Calculating with Moles

Because the amount of a substance and its mass are related, it is often useful to convert moles to grams, and vice versa. You can use **conversion factors** to relate units.

Using conversion factors

How did the shopkeeper mentioned on the previous page know the mass of 50 gumballs? He multiplied by a conversion factor to determine the number of gumballs on the scale from their combined mass. Multiplying by a conversion factor is like multiplying by 1 because both parts of the conversion factor are always equal.

The shopkeeper knows that exactly 10 gumballs have a combined mass of 21.4 g. This relationship can be written as two equivalent conversion factors, both of which are shown below.

$$\frac{10 \text{ gumballs}}{21.4 \text{ g}} \qquad \frac{21.4 \text{ g}}{10 \text{ gumballs}}$$

The shopkeeper can use one of these conversion factors to determine the mass of 50 gumballs because mass increases in a predictable way as more gumballs are added to the scale, as you can see from *Figure 35.*

▶ **conversion factor** a ratio that is derived from the equality of two different units and that can be used to convert from one unit to another
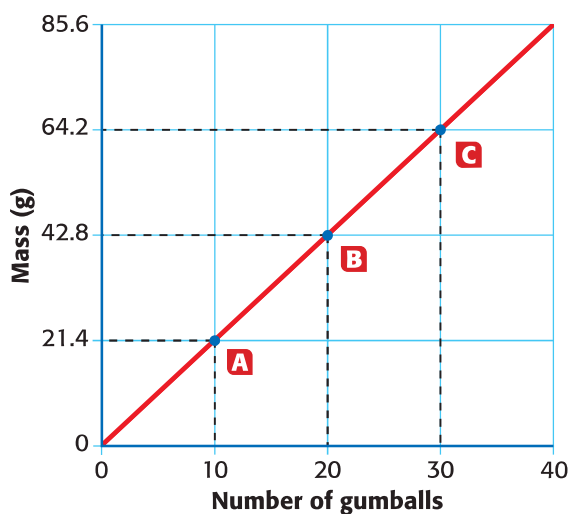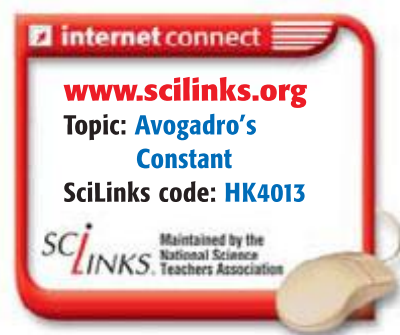
Figure 35
There is a direct relationship between the number of gumballs and their mass. Ten gumballs have a mass of 21.4 g, 20 gumballs have a mass of 42.8 g, and 30 gumballs have a mass of 64.2 g.

A

B

C

Math Skills

Conversion Factors What is the mass of exactly 50 gumballs?

1 **List the given and unknown values.**

Given: mass of 10 gumballs = 21.4 g

Unknown: mass of 50 gumballs = ? g

2 **Write down the conversion factor that converts number of gumballs to mass.**

The conversion factor you choose should have the unit you are solving for (g) in the numerator and the unit you want to cancel (number of gumballs) in the denominator.

$$\frac{21.4 \text{ g}}{10 \text{ gumballs}}$$

3 **Multiply the number of gumballs by this conversion factor, and solve.**

$$50 \text{ gumballs} \times \frac{21.4 \text{ g}}{10 \text{ gumballs}} = 107 \text{ g}$$

Practice

Conversion Factors

1. What is the mass of exactly 150 gumballs?

2. If you want 50 eggs, how many dozens must you buy? How many extra eggs do you have to take?

3. If a football player is tackled 1.7 ft short of the end zone, how many more yards does the team need to get a touchdown?
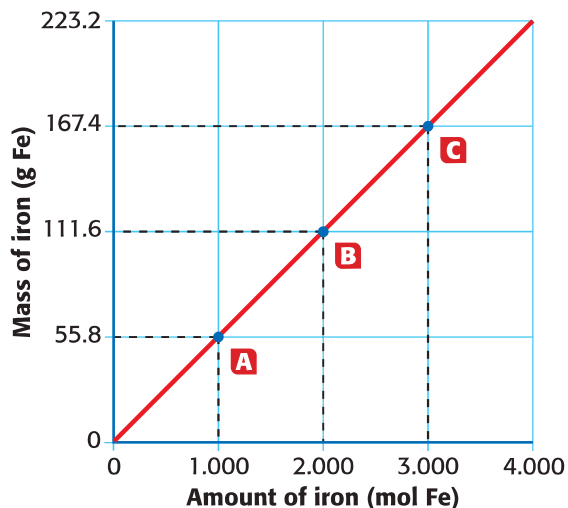
Relating amount to mass

Just as in the gumball example, there is also a relationship between the amount of an element in moles and its mass in grams. This relationship is graphed for iron nails in **Figure 36.** Because the amount of iron and the mass of iron are directly related, the graph is a straight line.

An element's molar mass can be used as if it were a conversion factor. Depending on which conversion factor you use, you can solve for either the amount of the element or its mass.

Figure 36

There is a direct relationship between the amount of an element and its mass.

$$\times \frac{\text{molar mass of element}}{1 \text{ mol of element}} =$$

Amount (mol) → **Mass (g)**

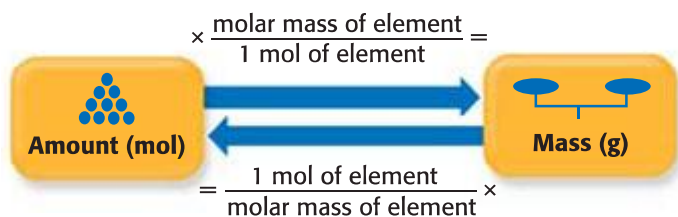$$= \frac{1 \text{ mol of element}}{\text{molar mass of element}} \times$$

Figure 37

The molar mass of an element allows you to convert between the amount of the element and its mass.

Converting moles to grams

Converting between the amount of an element in moles and its mass in grams is outlined in *Figure 37.* For example, you can determine the mass of 5.50 mol of iron by using *Figure 37* as a guide. First you must find iron in the periodic table. Its average atomic mass is 55.85 amu. This means iron's molar mass is 55.85 g/mol Fe. Now you can set up the problem using the molar mass as if it were a conversion factor, as shown in the sample problem below.

Math Skills

Converting Amount to Mass Determine the mass in grams of 5.50 mol of iron.

1 List the given and unknown values.

Given: amount of iron = 5.50 mol Fe

molar mass of iron = 55.85 g/mol Fe

Unknown: mass of iron = ? g Fe

2 Write down the conversion factor that converts moles to grams.

The conversion factor you choose should have what you are trying to find (grams of Fe) in the numerator and what you want to cancel (moles of Fe) in the denominator.

$$\frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}}$$

3 Multiply the amount of iron by this conversion factor, and solve.

$$5.50 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 307 \text{ g Fe}$$

Practice **HINT**

Notice how iron's molar mass, 55.85 g/mol Fe, includes units (g/mol) and a chemical symbol (Fe). The units specify that this mass applies to 1 mol of substance. The symbol for iron, Fe, clearly indicates the substance. Remember to always include units in your answers and make clear the substance to which these units apply. Otherwise, your answer has no meaning.

Practice

Converting Amount to Mass

What is the mass in grams of each of the following?

1. 2.50 mol of sulfur, S

2. 1.80 mol of calcium, Ca

3. 0.50 mol of carbon, C

4. 3.20 mol of copper, Cu

Converting Mass to Amount Determine the amount of iron present in 352 g of iron.

1 **List the given and unknown values.**

Given: mass of iron = 352 g Fe

molar mass of iron = 55.85 g/mol Fe

Unknown: amount of iron = ? mol Fe

2 **Write down the conversion factor that converts grams to moles.**

The conversion factor you choose should have what you are trying to find (moles of Fe) in the numerator and what you want to cancel (grams of Fe) in the denominator.

$$\frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}}$$

3 **Multiply the mass of iron by this conversion factor, and solve.**

$$352 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} = 6.30 \text{ mol Fe}$$

Practice HINT

Once you have learned how to convert mass to amount, you should use this sample problem to check your answers to the practice on the previous page.

SECTION 4 REVIEW

SUMMARY

▶ One mole of a substance has as many particles as there are atoms in exactly 12.00 g of carbon-12.

▶ Avogadro's constant, 6.022×10^{23}/mol, is equal to the number of particles in 1 mol.

▶ Molar mass is the mass in grams of 1 mol of a substance.

▶ An element's molar mass in grams is equal to its average atomic mass in amu.

▶ An element's molar mass can be used to convert from amount to mass, and vice versa.

1. **Define** Avogadro's constant. Describe how Avogadro's constant relates to a mole of a substance.

2. **Determine** the molar mass of the following elements:
   a. manganese, Mn   **c.** arsenic, As
   b. cadmium, Cd   **d.** strontium, Sr

3. **List** the two equivalent conversion factors for the molar mass of silver, Ag.

4. **Explain** why a graph showing the relationship between the amount of a particular element and the element's mass is a straight line.

5. **Critical Thinking** Which has more atoms: 3.0 g of iron, Fe, or 2.0 g of sulfur, S?

Math Skills

6. What is the mass in grams of 0.48 mol of platinum, Pt?

7. How many moles are present in 620 g of mercury, Hg?

8. How many moles are present in 11 g of silicon, Si?

9. How many moles are present in 205 g of helium, He?