**Principles of Science**
**Atomic Structure Worksheet**

*Fill in the blanks for the elements in this chart.*

| Element | Number of Protons | Number of Neutrons | Number of Electrons | Mass Number | Atomic Number |
|---|---|---|---|---|---|
| lithium | | | | | |
| carbon | | | | | |
| chlorine | | | | | |
| silver | | | | | |
| lead | | | | | |
| calcium | | | | | |
| tantalum | | | | | |
| radium | | | | | |
| samarium | | | | | |
| uranium | | | | | |
| americium | | | | | |
| lawrencium | | | | | |

**Principles of Science**
**Protons, Neutron, Electrons Practice**

*Fill in the blanks in the following worksheet. Please keep in mind that the isotope represented by each space may NOT be the most common isotope or the one closest in atomic mass to the value on the periodic table.*

| Atomic symbol | Atomic number | Protons | Neutrons | Electrons | Atomic mass |
|---|---|---|---|---|---|
| B | | | 6 | | |
| | 11 | | | | 24 |
| | | 31 | 37 | | |
| | | | | 39 | 89 |
| | 29 | | 35 | | |
| | | 43 | | | 100 |
| Pb | | | | | 207 |
| | | | 102 | 70 | |
| | | 89 | | | 225 |
| Mo | | | 53 | | |
| | 81 | | | | 206 |
| | 100 | | 159 | | |
| No | | | | | 261 |
| Yb | | | | | 172 |
| | | 106 | 159 | | |

**Principles of Science**
**Atomic Notation**

*Fill in the blanks in the following worksheet. Please keep in mind that the isotope represented by each space may NOT be the most common isotope or the one closest in atomic mass to the value on the periodic table.*

| element | atomic notation | atomic number | mass number | number of protons | number of neutrons | number of electrons |
|---|---|---|---|---|---|---|
| hydrogen | $^{1}_{1}H$ | | | | | |
| hydrogen | $^{2}_{1}H$ | | | | | |
| fluorine | | 9 | 19 | | | |
| sulfur | | | | 16 | 17 | |
| | | 16 | 34 | | | |
| | | | | | 36 | 29 |
| | $^{16}_{8}O$ | | | | | |
| | | | | 29 | 34 | |
| | | 6 | 14 | | | |
| | | | 14 | | 7 | |
| | | | 15 | 7 | | |
| Uranium | | | 238 | | | |
| | | | 234 | | | 92 |
| | | | | | 2 | 2 |
| | | | | 2 | 1 | |

**Principles of Science**
**How Do Isotopes Differ?**

*Directions: Most elements exist in nature as isotopes. Isotopes of an element are almost identical in their chemical properties and reactions. However, the nuclear properties of isotopes are different. Not only do isotopes differ in mass, but some may be radioactive. Using a periodic table, complete the information in the chart below.*

| Symbol | Atomic Number | Number of Protons | Mass Number | Number of Neutrons |
|---|---|---|---|---|
| 1. $^{1}_{1}H$ | | | 1 | |
| 2. $^{2}_{1}H$ | 1 | | | 1 |
| 3. $^{3}_{1}H$ | | | 3 | |
| 4. $^{4}_{2}He$ | | 2 | | 2 |
| 5. $^{12}_{6}C$ | | | 12 | |
| 6. $^{14}_{6}C$ | | | 14 | |
| 7. $^{18}_{8}O$ | | | 18 | |
| 8. $^{49}_{21}Sc$ | | 21 | | 28 |
| 9. $^{63}_{27}Co$ | | | 63 | |
| 10. $^{212}_{82}Pb$ | | | 212 | |
| 11. $^{222}_{88}Ra$ | | | 222 | |
| 12. $^{226}_{88}Ra$ | | | 226 | |
| 13. $^{235}_{92}U$ | | | 235 | |
| 14. $^{238}_{92}U$ | | | 238 | |

**Principles of Science**
**Structure of the Atom**

Directions: *Answer the following questions on the lines provided.*

**1.** How is the chemical symbol of an element determined?

**2.** Of what are atoms composed?

**3.** Are electrons, protons, or neutrons the smallest particles? If not, what are?

**4.** How many types of quarks are there and what is the name of one of them?

**5.** Why do scientists use models to study atoms?

**6.** Why has the atomic model changed over time?

**7.** Why is the current atomic model called the "Electron Cloud Model"?

Directions: *Match the term in Column I with the definition in Column II. Write the letter of the correct definition in the blank at the left.*

## Column I

_____ **8.** electron

_____ **9.** neutron

_____ **10.** nucleus

_____ **11.** proton

_____ **12.** quark

## Column II

**a.** positively charged particle

**b.** negatively charged particle

**c.** neutral particle

**d.** Smaller particles that make up protons and neutrons

**e.** positively charged center of an atom

**Principles of Science**
**Structure and Mass Reinforcement**

Directions: *Use the terms below to complete the following paragraphs about atoms , atomic mass, and isotopes. Terms may be used more than once.*

| | | | | |
|---|---|---|---|---|
| six | number | electrons | isotopes | electron |
| cloud neutron(s) | proton(s) | mass | quarks | six protons |

The electron has very little mass compared to the **1.**_____ or **2.**_____**.** The mass of the atom depends on the nucleus and how many **3.**_____and **4.**_____ it has. The sum of the protons and neutrons is the mass **5.**_____ of an atom. The number of neutrons in an atom can be found by subtracting the atomic number from the **6.**_____ number.

The mass of the atom is so small that there is a measure called the atomic **7.**_____ unit, designated by *amu*. **8.**_____ and **9.**_____ found in the nucleus are made up of **10.**_____ . There are **11.**_____ uniquely different quarks. **12.**_____ are found in an area around the nucleus called the **13.**_____. The nuclei of all atoms of a given element always have the same number of **14.**_____. They will also have the same number of **15.**_____ around the nucleus.

Some atoms may have more or fewer **16.**_____ than other atoms of the same element. Atoms of the same element with different numbers of neutrons are called **17.**_____. Every atom of carbon must contain **18.**_____ but some contain six neutrons and others have eight.

**Principles of Science**
**Masses of Atoms**

Directions: *Answer the following questions in the space provided.*

**1.** What are isotopes?

**2.** How do boron-10 and boron-11 differ?

**3.** What is the average atomic mass of an element?

**4.** Compare and contrast the atomic structures of the chlorine-35 and chlorine-37 isotopes.

**5.** Suppose that a newly discovered element called centium has three isotopes that occur in nature. These are centium-200, centium-203, and centium-209. Assume that these isotopes occur in equal amounts in nature. What will be the average atomic mass of this element?

## Principles of Science
## Isotopic Abundance Practice Problems

The **atomic mass** for each element appearing on the periodic table represents the weighted average of masses for each individual isotope of an element. For example, the atomic mass of carbon is reported as 12.011 amu (atomic mass units). Carbon is composed primarily of two isotopes; carbon-12 and carbon-14. The atomic mass is calculated using ***both*** the relative abundance and the masses for each of these two isotopes. Using the equation below, the atomic mass for carbon can be calculated.

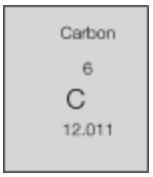
$$\text{atomic mass} = (\text{mass}_1 \times \%_1) + (\text{mass}_2 \times \%_2) + \ldots$$

Carbon-12 accounts for 99.45% of all of the carbon atoms, while carbon-14 only accounts for the remaining 0.55%. Since the carbon-12 isotope is more abundant, its mass is weighted more in the calculation of carbon's atomic mass. The calculation of the atomic mass is shown below.

| isotope | % abundance | mass (amu) |
|---|---|---|
| carbon-12 | 99.45 | 12.000 |
| carbon-14 | 0.55 | 14.003 |

$$\text{atomic mass} = (12.000 \cdot 0.9945) + (14.003 \cdot 0.0055)$$

$$\text{atomic mass} = (11.934) + (0.077) = 12.011 \text{ amu}$$




**Directions**: Use the equation for atomic mass to complete the following problems.

1. Argon has three naturally occurring isotopes: argon-36, argon-38, and argon-40. Based on argon's reported atomic mass, which isotope exist as the most abundant in nature? Explain.

2. Copper exists as a mixture of two isotopes. Copper-63 is 69.17% abundant and it has a mass of 62.9296 amu. Copper-65 is 30.83% abundant and it has a mass of 64.9278 amu. Calculate the atomic mass of copper.

3. Calculate the atomic mass of silicon. The three silicon isotopes have atomic masses and relative abundances of 27.9769 amu (92.2297%), 28.9765 amu (4.6832%) and 29.9738 amu (3.0872%).

4. Gallium has two naturally occurring isotopes. The mass of gallium-69 is 68.9256 amu and it is 60.108% abundant. The mass of gallium-71 is 70.9247 amu and it is 39.892% abundant. Calculate the atomic mass of gallium.

5. Bromine has two naturally occurring isotopes. Bromine-79 has a mass of 78.918 amu and is 50.69% abundant. Using the atomic mass reported on the periodic table, determine the mass of bromine-81, the other isotope of bromine.

6. Calculate the atomic mass of lead. The four lead isotopes have atomic masses and relative abundances of 203.973 amu (1.4%), 205.974 amu (24.1%), 206.976 amu (22.1%) and 207.977 amu (52.4%).

7. Antimony has two naturally occurring isotopes. The mass of antimony-121 is 120.904 amu and the mass of antimony-123 is 122.904 amu. Using the average mass from the periodic table, calculate the abundance of each isotope.

**Principles of Science**
**Average Atomic Mass**

The **average atomic mass** of an element can be determined from the relative amounts of each isotope. This is the mass used in most chemical calculations.

In a naturally occurring element, the **fractional abundance** is the percentage of the abundance of a particular isotope in the total sample of atoms, written as a decimal.

**To calculate average atomic mass of an element:**

Average atomic mass = (fractional abundance of isotope 1)(atomic mass of isotope 1) + (fractional abundance of isotope 2)(atomic mass of isotope 2) + . . . . . .

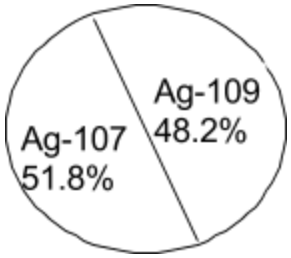
## Practice Problems

1. Chlorine has two isotopes. Chlorine-35 has an actual mass of 34.9689 u and chlorine-37 has a mass of 36.9659 u. In any sample of chlorine atoms, 75.771% will be chlorine-35 and 24.229% will be chlorine 37. Calculate the average atomic mass of chlorine.

2. Copper has two isotopes. Copper-63, which has an atomic mass of 62.93 u and copper-65, which has an atomic mass of 64.93 u. In any sample of copper atoms, 69.1% will be copper-63 and 30.9% will be copper-65. Calculate the average atomic mass of naturally occurring copper.

3. One atom has 20 protons and a mass of 44. Another atom has 20 protons and a mass number of 40. What is the identity of these atoms? How do you account for the difference in mass numbers?

4. The pie graph shows the abundance of the two kinds of silver atoms found in nature. The more abundant isotope has an atomic mass of a little less than 107, but the average atomic mass of silver on the periodic table is about 107.9. Explain why it is higher.




Calculate the average atomic masses using the following data for #5-14.

| 5. Isotope | mass (u) | fractional abundance |
|---|---|---|
| Mg-24 | 23.985 | 78.7% |
| Mg-25 | 24.986 | 10.13% |
| Mg-26 | 25.983 | 11.17% |

**Average atomic mass of magnesium =** _

| 6. Isotope | mass (u) | fractional abundance |
|---|---|---|
| Ir-191 | 191.0 | 37.58% |
| Ir-193 | 193.0 | 62.42% |

**Average atomic mass for iridium =** _

| 7. Isotope | mass (u) | fractional abundance |
|---|---|---|
| Li-6 | 6.015 | 7.59% |
| Li-7 | 7.016 | 92.41% |

**Average atomic mass of lithium =** _

| 8. Isotope | mass (u) | fractional abundance |
|---|---|---|
| Cr-50 | 49.946 | 4.35% |
| Cr-52 | 51.941 | 83.8% |
| Cr-53 | 52.941 | 9.5% |
| Cr-54 | 53.939 | 2.35% |

**Average atomic mass of chromium =** _

9.

| Isotope | mass (u) | fractional abundance |
|---|---|---|
| I-127 | 127.0 | 80% |
| I-126 | 126.0 | 17% |
| I-128 | 128.0 | 3% |

**Average atomic mass of iodine = _**

10.

| Isotope | mass (u) | fractional abundance |
|---|---|---|
| Au-197 | 196.56 | 50% |
| Au-198 | 197.96 | 50% |

**Average atomic mass of gold = _**

11.

| Isotope | mass (u) | fractional abundance |
|---|---|---|
| Fe-55 | 54.876 | 14.5% |
| Fe-56 | 55. 998 | 85.5% |

**Average atomic mass of iron = _**

12.

| Isotope | mass (u) | fractional abundance |
|---|---|---|
| H-1 | 0.98 | 99% |
| H-2 | 1.97 | 0.8% |
| H-3 | 2.98 | 0.2% |

**Average atomic mass of hydrogen = _**

13.

| Isotope | mass (u) | fractional abundance |
|---|---|---|
| N-14 | 14.0 | 95% |
| N-15 | 15.0 | 3% |
| N-16 | 16.0 | 2% |

**Average atomic mass of nitrogen = _**

14.

| Isotope | mass (u) | fractional abundance |
|---|---|---|
| C-12 | 12.0 | 98% |
| C-13 | 13.0 | 0.5% |
| C-14 | 14.0 | 1.5% |

**Average atomic mass of carbon = _**

**Principles of Science**
**Nova: Hunting the Elements**

Answer the questions that follow to the best of your ability. The questions are in chronological order.

1) Where does an element take its identity from? (5:30)

2) How much gold (Au) is extracted per ton of rock ore? (8:30)

3) How much does a gold (Au) bar weigh and how much is it worth? (13:00)

4) Why is copper (Cu) so widely sought on the world market and New York Mercantile Exchange? (16:00)

5) What is copper (Cu) combined with to make bronze? (18:00)

6) What makes metals like Copper (Cu) conductive to electricity? (20:00)

7) Bronze is an alloy. What is an alloy and why are they preferable at times? (22:00)

8) How does the atomic arrangement of atoms lead to its crystal structure like was seen in the sample of bronze with gold (Au) and tin (Sn) atoms? (32:00)

9) What is the atomic number and what does the atomic number indicate? (34:00)

10) Most of the periodic table is made of what type of elements? (35:00)

11) How did early chemists like Mendeleev classify the elements? (38:00)

12) How is the periodic table structured with regard to elements with similar properties? (40:00)

13) What makes noble gases stable? (43:00)

14) Why is an alkali metal element like Sodium (Na) so reactive? (45:00)

15) What does chlorine ($Cl^-$) do for sodium ($Na^+$)? What tasty substance is produced when this happens? (48:00)

16) What powers explosions and fire? (55:00)

17) What elements are basic to all living things? (59:00)

18) Why is Carbon (C) so good for forming the structure of life? (1:06:00).

19) What are at least three (3) other elements that are used for life functions and what are their uses? (1:12:00)

20) Why are cyanobacteria from places like volcanic pools so important for the production of oxygen in our atmosphere? (1:17:00)

21) What was the original element formed moments after the Big Bang? What then created higher order elements? (1:19:00)

22) How does silicon shape our technological reality? (1:22:00)

23) How are rare earth elements like neodymium (Nd) important to our technological world? (1:27:00)

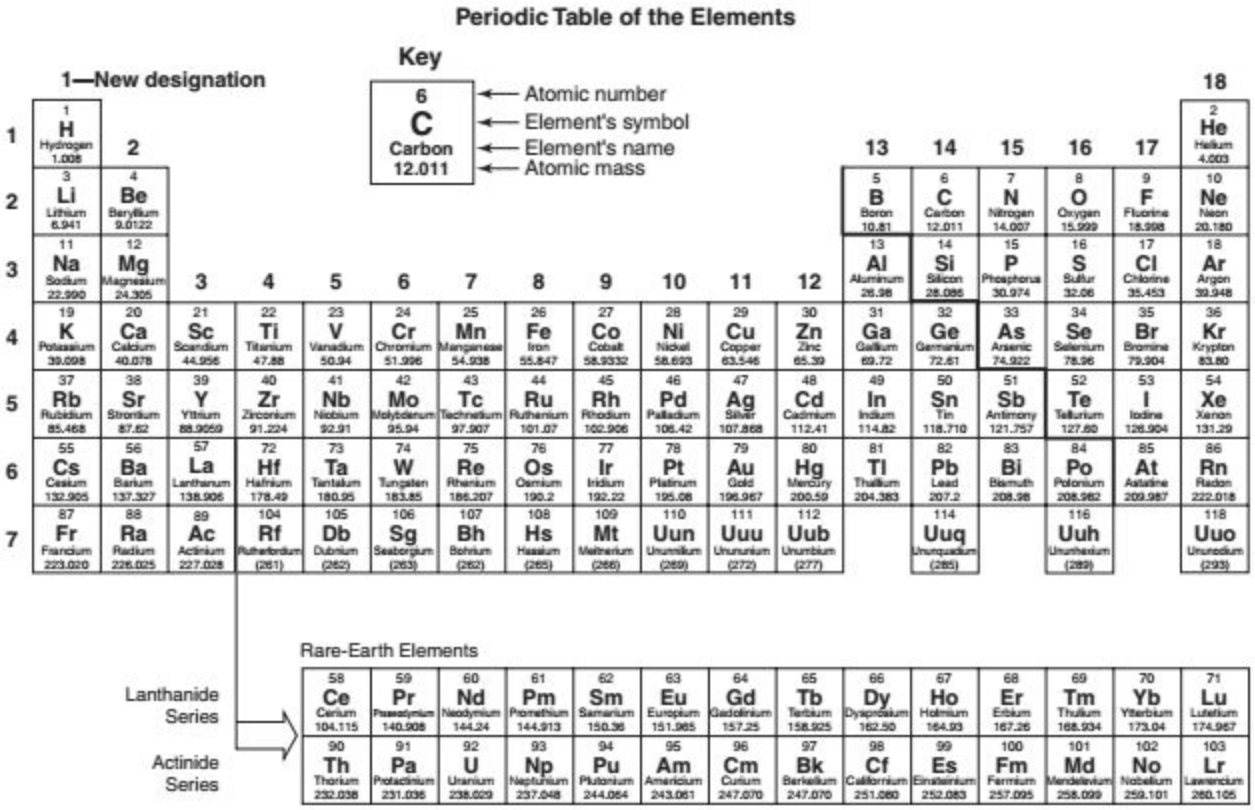
24) What is an isotope like Carbon-14? (1:42:00)

25) How can an isotope like Carbon-14 be used to date dead organisms? (1:44:00).

26) What is an unstable radioactive isotope? (1:46:00)

27) Why don't the man-made radioactive elements exist for very long? (1:58:00)

**Principles of Science**
**Periodic Table Basics**




Directions: *Use the periodic table above to answer the following questions.*

1. List two types of information that are given in each box of this periodic table.
   a. _____
   b. _____
2. Where are the metals located in the periodic table? _____
3. Where are the nonmetals located? _____
4. What are the elements in Groups 3 through 12 called? _____
5. What are the elements called that are next to the stairstep-shaped line on the right side of the table? _____
6. What do we call the letter or letters that represent an element? _____
7. How many elements are included in the modern periodic table? _____
8. What name is given to the elements in Group 18? _____

**Principles of Science**
**Bohr Models**

A **Bohr model** is a model of the atom developed by the passionate soccer player and physicist, Neils Bohr. The model shows the number of protons and neutrons in the nucleus of the atom. Outside of the nucleus, the model shows the atom's electrons in their **energy shells** or **energy levels**. The outermost energy level is called the **valence shell or level**. The electrons in the outermost shell are called **valence electrons**.

**Objective**: Describe the structure and parts of an atom

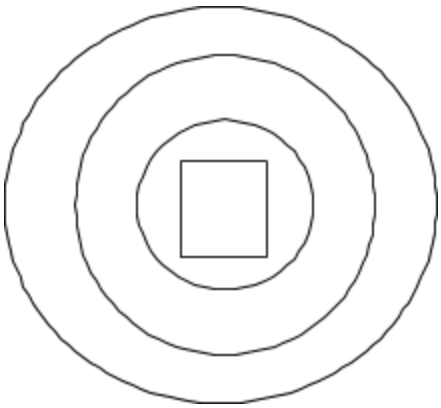
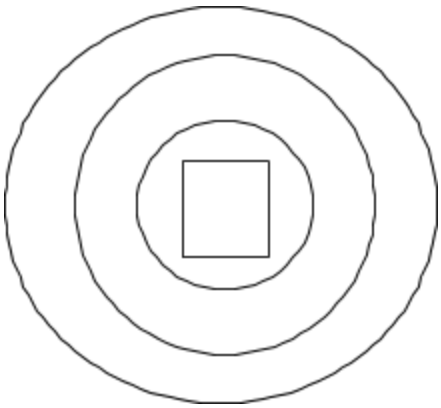
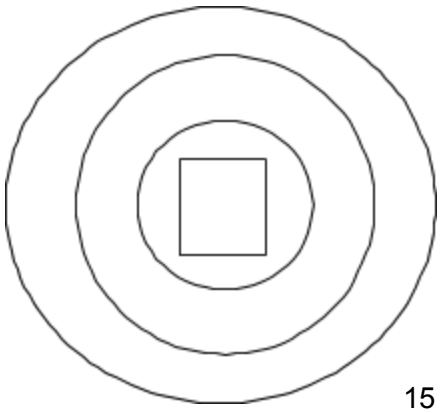
**Procedure:**

- Observe while your teacher demonstrates some Bohr models of different atoms. You may practice them on the Bohr models drawn below.
- Complete the Bohr Model Challenge by following the steps listed below. Remember to use your periodic table to help guide you!

**Steps for creating a Bohr Model:**

1. Draw the nucleus and energy shells for the atom. Determine the correct number of energy shells by finding the atom's period number on the periodic table. (This is the same as the row number.) Record the period number in the table.
2. Write the number of **n**eutrons and **p**rotons in the nucleus. You may write the number followed by an '**n**' for neutron and a '**p**' for proton.
3. Determine the number of electrons for the atom. Place the electrons in the energy levels by using the following rules:
    a. the first level (closest to the nucleus) holds 2 electrons
    b. the second level holds 8 electrons
    c. the third level holds 8 or more electrons
4. Write the number of valence electrons in the table.
5. Record the group number for the element in the table.
6. Determine if the element is a metal, non-metal or metalloid.
7. Answer the two questions at the end of the Bohr Model Challenge pages.

**Practice Bohr Models:**

Draw a Bohr model for the first 18 elements and fill in the missing information.

| Element Symbol | Bohr Model | # of valence electrons | Period | Group | Metal, nonmetal or metalloid |
|---|---|---|---|---|---|
| H | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Li | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Na | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Ar | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Be | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Mg | | | | | o Metal<br>o Non-metal<br>o Metalloid |

| Element Symbol | Bohr Model | # of valence electrons | Period | Group | Metal, nonmetal or metalloid |
|---|---|---|---|---|---|
| P | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| B | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Al | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| C | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Si | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| N | | | | | o Metal<br>o Non-metal<br>o Metalloid |

| Element Symbol | Bohr Model | # of valence electrons | Period | Group | Metal, nonmetal or metalloid |
|---|---|---|---|---|---|
| O | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| F | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Cl | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| He | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| Ne | | | | | o Metal<br>o Non-metal<br>o Metalloid |
| S | | | | | o Metal<br>o Non-metal<br>o Metalloid |

**Questions:**

1. What pattern do you notice in the number of protons as you move across the periodic table?
2. Compare the group number to the number of valence electrons? What do you notice?

**Principles of Science**
**Predicting an Element's Group and Period**

Several scientists, including Newlands, Meyer, and Mendeleev worked on classification systems that grouped elements according to their properties. They found that these properties repeated in a regular or periodic manner. This fact was used to predict properties of undiscovered elements.

Review electron arrangement from your textbook. In Table 1, write the maximum number of electrons that can fill each energy level on the blanks in the table heading. Write the total number of electrons for each element in the first column labeled Total. For each element, assign the correct number of electrons to each energy level. Complete Table 2 by using the information from the six elements studied.

Table 1

| Element | | Electrons | | |
|---|---|---|---|---|
| | **Total** | **Level 1** | **Level 2** | **Level 3** |
| **1.** Argon | | | | |
| **2.** Carbon | | | | |
| **3.** Helium | | | | |
| **4.** Lithium | | | | |
| **5.** Silicon | | | | |
| **6.** Sodium | | | | |

Table 2

| Element | Energy Level of Outer Electrons | Located in Period | Number of Outer Electrons | Located in Group |
|---|---|---|---|---|
| **7.** Ar | | | | |
| **8.** C | | | | |
| **9.** He | | | | |
| **10.** Li | | | | |
| **11.** Si | | | | |
| **12.** Na | | | | |

**13.** How is the element's period related to the number of energy levels over which its electrons are spread? _____

**14.** How can you predict an element's group and period? _____

**Principles of Science**
**Electron-Dot Diagrams**

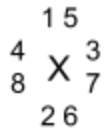
The electrons in an atom's outer energy level are the electrons that are important to consider in chemical bonds and chemical reactions. These electrons can be represented in a diagram called an electron dot diagram. The outermost electrons are drawn as dots around the chemical symbol. In this activity, you will draw electron dot diagrams for several elements.

## Procedure

1. Write the symbol for the element. For electron dot diagrams, this symbol represents the nucleus and all of the electrons of the atom except the outermost electrons.

2. Use the periodic table to determine how many outer electrons the element has. Do this by finding to which group the element belongs.

3. Draw a dot to represent each electron in the outer level of the element. Two electrons can be placed on each side of the symbol. Follow the pattern below for placing of the outer electrons:




## Conclude and Apply

**1.** Write electron dot diagrams for the elements listed.

**a.** hydrogen

**b.** neon

**c.** sodium

**d.** calcium

**e.** aluminum

**f.** fluorine

**g.** argon

**h.** potassium

**2.** Why do sodium and potassium have the same number of dots in their electron dot diagrams? What does this tell you about the chemistry of these two elements?

**Principles of Science**
**Properties of Atoms and the Periodic Table**

Directions: *Match the term in Column II with the definition in Column I. Write the letter of the correct term in the blank at the left.*

**Column I**

____ **1.** sum of the number of protons and neutrons in the nucleus

____ **2.** region around the nucleus where the electrons are found

____ **3.** positively charged center of an atom

____ **4.** vertical column in the periodic table

____ **5.** neutral particles in the nucleus of an atom

____ **6.** weighted average mass of the mixture of its isotopes

____ **7.** positively charged particles in an atom

____ **8.** table of the elements arranged according to repeated changes in properties

____ **9.** represents the electrons in the outer energy level of an element

____ **10.** negatively charged particles in an atom

____ **11.** atoms of the same element that have different numbers of neutrons

____ **12.** number of protons in an atom's nucleus

____ **13.** horizontal row in the periodic table

____ **14.** smallest known particle that makes up protons and neutrons

____ **15.** the smallest piece of matter that still retains the properties of the element

____ **16.** developed an early periodic chart

____ **17.** approximately $1.67 \times 10^{-24}$g

**Column II**

**a.** nucleus

**b.** electrons

**c.** protons

**d.** neutrons

**e.** quark

**f.** atomic number

**g.** mass number

**h.** isotope

**i.** average atomic mass

**j.** electron cloud

**k.** periodic table

**l.** atom

**m.** atomic mass unit

**n.** group

**o.** electron dot diagram

**p.** period

**q.** Dmitri Mendeleev