Inside the Atom

Are all atoms of an element alike?

Why?

The following activity will help you learn important aspects of an atom. How do we characterize atoms? How does the combination of subatomic particles affect the mass and charge of an atom? How are isotopes and ions related to atoms? This is just a sampling of what we will address. Throughout this activity you will want Model 1 (you may want to tear that page off) and your Periodic Table handy.

1. Refer to Model 1. What subatomic particles do the following symbols represent in the Atomic Diagrams?

▬ ⊕ ○

2. Complete the table in Model 1 by counting the protons, neutrons and electrons in each Atomic Diagram.

3. What do all hydrogen atoms (and ions) have in common?

4. What do all carbon atoms (and ions) have in common?

5. What do all magnesium atoms (and ions) have in common?

6. Refer to your Periodic Table.
   a) What *whole* number is in each box for each of the elements from Model 1?
   Hydrogen - Carbon - Magnesium -

   b) The numbers you recorded from the periodic table are called **atomic numbers**. What does the atomic number of an element represent?

   c) Refer to the Nuclide Symbols in Model 1. Which corner of the nuclide symbol contains the atomic number?

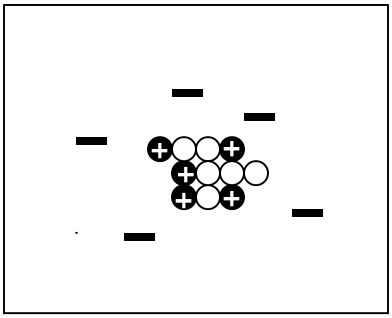
7. a) How many protons are in all chlorine atoms?

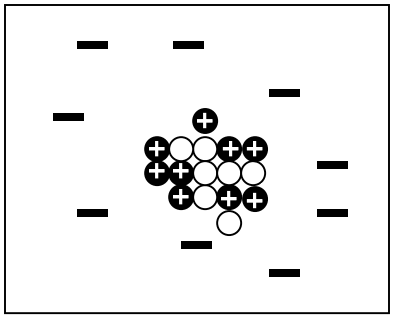
   b) Do you think chlorine atoms with 16 protons exist? Why or why not?

8. Refer again to Model 1. In the nuclide symbol of each atom, there is a superscripted number (i.e. ^{12}C). This number is also in the name of the atom (i.e. carbon-12). It is called the **mass number**.
   a) How is the mass number determined?

   b) Why is it called a "mass" number?

9. What are the mass numbers for the following atoms?





10. a) Which corner of the nuclide symbol contains the mass number?

b) How is the mass number of an isotope expressed in the name of an atom?

11. Write a nuclide symbol (similar to those in Model 1) for each of the Atomic Diagrams in #9.

12. Write the name of the atom (similar to those in Model 1) for each of the Atomic Diagrams in #9.

13. Fill in the following table.

Nuclide Symbol	$^{40}_{19}K$	$^{18}_{9}F$	
Atomic #			16
Mass #			
# of Protons			
# of Electrons			16
# of Neutrons			15

STOP

14. a) Do all isotopes of an element have the same atomic number? Give at least one example (or counter-example) from Model 1 that supports your answer.

b) Do all isotopes of an element have the same mass number? Give at least one example (or counter-example) from Model 1 that supports your answer.

15. Considering your answers to #14, write a definition of **isotope,** using a grammatically correct sentence. Your group must come to consensus on this definition.

16. Send a representative of your group to another group which has completed #15. This representative should compare answers to #15, and report back. You may then make changes to your definition of isotope if warranted.

17. Consult the following list of nuclide symbols: ${}^{204}_{82}Pb$, ${}^{82}_{35}Br$, ${}^{78}_{35}Br$, ${}^{208}_{82}Pb$, ${}^{204}_{78}Pt$, ${}^{205}_{82}Pb$.

a) Which of the atoms represented by these symbols are isotopes of each other?

b) Which part(s) of the nuclide symbol was the most helpful in answering part a) of this question?

18. a) In Model 1, how is the charge on an ion shown in the symbol?

b) In Model 1, how is a neutral atom indicated in the symbol?

c) In terms of atomic structure, what feature distinguishes a **neutral atom** from an **ion**? (Hint - Count the subatomic particles which have charge (protons and electrons) in each of the ions shown in Model 1.)

19. If an ion has a +2 charge, what has been done to the atom?

20. If an ion has a -2 charge, what has been done to the atom?

21. Could a +2 ion of calcium be made by adding two protons to a calcium atom? Explain.

22. Write a mathematical equation which could be used to calculate the charge on an ion.

23. Fill in the following table:

Nuclide Symbol	$^{65}_{29}Cu^{2+}$		$^{77}_{35}Br^{1-}$
Atomic #			
Mass #		57	
# of Protons		26	
# of Electrons		23	
# of Neutrons			

STOP

Extension Questions

24. Refer to the hydrogen isotopes in Model 1. They each have a special name derived from Latin (protium, deuterium and tritium). What do you think these names are based on?

25. One of your classmates is having trouble understanding ions. He explains the formation of an ion like this:

"When you add an electron, you get a + charge because adding is + in math."

How could you help this classmate understand the connection between his math understanding and how ions are formed?

26. Can two atoms with the same mass number ever be isotopes of each other? Why or why not?

27. All models have limitations. What characteristics of Model 1 are inconsistent with your understanding of what atoms look like?

Teacher Resources

Learning Objectives:

1. Students will be able to determine the number of protons, neutrons and electrons in an atom based on the symbol.
2. Students will be able to describe the similarities and differences in isotopes of an element.
3. Students will be able to describe why an ion has an overall charge.

Prerequisites:

1. Students should be able to name the three subatomic particles, their charges, a general idea of where they are in the atom (nucleus or outside the nucleus) and which of them have substantial mass.
2. Students should have some familiarity with atomic symbols (at least be able to find them on a Periodic Table).

Assessment Questions:

1) A neutral atom has 14 protons and 18 neutrons. Choose the correct symbol for this atom.

a. ${}^{32}_{18}Ar$ b. ${}^{32}_{14}Si$ c. ${}^{18}_{14}Si$ d. ${}^{14}_{32}Ge$

2) Which of the following pairs show two atoms with a different number of electrons?

a. ${}^{34}_{17}Cl^{1-}$ and ${}^{40}_{18}Ar$ c. ${}^{59}_{27}Co$ and ${}^{61}_{27}Co$

b. ${}^{16}_{8}O^{2-}$ and ${}^{19}_{9}F^{1-}$ d. ${}^{65}_{30}Zn$ and ${}^{65}_{30}Zn^{2+}$

3) There are three stable isotopes of Argon; Argon-36, Argon-38 and Argon-40. What would the atoms of these isotopes have in common? What would be different about their atoms?

Assessment Questions (Target Responses):

1) A neutral atom has 14 protons and 18 neutrons. Choose the correct symbol for this atom.

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b. ${}^{16}_{8}O^{2-}$ and ${}^{19}_{9}F^{1-}$ ***d.*** ${}^{65}_{30}Zn$ ***and*** ${}^{65}_{30}Zn^{2+}$

3) There are three stable isotopes of Argon; Argon-36, Argon-38 and Argon-40. What would the atoms of these isotopes have in common? What would be different about their atoms?

All of these atoms will have 18 protons and 18 electrons (if they are all neutral).
The three isotopes will have different numbers of neutrons (18, 20 and 22).

Teacher Tips:

- Students will need the 1st page (Model 1) throughout the activity. Therefore, it is helpful to copy it as a separate sheet that can be separated from the rest of the pages.
- Many students have the misconception that there is a "normal" atom of some element, and the rest of the versions of that atom are isotopes. For example Carbon-12 is "normal" because it has 6 protons and 6 neutrons, while Carbon-13 is an isotope because it is unbalanced. The stop-sign at number 16 is a good place to emphasize that all versions of atoms for a particular element are isotopes.

Materials:

- Students will need a Periodic Table

Target Responses:

1. Refer to Model 1. What do the following shapes represent in the Atomic Diagrams?

▬ *electron* ⊕ *proton* ○ *neutron*

2. Complete the table in Model 1 by counting the protons, neutrons and electrons in each Atomic Diagram.

	Isotopes of Hydrogen			Ion of Hydrogen
Nuclide Symbol	${}^{1}_{1}H$	${}^{2}_{1}H$	${}^{3}_{1}H$	${}^{1}_{1}H^{1+}$
# of Protons	*1*	*1*	*1*	*1*
# of Neutrons	*0*	*1*	*2*	*1*
# of Electrons	*1*	*1*	*1*	*0*
	Isotopes of Carbon			Ion of Carbon
Nuclide Symbol	${}^{12}_{6}C$	${}^{13}_{6}C$	${}^{14}_{6}C$	${}^{12}_{6}C^{1-}$
# of Protons	*6*	*6*	*6*	*6*
# of Neutrons	*6*	*7*	*8*	*6*
# of Electrons	*6*	*6*	*6*	*7*
	Isotopes of Magnesium			Ion of Magnesium
Nuclide Symbol	${}^{24}_{12}Mg$	${}^{25}_{12}Mg$	${}^{26}_{12}Mg$	${}^{24}_{12}Mg^{2+}$
# of Protons	*12*	*12*	*12*	*12*
# of Neutrons	*12*	*13*	*14*	*12*
# of Electrons	*12*	*12*	*12*	*10*

3. What do all hydrogen atoms (and ions) have in common?
   They all have 1 proton.

4. What do all carbon atoms (and ions) have in common?
   They all have 6 protons.

5. What do all magnesium atoms (and ions) have in common?
   They all have 12 protons.

6. Look at your Periodic Table.

a) What *whole* number is in each box for each of the elements from Model 1?

Hydrogen - *1* Carbon - *6* Magnesium - *12*

b) The numbers you recorded from the periodic table are called **atomic numbers**. What does the atomic number of an element represent?

The number of protons in the atom.

c) Refer to the Nuclide Symbols in Model 1. Which corner of the nuclide symbol contains the atomic number? *Bottom left corner*

7. a) How many protons are in all chlorine atoms? *17*

b) Do you think chlorine atoms with 16 protons exist? Why or why not?

No, an atom with 16 protons would be a sulfur atom. Each element has atoms with a unique number of protons.

8. Refer again to Model 1. In the nuclide symbol of each atom, there is a superscripted number (i.e. ^{12}C). This number is also in the name of the atom (i.e. carbon-12). It is called the **mass number**.

a) How is the mass number determined?

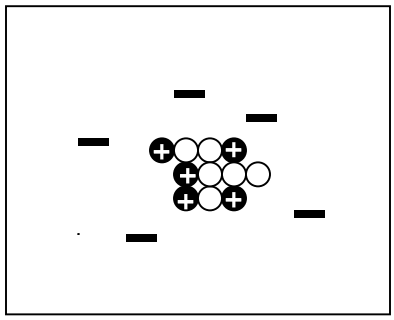
The number of protons and neutrons added together.

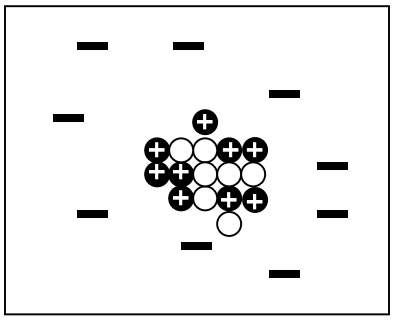
b) Why is it called a "mass" number?

These are the only subatomic particles that have substantial mass.

9. What are the mass numbers for the following atoms?

11 *16*





10. a) Which corner of the nuclide symbol contains the mass number? *Upper left corner.*

b) How is the mass number of an isotope expressed in the name of an atom?

name – mass#

11. Write a nuclide symbol (similar to those in Model 1) for each of the Atomic Diagrams in #9.

$^{11}_{5}B$ $^{16}_{9}F$

12. Write the name of the atom (similar to those in Model 1) for each of the Atomic Diagrams in #9.

Boron – 11 *Fluorine - 16*

13. Fill in the following table.

Nuclide Symbol	$^{40}_{19}K$	$^{18}_{9}F$	$^{31}_{16}S$
Atomic #	*19*	*9*	16
Mass #	*40*	*18*	*31*
# of Protons	*19*	*9*	*16*
# of Electrons	*19*	*9*	16
# of Neutrons	*21*	*9*	15

14. a) Do all isotopes of an element have the same atomic number? Give at least one example (or counter-example) from Model 1 that supports your answer.

Yes, all the magnesium atoms have 12 protons, so they all have an atomic number of 12.

b) Do all isotopes of an element have the same mass number? Give at least one example (or counter-example) from Model 1 that supports your answer.

No, each of the magnesium atoms shown has a different mass number, 24, 25 & 26.

15. Considering your answers to #14, write a definition of **isotope,** using a grammatically correct sentence. Your group must come to consensus on this definition.

Isotopes are atoms of the same element, having the same atomic number, with different mass numbers.

16. Send a representative of your group to another group which has completed #15. This representative should compare answers to #15, and report back. You may then make changes to your definition of isotope if warranted.

17. Consult the following list of nuclear symbols: $^{204}_{82}Pb$, $^{82}_{35}Br$, $^{78}_{35}Br$, $^{208}_{82}Pb$, $^{204}_{78}Pt$, $^{205}_{82}Pb$.

a) Which of the atoms represented by these symbols are isotopes of each other?

$^{204}_{82}Pb$ $^{208}_{82}Pb$ $^{205}_{82}Pb$ $^{82}_{35}Br$ $^{78}_{35}Br$

b) Which part(s) of the nuclide symbol was the most helpful in answering part a) of this question?

The element symbols should be the same if they are isotopes. Also, the atomic numbers (lower left) should be the same if they are isotopes.

18. a) In Model 1, how is the charge on an ion shown in the symbol?

A + or – number in the upper right corner of the symbol.

b) In Model 1, how is a neutral atom indicated in the symbol?

There is no number in the upper right corner of the symbol.

c) In terms of atomic structure, what feature distinguishes a **neutral atom** from an **ion**? (Hint – Count the subatomic particles which have charge (protons and electrons) in each of the ions shown in Model 1.)

The number of protons and electrons are not equal.

19. If an ion has a +2 charge, what has been done to the atom?

Two electrons have been removed from a neutral atom.

20. If an ion has a -2 charge, what has been done to the atom?

Two electrons have been added to a neutral atom.

21. Could a +2 ion of calcium be made by adding two protons to a calcium atom? Explain.

By removing protons, the atomic number would change and the atom would no longer be calcium.

22. Write a mathematical equation which could be used to calculate the charge on an ion.

Charge = # protons - # electrons

23. Fill in the following table:

Nuclide Symbol	$^{65}_{29}Cu^{2+}$	$^{77}_{26}Fe^{3+}$	$^{77}_{35}Br^{1-}$
Atomic #	*29*	*26*	*35*
Mass #	*65*	57	*77*
# of Protons	*29*	26	*35*
# of Electrons	*27*	23	*36*
# of Neutrons	*36*	*31*	*41*

24. Refer to the hydrogen isotopes in Model 1. They each have a special name derived from Latin (protium, deuterium and tritium). What do you think these names are based on?

The names refer to the mass number. *(Answers will vary)*
Protium = 1
Deuterium = 2
Tritium = 3

25. One of your classmates is having trouble understanding ions. He explains the formation of an ion like this:

"When you add an electron, you get a + charge because adding is + in math."

How could you help this classmate understand the connection between his math understanding and how ions are formed?

The electrons have a negative charge so when you ADD one you are adding a negative. *(Answers will vary)*

26. Can two atoms with the same mass number ever be isotopes of each other? Why or why not?

If two atoms have the same mass number either they are identical atoms (and therefore would not be isotopes) or they are atoms with different atomic numbers that just "happen" to have the same mass number. To be isotopes, the atoms must have the same atomic number.

27. All models have limitations. What characteristics of Model 1 are inconsistent with your understanding of what atoms look like?

Electrons are MUCH smaller than protons and neutrons. *(Answers will vary)*
Protons are not black.
Electrons are not rectangular.
Protons do not have plus signs on them.
Nuclei are actually three dimensional clusters, not flat.