Key Ideas

Chemists use a unit called the mole to keep track of the number of molecules or atoms in a sample. A mole represents an extremely large number. Scientists use scientific notation to express extremely large or small numbers. The mass (in grams) of one mole of atoms of a substance can be found on the periodic table. Called the molar mass, it is the same number that represents the atomic mass, but with different units.

As a result of this lesson, students will be able to
- translate numbers into scientific notation, and vice versa
- explain the magnitude of a mole
- define molar mass for an element and find its value on the periodic table

Focus on Understanding

- Students might have difficulty grasping how the average atomic mass and the molar mass can be the same number. It is simply because 1 g is equivalent to 602 sextillion amu—but such a large number is difficult to grasp.

Key Terms

scientific notation
molar mass

What Takes Place

In this activity, students develop some proficiency in interpreting and translating very large and very small numbers and practice using scientific notation. They also are reintroduced to the concept of a mole in order to grasp its size in relation to mass amounts. During the discussion, molar mass is defined for a mole of atoms.

Materials

- student worksheet
Billions and Billions
Avogadro’s Number

Engage (5 minutes)

*Key Question:* What is the relationship between mass and moles?

**ChemCatalyst**

Which do you think is more toxic, 1 mol of arsenic, As, or 10 g of arsenic? Explain your reasoning.

**Sample Answer:** Students can estimate the answer by recalling how many atoms are in a mole and how many atoms are in 1 mg of arsenic. One mole of arsenic weighs 74.9 g, so it is more toxic.

**Discuss the ChemCatalyst**

- Discuss the relationship between mass and moles of atoms.

**Sample Questions**

- What do you need to know in order to answer this question?
- Which do you think has more atoms, 1 mol of arsenic or 10 g of arsenic?
- What do moles keep track of?

Explore (15 minutes)

**Introduce the Classwork**

- Remind students that they can track the numbers of molecules and atoms with a unit called the mole ( abbreviated mol). Write this on the board:

\[ 1 \text{ mole} \equiv 602,000,000,000,000,000,000,000, \text{ or } 602 \text{ sextillion} \]

- Pass out worksheets. Students can work in pairs or individually on the worksheet.
**Purpose**
To find the relationship between mass and number of atoms.

**Analysis**

1. The table on the next page shows the mass of different numbers of atoms of zinc, aluminum, and iron. Complete the table.

2. What is scientific notation?

   *It is a shorthand way of expressing very large numbers or very small numbers. The exponent tells where the decimal point should be.*

3. Why do you think scientists use scientific notation?

   *Because the numbers have so many zeros it's hard to write them out*

4. What are two ways of writing the smallest number in the table? What does it represent?

   0.000000000000000000011 g, or $1.1 \times 10^{-20}$ g. This number represents the mass of 100 atoms of zinc.

5. What are two ways of writing the largest number in the table? What does it represent?

   $1,204,000,000,000,000,000,000,000$ atoms, or $1.204 \times 10^{24}$ atoms. This number represents 111.6 g of iron.

6. Which has the most mass, 1 trillion atoms of zinc, 100 trillion atoms of iron, or 500 trillion atoms of aluminum? Explain how you can tell.

   500 trillion atoms of aluminum has the most mass. You can tell because there are fewer zeros behind the decimal point in the number representing the mass.

7. How many zinc atoms are there in 65.4 g?

   There are 602 sextillion atoms of zinc in 65.4 g.

8. Some of the numbers in scientific notation have a negative exponent, and some have a positive exponent. Explain the difference between these two types of numbers.

   The numbers with a negative exponent in scientific notation are all very small numbers less than 1. The numbers with a positive exponent in scientific notation are all numbers larger than 1.

9. What do 65.4 g of zinc, 27.0 g of aluminum, and 55.8 g of iron have in common?

   These three masses all contain the same number of atoms—602 sextillion. These numbers are also the value of the atomic mass for each of these elements on the periodic table.

10. What name do chemists give to a collection of 602 sextillion objects?

    a mole
<table>
<thead>
<tr>
<th>Substance</th>
<th>Amount</th>
<th>Number of atoms</th>
<th>Number of atoms in scientific notation</th>
<th>Mass (g)</th>
<th>Mass in scientific notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>zinc Zn(s)</td>
<td>1 hundred</td>
<td>100</td>
<td>$1.0 \times 10^2$</td>
<td>$0.0000000000000000011$ g</td>
<td>$1.1 \times 10^{-20}$ g</td>
</tr>
<tr>
<td></td>
<td>1 hundred thousand</td>
<td>100,000</td>
<td>$1.0 \times 10^5$</td>
<td>$0.0000000000000000011$ g</td>
<td>$1.1 \times 10^{-17}$ g</td>
</tr>
<tr>
<td></td>
<td>1 trillion</td>
<td>1,000,000,000</td>
<td>$1.0 \times 10^{12}$</td>
<td>$0.000000000000011$ g</td>
<td>$1.1 \times 10^{-18}$ g</td>
</tr>
<tr>
<td></td>
<td>602 sextillion</td>
<td>602,000,000,000</td>
<td>$6.02 \times 10^{23}$</td>
<td>65.4 g</td>
<td>$6.54 \times 10^1$ g</td>
</tr>
<tr>
<td>aluminum Al(s)</td>
<td>1 million</td>
<td>1,000,000</td>
<td>$1.0 \times 10^6$</td>
<td>$0.00000000000045$ g</td>
<td>$4.5 \times 10^{-17}$ g</td>
</tr>
<tr>
<td></td>
<td>500 trillion</td>
<td>500,000,000</td>
<td>$5.0 \times 10^{14}$</td>
<td>$0.0000022$ g</td>
<td>$2.2 \times 10^{-8}$ g</td>
</tr>
<tr>
<td></td>
<td>1 quintillion</td>
<td>1,000,000,000</td>
<td>$1.0 \times 10^{18}$</td>
<td>$0.0000045$ g</td>
<td>$4.5 \times 10^{-8}$ g</td>
</tr>
<tr>
<td></td>
<td>602 sextillion</td>
<td>602,000,000,000</td>
<td>$6.02 \times 10^{23}$</td>
<td>27.0 g</td>
<td>$2.70 \times 10^1$ g</td>
</tr>
<tr>
<td>iron Fe(s)</td>
<td>1 billion</td>
<td>1,000,000,000</td>
<td>$1.0 \times 10^9$</td>
<td>$0.000000000000093$ g</td>
<td>$9.3 \times 10^{-24}$ g</td>
</tr>
<tr>
<td></td>
<td>100 trillion</td>
<td>100,000,000,000</td>
<td>$1.0 \times 10^{19}$</td>
<td>$0.0000000000093$ g</td>
<td>$9.3 \times 10^{-9}$ g</td>
</tr>
<tr>
<td></td>
<td>602 sextillion</td>
<td>602,000,000,000</td>
<td>$6.02 \times 10^{25}$</td>
<td>55.8 g</td>
<td>$5.58 \times 10^1$ g</td>
</tr>
<tr>
<td></td>
<td>1,204 sextillion</td>
<td>1,204,000,000,000</td>
<td>$1.204 \times 10^{24}$</td>
<td>111.6 g</td>
<td>$1.12 \times 10^2$ g</td>
</tr>
</tbody>
</table>
Explain and Elaborate (20 minutes)

Discuss Scientific Notation

• Ask students to come to the board to complete some problems involving scientific notation. Ask students to translate longhand numbers into scientific notation and vice versa. If you wish, you can put numbers on a number line.

\[ 1.0 \times 10^4 = 10,000 \]

\[ 1.0 \times 10^{-4} = 0.0001 = \frac{1}{10,000} = \frac{1}{1.0 \times 10^4} \]

\[ 2.65 \times 10^4 = 26,500 \]

Sample Questions

• Why are numbers expressed in scientific notation?
• What does the exponent tell you?
• How are numbers in scientific notation added?
• How are numbers in scientific notation multiplied? divided?

Key Points

Scientific notation is a convenient way to write numbers that have lots of zeros, either because they are very large or because they are very small. Scientific notation keeps track of where the decimal point should be in any given number.

A number in standard notation can be converted to scientific notation by writing it as a decimal with one digit to the left of the decimal point times a power of ten. A number written in scientific notation has the form \( a \times 10^n \) where \( 1 \leq a < 10 \) or \( -10 < a \leq -1 \) and \( n \) is an integer (indicating what power of ten to multiply by). To convert a number (either positive or negative) in scientific notation back into standard notation, check the exponent, \( n \), to find out how many places to move the decimal point. The sign of the exponent indicates which direction the decimal should be moved to obtain the correct value in standard notation.

\[ 1.56 \times 10^4 = 15,600 \quad \text{Move the decimal point four places to the right.} \]

\[ 1.56 \times 10^{-4} = 0.000156 \quad \text{Move the decimal point four places to the left.} \]

You might want to remind students that if the absolute value of the number in standard notation is between 1 and 10, it could be written in scientific notation with an exponent equal to 0.

\[ 1.56 = 1.56 \times 10^0 \]
Discuss the Mole and Avogadro’s Number

**Sample Questions**

- What is the mass of 602 sextillion atoms of iron?
- What unit represents 602 sextillion objects?
- What is Avogadro’s number?
- Why do chemists keep track of atoms and molecules by using the unit moles?

**Key Points**

**Very small amounts of a substance contain enormously large numbers of atoms.** For example, only 0.000000022 g of aluminum contains 500 trillion, or 500,000,000,000,000,000,000,000 atoms. Keeping track of all these atoms, even if you are using scientific notation, is cumbersome. So chemists use a unit called the mole. You were introduced to the mole in Unit 3: Weather. One mole is equal to 602 sextillion objects. One mole is also referred to as Avogadro’s number.

**The mole is simply a counting unit.** Just as one dozen is always equal to 12 objects, one mole is always equal to $6.02 \times 10^{23}$ objects.

$$1 \text{ mole} = 602 \text{ sextillion}$$
$$= 602,000,000,000,000,000,000$$
$$= 6.02 \times 10^{23}$$

**Introduce Molar Mass**

- Quiz students on using the periodic table to find the mass of 1 mol of a variety of atoms.
- Revisit the ChemCatalyst. Using the periodic table, you can determine that 1 mol of arsenic has a mass of 74.92 g. Thus, 1 mol of arsenic is more toxic than 10 g of arsenic.

**Sample Questions**

- Where can you find the mass of 602 sextillion atoms?
- Where can you find the mass of 1 mol of a substance?
- What is the mass of 1 mol of arsenic atoms? (74.92 g)
- Would you rather be exposed to 1 billion arsenic atoms or 1 mol of arsenic atoms? Explain.

**Key Point**

**The mass of 1 mol of a substance is called the molar mass.** The molar mass of each element can be found on the periodic table. If you want to determine the mass of a mole of a particular type of atom, you can simply look up the average atomic mass of that element on the periodic table. For example, 1 mol of bromine atoms has a mass of 79.9 g, while 1 mol of potassium atoms has a mass of 39.1 g. Notice that the numbers for average atomic mass and molar mass are the same—only the units are different. In other words, the average mass of one atom of arsenic is 74.9 amu, and the mass of 1 mol of arsenic atoms is 74.9 g. (You might want to tell students to round molar masses to the nearest tenth of a gram.)
Wrap-up

Key Question: What is the relationship between mass and moles?

- One mole of a substance is equal to 602 sextillion—or 602,000,000,000,000,000,000,000—objects. This is also called Avogadro’s number.
- Scientific notation is a convenient way to express numbers that have many zeros.
- The atomic mass given on the periodic table is equivalent to the mass of 1 mole of atoms of the element in grams, called molar mass.
- Molar mass allows you to convert between moles of atoms and grams of atoms.

Evaluate (5 minutes)

Check-in
If you have 1 mol of aluminum and 1 mol of iron, which has more mass? How many atoms are in each sample?

Answer: By consulting the periodic table, you can see that 1 mol of iron has about twice as much mass as 1 mol of aluminum. A mole of aluminum atoms has a mass of 26.98 g. A mole of iron atoms has a mass of 55.85 g. Each sample contains $6.02 \times 10^{23}$ atoms.

Homework

Assign the reading and exercises for Toxins Lesson 9 in the student text.