding the nucleus. This cloud represents the constant motion of electrons around the nucleus and where electrons are likely to be found.

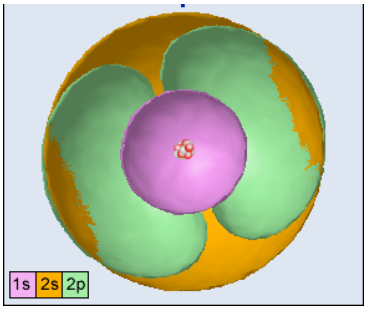
1. Which subatomic particle is responsible for determining the identity of the atom?
The number of protons (atomic number) determines its identity.

2. Which two subatomic particles make up most of an atom's mass?
Protons and neutrons make up most of the atom's mass. The mass of electrons is negligible in comparison.

3. Atoms that have lost or gained electrons have a net positive or negative charge. What are these atoms called? *Ions*

4. Which subatomic particle differs in isotopes of the same element? For example, what is different about carbon-12 versus carbon-14?
The number of neutrons varies among isotopes of the same element. The number of protons must be the same if it is the same element.

5. Below is a cross-section of a boron atom. What is being shown in the areas of different shapes around the nucleus? What does this tell you about a boron atom?



The overlapping electron orbitals are shown in these areas. They are regions where electrons are likely to be found at any given time. There are three orbitals – 1s, 2s, and 2p.

6. Explain one trend in how atoms are arranged on the periodic table.
Answers may vary. Sample answers: Atoms increase in mass from left to right. Atoms increase in radius from top to bottom. Atoms get bigger as you go down a column (group). Atoms decrease in radius from left to right.

7. **Career connection:** This will be new from year to year. In 2010, the most recent element is #117. http://www.webelements.com/nexus/chemistry/synthesis-new-element-atomic-number-z117