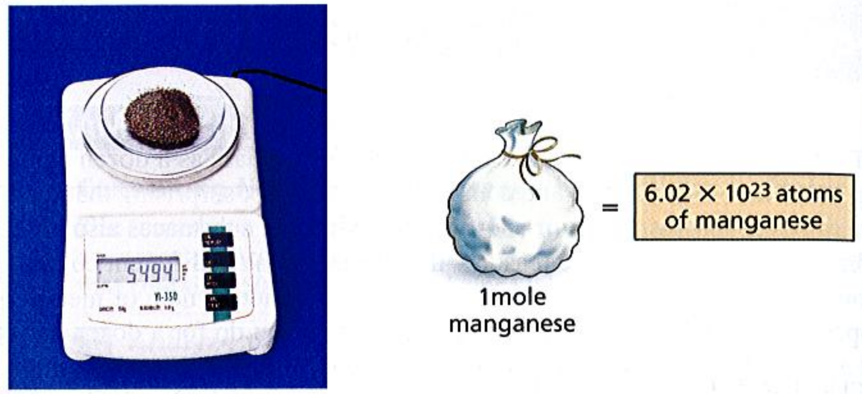
Figure 11-4

One mole of manganese, represented by a bag of particles, contains Avogadro's number of atoms and has a mass equal to its atomic mass in grams. The same is true for all the elements.



One Step Problems (Part II)

Using Molar Mass

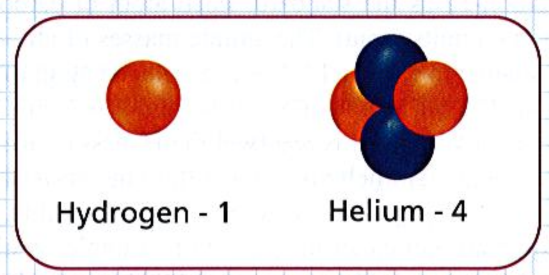
Imagine that your class bought jellybeans in bulk to sell by the dozen at a candy sale. You soon realize that it's too much work counting out each dozen, so instead you decide to measure the jellybeans by mass. You find that 1 dozen jellybeans has a mass of 35 g. What mass of jellybeans should you measure if a customer wants 5 dozen? The conversion factor that relates mass and dozens of jellybeans is

$$\frac{35 \text{ g jellybeans}}{1 \text{ dozen}}$$

problem-solving LAB

Molar Mass, Avogadro's Number and the Atomic Nucleus

Formulating models A nuclear model of mass can provide a simple picture of the connections between the mole, molar mass, and the number of representative particles in a mole.



Analysis

The diagram shows models of the nuclei of hydrogen-1 and helium-4. The hydrogen-1 nucleus contains one proton with a mass of 1.007 amu. The mass of the proton in grams has been found experimentally to be 1.672×10^{-24} g. Helium-4 contains two protons and two neutrons and has a mass of approximately 4 amu.

1. What is the mass in grams of one helium atom? (The mass of a neutron is approximately the same as the mass of a proton.)
2. Carbon-12 contains six protons and six neutrons. Draw a model of the nucleus of carbon-12 and calculate the mass of one atom in amu and in grams.

Thinking Critically

1. How many atoms of hydrogen-1 are in a 1.007-g sample? Recall that 1.007 amu is the mass of one atom of hydrogen-1. Round your answer to two significant digits.
2. If you had samples of helium and carbon that contained the same number of atoms as you calculated in question 1, what would be the mass in grams of each sample?
3. What can you conclude about the relationship between the number of atoms and the mass of each sample?

You would multiply the number of dozens to be sold by this conversion factor.

Note how the units cancel to give you the mass of 5 dozen jellybeans.

Now, suppose that while working in chemistry lab, you need 3.00 moles of manganese (Mn) for a chemical reaction. How can you measure that amount? Like the 5 dozen jellybeans, the number of moles of manganese can be converted to an equivalent mass and measured on a balance. To calculate mass from the number of moles, you need to multiply the number of moles of manganese required in the reaction (3.00 moles of Mn) by a conversion factor that relates mass and moles of manganese. That conversion factor is the molar mass of manganese (54.9 g/mol).

If you measure 165 g of manganese on a balance, you will have the 3.00 moles of manganese you need for the reaction. The reverse conversion—from mass to moles—also involves the molar mass as a conversion factor, but it is the inverse of the molar mass that is used. Can you explain why?

EXAMPLE PROBLEM 11-2

Mole to Mass Conversion

Chromium (Cr) is a transition element used as a coating on metals and in steel alloys to control corrosion. Calculate the mass in grams of 0.0450 moles of chromium.

1. Analyze the Problem

You are given the number of moles of chromium and must convert it to an equivalent mass using the molar mass of chromium from the periodic table. Because the sample is less than one-tenth mole, the answer should be less than one-tenth the molar mass.

Known	Unknown
number of moles = 0.0450 mol Cr	mass = ? g Cr
molar mass Cr = 52.00 g/mol Cr	

2. Solve for the Unknown

Multiply the known number of moles of chromium by the conversion factor that relates grams of chromium to moles of chromium, the molar mass.

3. Evaluate the Answer

The known number of moles of chromium has the smallest number of significant figures (3), so the answer is correctly stated with three digits. The answer is less than one-tenth the mass of one mole as predicted and has the correct unit.

Chromium resists corrosion, which means it doesn't react readily with oxygen in the air. It was used in this 1948 Cadillac to protect the steel and add glitter.

PRACTICE PROBLEMS

11. Determine the mass in grams of each of the following.

a. 3.57 mol Al
b. 42.6 mol Si
c. 3.45 mol Co
d. 2.45 mol Zn

EXAMPLE PROBLEM 11-3

Mass to Mole Conversion

Calcium, the fifth most abundant element on Earth, is always found combined with other elements because of its high reactivity. How many moles of calcium chloride are in 525 g calcium chloride (CaCl)?

Math Handbook

Review the meaning of inverse in the **Math Handbook** on page 905 of this text.

1. Analyze the Problem

You are given the mass of calcium and must convert the mass to moles of calcium. The mass of calcium is more than ten times larger than the molar mass. Therefore, the answer should be greater than ten moles.

Known	Unknown
mass = 525 g Ca	number of moles = ? mol Ca
molar mass Ca =	

2. Solve for the Unknown

Multiply the known amount of calcium by the conversion factor that relates moles of calcium to grams of calcium, the inverse of molar mass.

PRACTICE PROBLEMS

12. Determine the number of moles in each of the following.

a. 25.5 g Ag
b. 300.0 g S
c. 125 g Zn
d. 1.00 kg Fe

Practice! For more practice with mass and mole conversions, go to **Supplemental Practice Problems** in Appendix A.

Conversions from mass to atoms and atoms to mass So far, you have learned how to convert mass to the number of moles and the number of moles to mass. You can go one step further and convert mass to the number of atoms. Recall the jellybeans you were selling at the candy sale. At the end of the day, you find that 550 g of jellybeans are left unsold. Without counting, can you determine how many jellybeans this is? You know that one dozen jellybeans has a mass of 35 g and that 1 dozen contains 12 jellybeans. Thus, you can first convert the 550 g to dozens of jellybeans by using the conversion factor that relates dozens and mass.

Next, you can determine how many jellybeans are in 16 dozen by multiplying by the conversion factor that relates number of particles (jellybeans) and dozens.

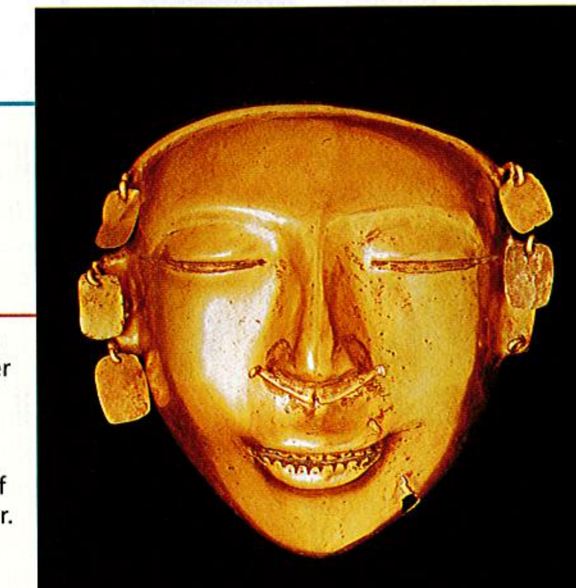
The 550 g of leftover jellybeans is equal to 192 jellybeans.

Just as you cannot make a direct conversion from the mass of jellybeans to the number of jellybeans, you cannot make a direct conversion from the mass of a substance to the number of representative particles in that substance. You must first convert the mass to moles by multiplying by a conversion factor that relates moles and mass. Can you identify the conversion factor? The number of moles must then be multiplied by a conversion factor that relates the number of representative particles to moles. That conversion factor is Avogadro's number.

EXAMPLE PROBLEM 11-4

Mass to Atoms Conversion

Gold is one of a group of metals called the coinage metals (copper, silver, and gold). How many atoms of gold (Au) are in a pure gold nugget having a mass of 25.0 g.



Gold is called a noble metal because it doesn't react readily with other elements. Early civilizations used nearly pure gold for coins and ornaments such as this gold mask from Quimbaya, Columbia, A.D. 1000-1500.

1. Analyze the Problem

You are given a mass of gold and must determine how many atoms it contains. Because you cannot go directly from mass to the number of atoms, you must first convert mass to moles using molar mass. Then, you can convert moles to the number of atoms using Avogadro's number. The given mass of the gold nugget is about one-eighth the molar mass of gold (196.97 g/mol), so the number of gold atoms should be approximately one-eighth Avogadro's number.

Known	Unknown
mass = 25.0 g Au	number of atoms = ? atoms Au
molar mass Au = 196.97 g/mol Au	

2. Solve for the Unknown

3. Evaluate the Answer

The mass of gold has the smallest number of significant figures (3), so the answer is expressed correctly with three digits. The answer is approximately one-eighth Avogadro's number as predicted, and the unit is correct.

PRACTICE PROBLEMS

13. How many atoms are in each of the following samples?

a. 55.2 g Li
b. 0.230 g Pb
c. 11.5 g Hg
d. 45.6 g Si
e. 0.120 kg Ti

EXAMPLE PROBLEM 11-5

Atoms to Mass Conversion

Helium is an unreactive noble gas often found in underground deposits mixed with methane. The mixture is separated by cooling the gaseous mixture until all but the helium has liquified.

A party balloon contains 5.50×10^{22} atoms of helium (He) gas. What is the mass in grams of the helium?

1. Analyze the Problem

You are given the number of atoms of helium and must find the mass of the gas.

Known	Unknown
number of atoms = 5.50×10^{22} atoms He	mass = ? g He
molar mass He = 4.00 g/mol He	

2. Solve for the Unknown

Multiply the number of atoms of helium by the inverse of Avogadro's number as a conversion factor.

$$\cancel{\text{atoms He}} \times \frac{1 \text{ mol He}}{6.02 \times 10^{23} \cancel{\text{ atoms He}}} = \text{moles He}$$

$$5.50 \times 10^{22} \cancel{\text{ atoms He}} \times \frac{1 \text{ mol He}}{6.02 \times 10^{23} \cancel{\text{ atoms He}}} = 0.0914 \text{ mol He}$$

Multiply the calculated number of moles of helium by the conversion factor that relates mass of helium to moles of helium, molar mass.

$$\text{moles He} \times \frac{\text{number of grams He}}{1 \text{ mole He}} = \text{mass He}$$

$$0.0914 \cancel{\text{ mol He}} \times \frac{4.00 \text{ g He}}{1 \cancel{\text{ mol He}}} = 0.366 \text{ g He}$$

3. Evaluate the Answer

The answer is expressed correctly with three significant figures and has the expected unit.

PRACTICE PROBLEMS

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

a. 6.02×10^{24} atoms Bi
b. 1.00×10^{24} atoms Mn
c. 3.40×10^{22} atoms He
d. 1.50×10^{15} atoms N
e. 1.50×10^{15} atoms U

Helium gas, used in party balloons, is heavier than hydrogen gas but safer because it is unreactive and will not burn as hydrogen does.

Practice!

For more practice with mass and number of atoms conversions, go to **Supplemental Practice Problems** in Appendix A.

Now that you have learned about and practiced conversions between mass, moles, and representative particles, you can see that the mole is at the center of these calculations. Mass must always be converted to moles before being converted to atoms, and atoms must similarly be converted to moles before calculating their mass. **Figure 11-5** shows the steps to follow as you work with these conversions.

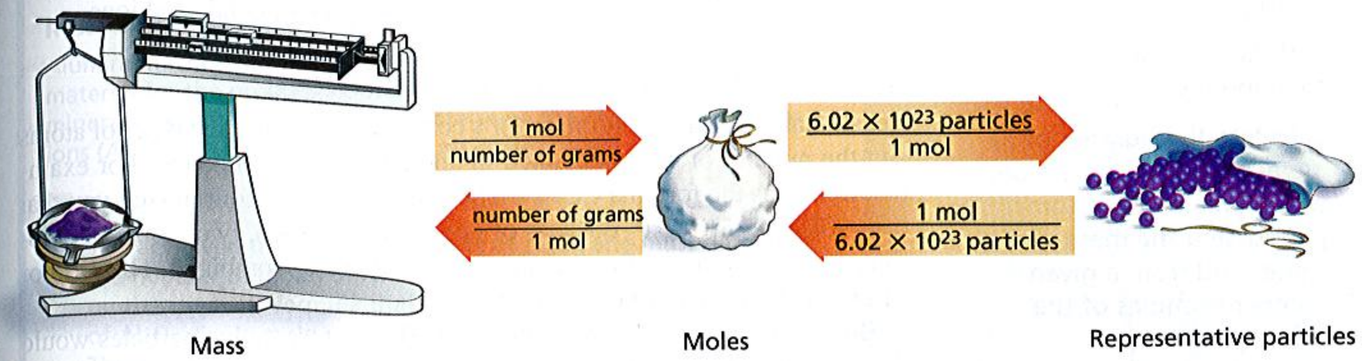


Figure 11-5

The mole is at the center of conversions between mass and particles. Two steps are needed to go from mass to representative particles or the reverse.

In **Figure 11-5**, mass is represented by a laboratory balance, moles are represented by a bag or bundle of particles, and representative particles are represented by the contents that are spilling out of the bag. You can see that two steps are needed to convert from mass on the left to representative particles on the right or to convert from representative particles on the right to mass on the left. The conversion factors for these conversions are given on the arrows pointing left and right. In the Example Problems, you have been making each of these conversions in separate steps, but you could make the same conversions in one calculation. For example, suppose you want to find out how many molecules of water are in 1.00 g of water. This calculation involves the conversion factors on the arrows pointing to the right. You could set up your calculation like this.

$$1.00 \cancel{\text{ g } H_2O} \times \frac{1 \cancel{\text{ mol } H_2O}}{18.02 \cancel{\text{ g } H_2O}} \times \frac{6.02 \times 10^{23} \text{ molecules } H_2O}{1 \cancel{\text{ mol } H_2O}}$$

$$= 3.34 \times 10^{22} \text{ molecules } H_2O$$

Note that the units cancel to give the answer in molecules of water. Do the reverse calculation yourself using the conversion factors on the arrows pointing from right to left. What is the mass of 3.34×10^{22} molecules of water? What answer should you expect? What unit?

The Molar Mass of Compounds

The mass of your backpack is the sum of the mass of the pack plus the masses of the books, notebooks, pencils, lunch, and miscellaneous items you put into it. You could find its mass by determining the mass of each item separately and adding them together. Similarly, the mass of a mole of a compound equals the sum of the masses of every particle that makes up the compound. You know how to use the molar mass of an element as a conversion factor in calculations. You also know that a chemical formula indicates the number of moles of each element in a compound. With this information, you can now determine the molar mass of a compound.

Suppose you want to determine the molar mass of potassium chromate (K_2CrO_4). Using the periodic table, the mass of one mole of each element present in potassium chromate can be determined. That mass is then multiplied by the number of moles of that element in the chemical formula. Adding the masses of all elements present will yield the molar mass of K_2CrO_4.

$$\text{number of moles} \times \text{molar mass} = \text{number of grams}$$

$$2.000\ \cancel{\text{mol K}} \times \frac{39.10\text{ g K}}{1\ \cancel{\text{mol K}}} = 78.20\text{ g}$$

$$1.000\ \cancel{\text{mol Cr}} \times \frac{52.00\text{ g Cr}}{1\ \cancel{\text{mol Cr}}} = 52.00\text{ g}$$

$$4.000\ \cancel{\text{mol O}} \times \frac{16.00\text{ g O}}{1\ \cancel{\text{mol O}}} = \underline{64.00\text{ g}}$$

$$\text{molar mass } K_2CrO_4 = 194.20\text{ g}$$

PRACTICE PROBLEMS

25. Determine the molar mass of each of the following ionic compounds: $NaOH$, $CaCl_2$, $KC_2H_3O_2$, $Sr(NO_3)_2$, and $(NH_4)_3PO_4$.

26. Calculate the molar mass of each of the following molecular compounds: C_2H_5OH, $C_{12}H_{22}O_{11}$, HCN, CCl_4, and H_2O.

Practice!

For more practice calculating the molar mass of a compound, go to **Supplemental Practice Problems** in Appendix A.

The molar mass of a compound demonstrates the law of conservation of mass. The sum of the masses of the elements that reacted to form the compound equals the mass of the compound. **Figure 11-7** shows 194 g, or one mole, of K_2CrO_4 and masses equal to one mole of two other substances.

Figure 11-7

Each substance contains different numbers and kinds of atoms so their molar masses are different. The molar mass of each compound is the sum of the masses of all the elements contained in the compound.

Converting Moles of a Compound to Mass

Suppose you need to measure a certain number of moles of a compound for an experiment. First, you must calculate the mass in grams that corresponds to the necessary number of moles. Then, that mass can be measured on a balance. In Example Problem 11-2, you learned how to convert the number of moles of elements to mass using molar mass as the conversion factor. The procedure is the same for compounds except that you must first calculate the molar mass of the compound.

EXAMPLE PROBLEM 11-7

Mole-to-Mass Conversion for Compounds

The characteristic odor of garlic is due to the compound allyl sulfide ($(C_3H_5)_2S$). What is the mass of 2.50 moles of allyl sulfide?

1. Analyze the Problem

You are given 2.50 mol $(C_3H_5)_2S$ and must convert the moles to mass using the molar mass as a conversion factor. The molar mass is the sum of the molar masses of all the elements in $(C_3H_5)_2S$.

Known

number of moles = 2.50 mol $(C_3H_5)_2S$

Unknown

molar mass $(C_3H_5)_2S$ = ? g/mol $(C_3H_5)_2S$

mass = ? g $(C_3H_5)_2S$

2. Solve for the Unknown

Calculate the molar mass of $(C_3H_5)_2S$.

$$1\ \cancel{\text{mol S}} \times \frac{32.07\text{ g S}}{1\ \cancel{\text{mol S}}} = 32.07\text{ g S}$$

$$6\ \cancel{\text{mol C}} \times \frac{12.01\text{ g C}}{1\ \cancel{\text{mol C}}} = 72.06\text{ g C}$$

$$10\ \cancel{\text{mol H}} \times \frac{1.008\text{ g H}}{1\ \cancel{\text{mol H}}} = \underline{10.08\text{ g H}}$$

$$\text{molar mass } (C_3H_5)_2S = 114.21\text{ g/mol } (C_3H_5)_2S$$

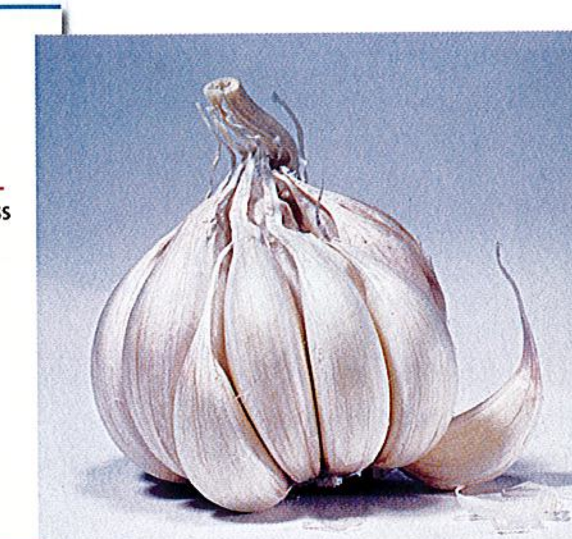
Convert mol $(C_3H_5)_2S$ to g $(C_3H_5)_2S$ by using the molar mass as a conversion factor.

$$\text{moles } (C_3H_5)_2S \times \frac{\text{number of grams } (C_3H_5)_2S}{1\text{ mole } (C_3H_5)_2S} = \text{mass } (C_3H_5)_2S$$

$$2.50\ \cancel{\text{mol } (C_3H_5)_2S} \times \frac{114.21\text{ g } (C_3H_5)_2S}{1\ \cancel{\text{mol } (C_3H_5)_2S}} = 286\text{ g } (C_3H_5)_2S$$

3. Evaluate the Answer

Mol $(C_3H_5)_2S$ has the smaller number of significant figures (3), so the answer is expressed correctly with three digits. The unit, g, is correct.



The pungent odor of garlic is characteristic of sulfides. Sulfides, including hydrogen sulfide, are noted for their strong, often unpleasant odors. The sulfur atom in allyl sulfide forms a chemical bond to each of the two C_3H_5 groups in the molecule.

PRACTICE PROBLEMS

27. What is the mass of 3.25 moles of sulfuric acid (H_2SO_4)?

28. What is the mass of 4.35 × 10^{-2} moles of zinc chloride ($ZnCl_2$)?

29. How many grams of potassium permanganate are in 2.55 moles?

Practice!

For more practice converting moles of a compound to mass, go to **Supplemental Practice Problems** in Appendix A.

Converting the Mass of a Compound to Moles

Imagine that the experiment you are doing in the laboratory produces 5.55 g of a compound. How many moles is this? To find out, you calculate the molar mass of the compound and determine it to be 185.0 g/mol. The molar mass relates grams and moles, but this time you need the inverse of the molar mass as the conversion factor.

$$5.50\ \cancel{\text{g compound}} \times \frac{1\ \text{mol compound}}{185.0\ \cancel{\text{g compound}}} = 0.0297\ \text{mol compound}$$

This compound, commonly called lime, is calcium oxide (CaO). Calcium oxide reacts with water to produce calcium hydroxide. Lime is a component of cement and is used to counteract excess acidity in soil.

EXAMPLE PROBLEM 11-8

Mass-to-Mole Conversion for Compounds

Calcium hydroxide ($Ca(OH)_2$) is used to remove sulfur dioxide from the exhaust gases emitted by power plants and for softening water by the elimination of Ca^{2+} and Mg^{2+} ions. Calculate the number of moles of calcium hydroxide in 325 g.

1. Analyze the Problem

You are given 325 g $Ca(OH)_2$ and are solving for the number of moles of $Ca(OH)_2$. You must first calculate the molar mass of $Ca(OH)_2$.

Known	Unknown
mass = 325 g $Ca(OH)_2$	molar mass = ? g/mol $Ca(OH)_2$
	number of moles = ? mol $Ca(OH)_2$

2. Solve for the Unknown

Determine the molar mass of $Ca(OH)_2$.

$$1\ \text{mol Ca} \times \frac{40.08\ \text{g Ca}}{1\ \text{mol Ca}} = 40.08\ \text{g}$$

$$2\ \text{mol O} \times \frac{16.00\ \text{g O}}{1\ \text{mol O}} = 32.00\ \text{g}$$

$$2\ \text{mol H} \times \frac{1.008\ \text{g H}}{1\text{mol H}} = \underline{2.016\ \text{g}}$$

molar mass of $Ca(OH)_2$ = 74.096 g/mol = 74.10 g/mol

Use the inverse of molar mass as the conversion factor to calculate moles.

$$325\ \cancel{\text{g Ca(OH)}_2} \times \frac{1\ \text{mol Ca(OH)}_2}{74.10\ \cancel{\text{g Ca(OH)}_2}} = 4.39\ \text{mol Ca(OH)}_2$$

3. Evaluate the Answer

The given mass of $Ca(OH)_2$ has fewer digits than any other value in the calculations so it determines the number of significant figures in the answer (3). To check the reasonableness of the answer, round off the molar mass of $Ca(OH)_2$ to 75 g/mol and the given mass of $Ca(OH)_2$ to 300 g. Seventy- five is contained in 300 four times. Thus, the answer is reasonable.

PRACTICE PROBLEMS

30. Determine the number of moles present in each of the following.

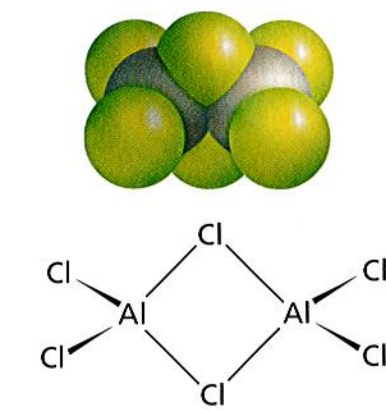
a. 22.6 g $AgNO_3$
b. 6.50 g $ZnSO_4$
c. 35.0 g HCl
d. 25.0 g Fe_2O_3
e. 254 g $PbCl_4$

Practice!

For more practice converting the mass of a compound to moles, go to **Supplemental Practice Problems** in Appendix A.

Converting the Mass of a Compound to Number of Particles

Example Problem 11-8 illustrated how to find the number of moles of a compound contained in a given mass. Now, you will learn how to calculate the number of representative particles—molecules or formula units—contained in a given mass and, in addition, the number of atoms or ions. Recall that no direct conversion is possible between mass and number of particles. You must first convert the given mass to moles by multiplying by the inverse of the molar mass. Then, you can convert moles to the number of representative particles by multiplying by Avogadro's number. To determine numbers of atoms or ions in a compound, you will need conversion factors that are ratios of the number of atoms or ions in the compound to one mole of compound. These are based on the chemical formula. Example Problem 11-9 provides practice in solving this type of problem.



At ordinary temperatures, aluminum chloride is a solid with the formula $AlCl_3$. In the vapor phase, however, aluminum chloride exists as a doubled molecule, or dimer, with the formula Al_2Cl_6.

EXAMPLE PROBLEM 11-9

Conversion from Mass to Moles to Particles

Aluminum chloride is used in refining petroleum and manufacturing rubber and lubricants. A sample of aluminum chloride ($AlCl_3$) has a mass of 35.6 g.

a. How many aluminum ions are present?
b. How many chloride ions are present?
c. What is the mass in grams of one formula unit of aluminum chloride?

1. Analyze the Problem

You are given 35.6 g $AlCl_3$ and must calculate the number of Al^{3+} ions, the number of Cl^- ions, and the mass in grams of one formula unit of $AlCl_3$. Molar mass, Avogadro's number, and ratios from the chemical formula are the necessary conversion factors. The ratio of Al^{3+} ions to Cl^- ions in the chemical formula is 1:3. Therefore, the calculated numbers of ions should be in that ratio. The mass of one formula unit in grams should be an extremely small number.

Known	Unknown
mass = 35.6 g $AlCl_3$	number of ions = ? Al^{3+} ions
	number of ions = ? Cl^- ions
	mass = ? g/formula unit $AlCl_3$

2. Solve for the Unknown

Determine the molar mass of $AlCl_3$.

$$1\ \cancel{\text{mol Al}} \times \frac{26.98\ \text{g Al}}{1\ \cancel{\text{mol Al}}} = 26.98\ \text{g Al}$$

$$3\ \cancel{\text{mol Cl}} \times \frac{35.45\ \text{g Cl}}{1\ \cancel{\text{mol Cl}}} = \underline{106.35\ \text{g Cl}}$$

Molar mass of $AlCl_3$ = 133.33 g/mol $AlCl_3$

Multiply by the inverse of the molar mass as a conversion factor to convert the mass of $AlCl_3$ to moles.

$$\cancel{\text{grams AlCl}_3} \times \frac{1\ \text{mol AlCl}_3}{\cancel{\text{grams AlCl}_3}} = \text{moles AlCl}_3$$

$$35.6\ \cancel{\text{g AlCl}_3} \times \frac{1\ \text{mol AlCl}_3}{133.33\ \cancel{\text{g AlCl}_3}} = 0.267\ \text{mol AlCl}_3$$

Continued on next page

Multiply by Avogadro's number to calculate the number of formula units of $AlCl_3$.

$$0.267\ \cancel{\text{mol AlCl}_3} \times \frac{6.02 \times 10^{23}\ \text{formula units}}{1\ \cancel{\text{mol AlCl}_3}} = 1.61 \times 10^{23}\ \text{formula units AlCl}_3$$

To calculate the number of Al^{3+} and Cl^{-} ions, use the ratios from the chemical formula as conversion factors.

$$1.61 \times 10^{23}\ \cancel{\text{AlCl}_3\ \text{formula unit}} \times \frac{1\ \text{Al}^{3+}\ \text{ion}}{1\ \cancel{\text{AlCl}_3\ \text{formula unit}}} = 1.61 \times 10^{23}\ \text{Al}^{3+}\ \text{ions}$$

$$1.61 \times 10^{23}\ \cancel{\text{AlCl}_3\ \text{formula unit}} \times \frac{3\ \text{Cl}^{-}\ \text{ions}}{1\ \cancel{\text{AlCl}_3\ \text{formula unit}}} = 4.83 \times 10^{23}\ \text{Cl}^{-}\ \text{ions}$$

Calculate the mass in grams of one formula unit of $AlCl_3$. Start with molar mass and use the inverse of Avogadro's number as a conversion factor.

$$\frac{133.33\ \text{g AlCl}_3}{1\ \cancel{\text{mol}}} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\ \text{formula unit}} = 2.21 \times 10^{-22}\ \text{g AlCl}_3/\text{formula unit}$$

3. Evaluate the Answer

A minimum of three significant figures is used in each value in the calculations. Therefore, the answers have the correct number of digits. The number of Cl^{-} ions is three times the number of Al^{3+} ions, as predicted. The mass of a formula unit of $AlCl_3$ can be checked by calculating it in a different way: Divide the mass of $AlCl_3$ (35.6 g) by the number of formula units contained in the mass (1.61×10^{23} formula units) to obtain the mass of one formula unit. The two answers are the same.

PRACTICE PROBLEMS

32. What mass of sodium chloride contains 4.59×10^{24} formula units?

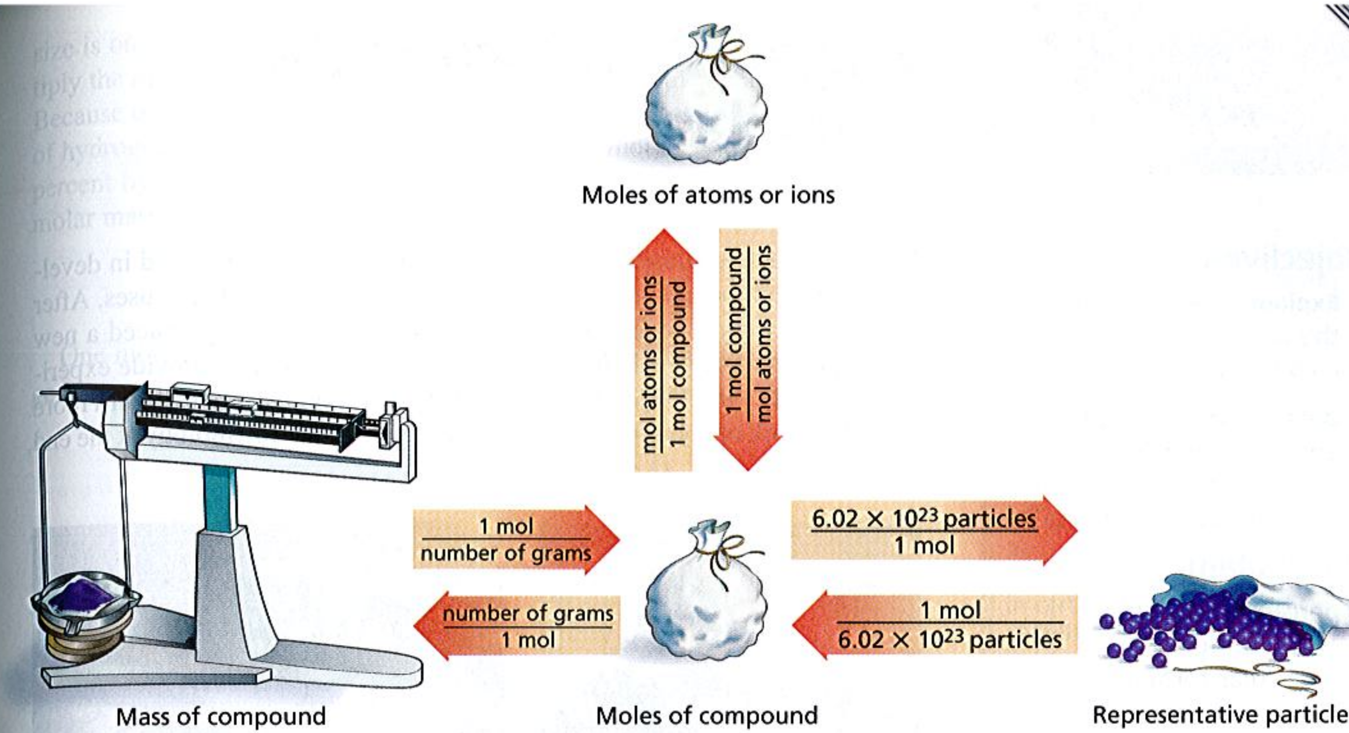
34. A sample of sodium sulfite (Na_2SO_3) has a mass of 2.25 g.

c. What is the mass in grams of one formula unit of Na_2SO_3?

35. A sample of carbon dioxide has a mass of 52.0 g.

c. What is the mass in grams of one molecule of CO_2?

Practice! For more practice calculating the number of ions or atoms in a mass of a compound and the mass in grams of one formula unit, go to **Supplemental Practice Problems** in Appendix A.



Conversions among mass, moles, and the number of particles are summarized in **Figure 11-8**. Refer to this diagram often until you become familiar with the calculations. Note that the molar mass (number of grams/1 mol) and the inverse of molar mass (1 mol/number of grams) are the conversion factors between the mass of a substance and the number of moles of the substance. Avogadro's number and its inverse are the conversion factors between the moles of a substance and the number of representative particles. To convert between the number of moles of a compound and the number of moles of atoms or ions contained in the compound, you need the ratio of moles of atoms or ions to 1 mole of compound or its inverse, which are shown on the upward and downward arrows in **Figure 11-8**. These ratios are derived from the subscripts in the chemical formula. What ratio would you use to find the moles of hydrogen atoms in four moles of water?

Figure 11-8

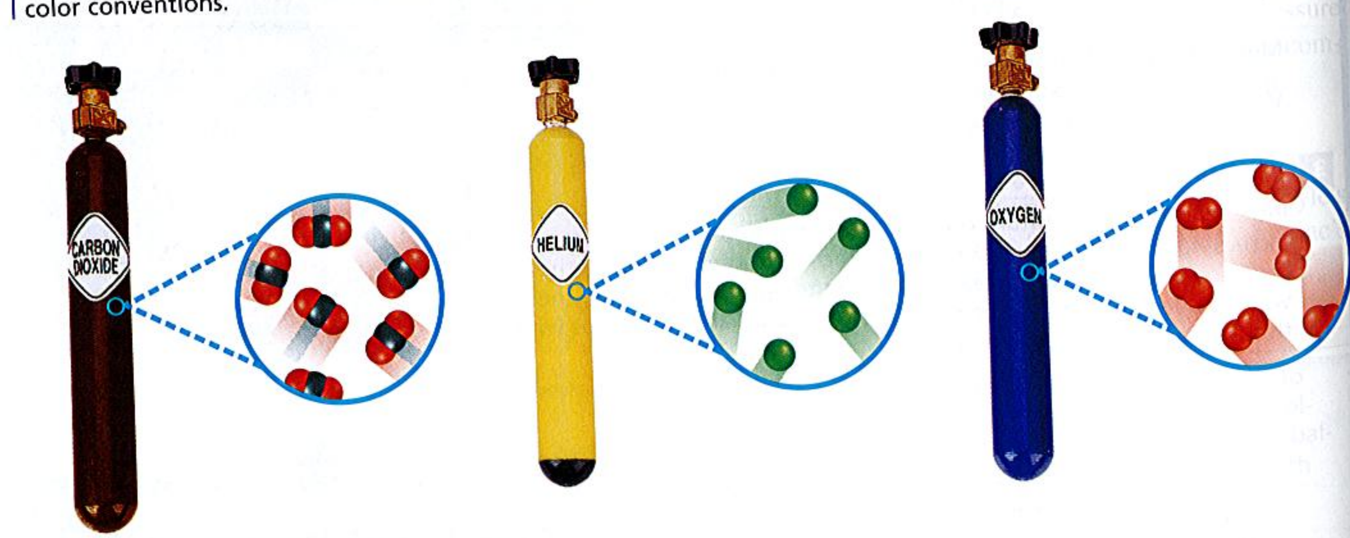
Note the central position of the mole. To go from the left, right, or top of the diagram to any other place, you must go through the mole. The conversion factors on the arrows provide the means for making the conversions.

Avogadro's Principle

The particles making up different gases can vary greatly in size. However, according to the kinetic-molecular theory, the particles in a gas sample are usually far enough apart that size has a negligible influence on the volume occupied by a fixed number of particles, as shown in **Figure 14-7**. For example, 1000 relatively large krypton gas particles occupy the same volume as 1000 much smaller helium gas particles at the same temperature and pressure. It was Avogadro who first proposed this idea in 1811. Today, it is known as **Avogadro's principle**, which states that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.

Figure 14-7

Compressed gas tanks of equal volume that are at the same pressure and temperature contain equal numbers of gas particles, regardless of which gas they contain. Refer to **Table C-1** in Appendix C for a key to atom color conventions.



Remember from Chapter 11 that the most convenient unit for counting numbers of atoms or molecules is the mole. One mole contains 6.02×10^{23} particles. The **molar volume** for a gas is the volume that one mole occupies at 0.00°C and 1.00 atm pressure. These conditions of temperature and pressure are known as standard temperature and pressure (STP). Avogadro showed experimentally that one mole of any gas will occupy a volume of 22.4 L at STP. The fact that this value is the same for all gases greatly simplifies many gas law calculations. Because the volume of one mole of a gas at STP is 22.4 L, you can use the following conversion factor to find the number of moles, the mass, and even the number of particles in a gas sample.

$$\text{Conversion factor: } \frac{22.4 \text{ L}}{1 \text{ mol}}$$

Volume to Moles Conversion

Carbon dioxide (CO) is a gas produced following the combustion of gasoline in a car engine. Calculate the moles of 35.9 liters of carbon dioxide.

Analyze the Problem

You are given the volume of the gas. According to Avogadro's principle, 1 mol of gas occupies 22.4 L at STP. The number of moles of gas should be divided by the conversion factor to find the number if moles.

Known	Unknown
Volume=35.9 L	number of moles= ? mol

Solve for the Unknown

Math Handbook

Review unit conversion in the **Math Handbook** on page 901 of this textbook.