

Skills Worksheet

Problem Solving**Mole Concept**

Suppose you want to carry out a reaction that requires combining one atom of iron with one atom of sulfur. How much iron should you use? How much sulfur? When you look around the lab, there is no device that can count numbers of atoms. Besides, the merest speck (0.001 g) of iron contains over a billion billion atoms. The same is true of sulfur.

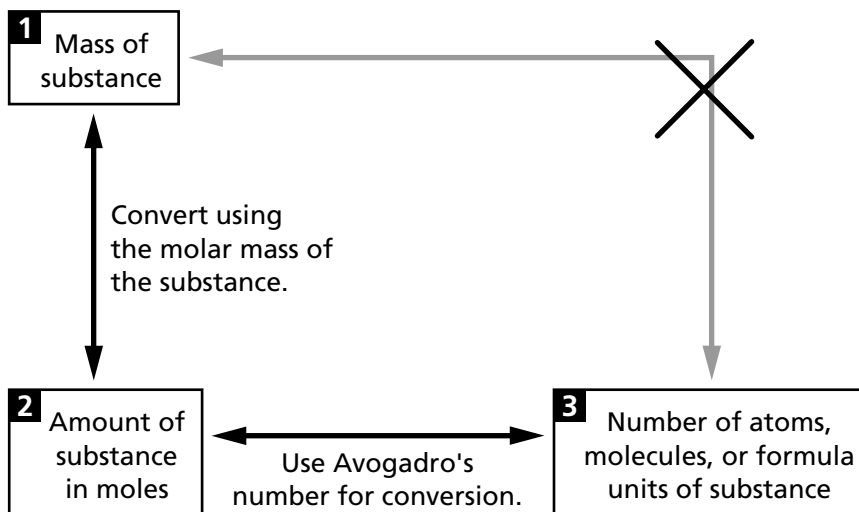
Fortunately, you do have a way to relate mass and numbers of atoms. One iron atom has a mass of 55.847 amu, and 55.847 g of iron contains $6.022\ 137 \times 10^{23}$ atoms of iron. Likewise, 32.066 g of sulfur contains $6.022\ 137 \times 10^{23}$ atoms of sulfur. Knowing this, you can measure out 55.847 g of iron and 32.066 g of sulfur and be pretty certain that you have the same number of atoms of each.

The number $6.022\ 137 \times 10^{23}$ is called Avogadro's number. For most purposes it is rounded off to 6.022×10^{23} . Because this is an awkward number to write over and over again, chemists refer to it as a *mole* (abbreviated mol). 6.022×10^{23} objects is called a mole, just as you call 12 objects a dozen.

Look again at how these quantities are related.

$$55.847 \text{ g of iron} = 6.022 \times 10^{23} \text{ iron atoms} = 1 \text{ mol of iron}$$

$$32.066 \text{ g of sulfur} = 6.022 \times 10^{23} \text{ sulfur atoms} = 1 \text{ mol of sulfur}$$

**General Plan for Converting Mass, Amount,
and Numbers of Particles**

Problem Solving *continued***PROBLEMS INVOLVING ATOMS AND ELEMENTS****Sample Problem 1**

A chemist has a jar containing 388.2 g of iron filings. How many moles of iron does the jar contain?

Solution**ANALYZE**

What is given in the problem? **mass of iron in grams**

What are you asked to find? **amount of iron in moles**

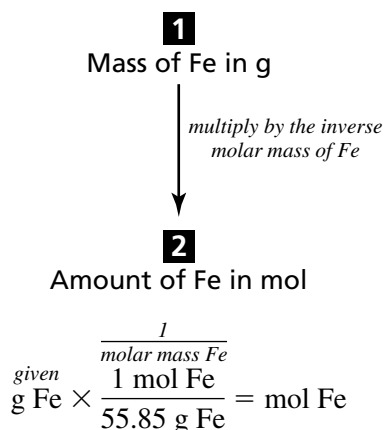
Items	Data
Mass of iron	388.2 g
Molar mass of iron*	55.85 g/mol
Amount of iron	? mol

*determined from the periodic table

PLAN

What step is needed to convert from grams of Fe to number of moles of Fe?

The molar mass of iron can be used to convert mass of iron to amount of iron in moles.

**COMPUTE**

$$388.2 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} = 6.951 \text{ mol Fe}$$

EVALUATE

Are the units correct?

Yes; the answer has the correct units of moles of Fe.

Problem Solving *continued*

Is the number of significant figures correct?

Yes; the number of significant figures is correct because there are four significant figures in the given value of 388.2 g Fe.

Is the answer reasonable?

Yes; 388.2 g Fe is about seven times the molar mass. Therefore, the sample contains about 7 mol.

Practice

1. Calculate the number of moles in each of the following masses:

a. 64.1 g of aluminum ans: 2.38 mol Al

b. 28.1 g of silicon ans: 1.00 mol Si

c. 0.255 g of sulfur ans: 7.95×10^{-3} mol S

d. 850.5 g of zinc ans: 13.01 mol Zn

Problem Solving *continued***Sample Problem 2**

A student needs 0.366 mol of zinc for a reaction. What mass of zinc in grams should the student obtain?

Solution**ANALYZE**

What is given in the problem? **amount of zinc needed in moles**

What are you asked to find? **mass of zinc in grams**

Items	Data
Amount of zinc	0.366 mol
Molar mass of zinc	65.39 g/mol
Mass of zinc	? g

PLAN

What step is needed to convert from moles of Zn to grams of Zn?

The molar mass of zinc can be used to convert amount of zinc to mass of zinc.

2 Amount of Zn in mol $\xrightarrow{\text{multiply by the molar mass of Zn}}$ Mass of Zn in mol **1**

$$\text{given mol Zn} \times \frac{\text{molar mass Zn } 65.39 \text{ g Zn}}{1 \text{ mol Zn}} = \text{g Zn}$$

COMPUTE

$$0.366 \cancel{\text{ mol Zn}} \times \frac{65.39 \text{ g Zn}}{1 \cancel{\text{ mol Zn}}} = 23.9 \text{ g Zn}$$

EVALUATE

Are the units correct?

Yes; the answer has the correct units of grams of Zn.

Is the number of significant figures correct?

Yes; the number of significant figures is correct because there are three significant figures in the given value of 0.366 mol Zn.

Is the answer reasonable?

Yes; 0.366 mol is about 1/3 mol. 23.9 g is about 1/3 the molar mass of Zn.

Problem Solving *continued*

Practice

1. Calculate the mass of each of the following amounts:

a. 1.22 mol sodium **ans: 28.0 g Na**

b. 14.5 mol copper **ans: 921 g Cu**

c. 0.275 mol mercury **ans: 55.2 g Hg**

d. 9.37×10^{-3} mol magnesium **ans: 0.228 Mg**

Problem Solving *continued***Sample Problem 3**How many moles of lithium are there in 1.204×10^{24} lithium atoms?**Solution****ANALYZE**What is given in the problem? **number of lithium atoms**What are you asked to find? **amount of lithium in moles**

Items	Data
Number of lithium atoms	1.204×10^{24} atoms
Avogadro's number—the number of atoms per mole	6.022×10^{23} atoms/mol
Amount of lithium	? mol

PLAN

What step is needed to convert from number of atoms of Li to moles of Li?

Avogadro's number is the number of atoms per mole of lithium and can be used to calculate the number of moles from the number of atoms.

3 Number of Li atoms $\xrightarrow[\text{multiply by the inverse of Avogadro's number}]{} \xrightarrow{\text{2}}$ Amount of Li in mol

$$\text{atoms Li} \times \frac{\overset{\text{given}}{1} \text{ mol Li}}{6.022 \times 10^{23} \text{ atoms Li}} = \text{mol Li}$$

COMPUTE

$$1.204 \times 10^{24} \text{ atoms Li} \times \frac{1 \text{ mol Li}}{6.022 \times 10^{23} \text{ atoms Li}} = 1.999 \text{ mol Li}$$

EVALUATE

Are the units correct?

Yes; the answer has the correct units of moles of Li.

Is the number of significant figures correct?

Yes; four significant figures is correct.

Is the answer reasonable?

Yes; 1.204×10^{24} is approximately twice Avogadro's number. Therefore, it is reasonable that this number of atoms would equal about 2 mol.

Problem Solving *continued*

Practice

1. Calculate the amount in moles in each of the following quantities:

a. 3.01×10^{23} atoms of rubidium **ans: 0.500 mol Rb**

b. 8.08×10^{22} atoms of krypton **ans: 0.134 mol Kr**

c. 5 700 000 000 atoms of lead **ans: 9.5×10^{-15} mol Pb**

d. 2.997×10^{25} atoms of vanadium **ans: 49.77 mol V**

Problem Solving *continued*

CONVERTING THE AMOUNT OF AN ELEMENT IN MOLES TO THE NUMBER OF ATOMS

In Sample Problem 3, you were asked to determine the number of moles in 1.204×10^{24} atoms of lithium. Had you been given the amount in moles and asked to calculate the number of atoms, you would have simply multiplied by Avogadro's number. Steps 2 and 3 of the plan for solving Sample Problem 3 would have been reversed.

Practice

1. Calculate the number of atoms in each of the following amounts:

a. 1.004 mol bismuth **ans: 6.046×10^{23} atoms Bi**

b. 2.5 mol manganese **ans: 1.5×10^{24} atoms Mg**

c. 0.000 000 2 mol helium **ans: 1×10^{17} atoms He**

d. 32.6 mol strontium **ans: 1.96×10^{25} atoms Sr**

Problem Solving *continued***Sample Problem 4**

How many boron atoms are there in 2.00 g of boron?

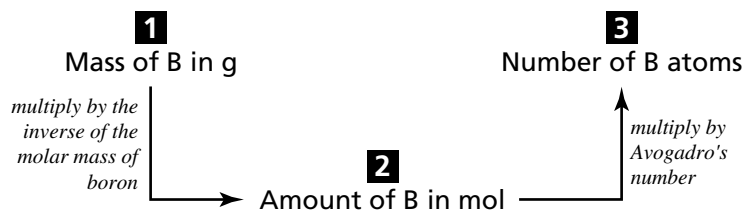
Solution**ANALYZE**What is given in the problem? **mass of boron in grams**What are you asked to find? **number of boron atoms**

Items	Data
Mass of boron	2.00 g
Molar mass of boron	10.81 g/mol
Avogadro's number—the number of boron atoms per mole of boron	6.022×10^{23} atoms/mol
Number of boron atoms	? atoms

PLAN

What steps are needed to convert from grams of B to number of atoms of B?

First, you must convert the mass of boron to moles of boron by using the molar mass of boron. Then you can use Avogadro's number to convert amount in moles to number of atoms of boron.



$$\text{given g B} \times \frac{1 \text{ mol B}}{10.81 \text{ g B}} \times \frac{6.022 \times 10^{23} \text{ atoms B}}{1 \text{ mol B}} = \text{atoms B}$$

COMPUTE

$$2.00 \text{ g B} \times \frac{1 \text{ mol B}}{10.81 \text{ g B}} \times \frac{6.022 \times 10^{23} \text{ atoms B}}{1 \text{ mol B}} = 1.11 \times 10^{23} \text{ atoms B}$$

EVALUATE

Are the units correct?

Yes; the answer has the correct units of atoms of boron.

Is the number of significant figures correct?

Yes; the mass of boron was given to three significant figures.

Problem Solving *continued*

Is the answer reasonable?

Yes; 2 g of boron is about 1/5 of the molar mass of boron. Therefore, 2.00 g boron will contain about 1/5 of an Avogadro's constant of atoms.

Practice

1. Calculate the number of atoms in each of the following masses:

a. 54.0 g of aluminum ans: 1.21×10^{24} atoms Al

b. 69.45 g of lanthanum ans: 3.011×10^{23} atoms La

c. 0.697 g of gallium ans: 6.02×10^{21} atoms Ga

d. 0.000 000 020 g beryllium ans: 1.3×10^{15} atoms Be

Problem Solving *continued*

CONVERTING NUMBER OF ATOMS OF AN ELEMENT TO MASS

Sample Problem 4 uses the progression of steps 1 → 2 → 3 to convert from the mass of an element to the number of atoms. In order to calculate the mass from a given number of atoms, these steps will be reversed. The number of moles in the sample will be calculated. Then this value will be converted to the mass in grams.

Practice

1. Calculate the mass of the following numbers of atoms:

a. 6.022×10^{24} atoms of tantalum **ans: 1810. g Ta**

b. 3.01×10^{21} atoms of cobalt **ans: 0.295 g Co**

c. 1.506×10^{24} atoms of argon **ans: 99.91 g Ar**

d. 1.20×10^{25} atoms of helium **ans: 79.7 g He**

Problem Solving *continued***PROBLEMS INVOLVING MOLECULES, FORMULA UNITS, AND IONS**

How many water molecules are there in 200.0 g of water? What is the mass of 15.7 mol of nitrogen gas? Both of these substances consist of molecules, not single atoms. Look back at the diagram of the General Plan for Converting Mass, Amount, and Numbers of Particles. You can see that the same conversion methods can be used with molecular compounds and elements, such as CO_2 , H_2O , H_2SO_4 , and O_2 .

For example, 1 mol of water contains 6.022×10^{23} H_2O molecules. The mass of a molecule of water is the sum of the masses of two hydrogen atoms and one oxygen atom, and is equal to 18.02 amu. Therefore, 1 mol of water has a mass of 18.02 g. In the same way, you can relate amount, mass, and number of formula units for ionic compounds, such as NaCl , CaBr_2 , and $\text{Al}_2(\text{SO}_4)_3$.

Sample Problem 5

How many moles of carbon dioxide are in 66.0 g of dry ice, which is solid CO_2 ?

Solution**ANALYZE**

What is given in the problem? **mass of carbon dioxide**

What are you asked to find? **amount of carbon dioxide**

Items	Data
Mass of CO_2	66.0 g
Molar mass of CO_2	44.0 g/mol
Amount of CO_2	? mol

PLAN

What step is needed to convert from grams of CO_2 to moles of CO_2 ?

The molar mass of CO_2 can be used to convert mass of CO_2 to moles of CO_2 .

1 Mass of CO_2 in g $\xrightarrow{\text{multiply by the inverse of the molar mass of } \text{CO}_2}$ **2** Amount of CO_2 in mol

$$\text{g CO}_2 \times \frac{1 \text{ mol CO}_2}{44.01 \text{ g CO}_2} = \text{mol CO}_2$$

COMPUTE

$$66.0 \text{ g } \cancel{\text{CO}_2} \times \frac{1 \text{ mol CO}_2}{44.01 \text{ g } \cancel{\text{CO}_2}} = 1.50 \text{ mol CO}_2$$

Problem Solving *continued*

EVALUATE

Are the units correct?

Yes; the answer has the correct units of moles CO₂.

Is the number of significant figures correct?

Yes; the number of significant figures is correct because the mass of CO₂ was given to three significant figures.

Is the answer reasonable?

Yes; 66 g is about 3/2 the value of the molar mass of CO₂. It is reasonable that the sample contains 3/2 (1.5) mol.

Practice

1. Calculate the number of moles in each of the following masses:

a. 3.00 g of boron tribromide, BBr₃ ans: 0.0120 mol BBr₃

b. 0.472 g of sodium fluoride, NaF ans: 0.0112 mol NaF

c. 7.50×10^2 g of methanol, CH₃OH ans: 23.4 mol CH₃OH

d. 50.0 g of calcium chlorate, Ca(ClO₃)₂ ans: 0.242 mol Ca(ClO₃)₂

Problem Solving *continued*

CONVERTING MOLES OF A COMPOUND TO MASS

Perhaps you have noticed that Sample Problems 1 and 5 are very much alike. In each case, you multiplied the mass by the inverse of the molar mass to calculate the number of moles. The only difference in the two problems is that iron is an element and CO_2 is a compound containing a carbon atom and two oxygen atoms.

In Sample Problem 2, you determined the mass of 1.366 mol of zinc. Suppose that you are now asked to determine the mass of 1.366 mol of the molecular compound ammonia, NH_3 . You can follow the same plan as you did in Sample Problem 2, but this time use the molar mass of ammonia.

Practice

1. Determine the mass of each of the following amounts:

a. 1.366 mol of NH_3 **ans: 23.28 g NH_3**

b. 0.120 mol of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$ **ans: 21.6 g $\text{C}_6\text{H}_{12}\text{O}_6$**

c. 6.94 mol barium chloride, BaCl_2 **ans: 1.45×10^3 g or 1.45 kg BaCl_2**

d. 0.005 mol of propane, C_3H_8 **ans: 0.2 g C_3H_8**

Problem Solving *continued***Sample Problem 6**Determine the number of molecules in 0.0500 mol of hexane, C_6H_{14} .**Solution****ANALYZE**What is given in the problem? **amount of hexane in moles**What are you asked to find? **number of molecules of hexane**

Items	Data
Amount of hexane	0.0500 mol
Avogadro's number—the number of molecules per mole of hexane	6.022×10^{23} molecules/mol
Molecules of hexane	? molecules

PLANWhat step is needed to convert from moles of C_6H_{14} to number of molecules of C_6H_{14} ?**Avogadro's number is the number of molecules per mole of hexane and can be used to calculate the number of molecules from number of moles.**

2 Amount of C_6H_{14} in mol $\xrightarrow[\text{Avogadro's number}]{\text{multiply by}}$ Number of C_6H_{14} molecules **3**

$$\text{mol } C_6H_{14} \times \frac{\overset{\text{Avogadro's number}}{6.022 \times 10^{23} \text{ molecules } C_6H_{14}}}{1 \text{ mol } C_6H_{14}} = \text{molecules } C_6H_{14}$$

COMPUTE

$$0.0500 \cancel{\text{ mol } C_6H_{14}} \times \frac{6.022 \times 10^{23} \text{ molecules } C_6H_{14}}{1 \cancel{\text{ mol } C_6H_{14}}} = 3.01 \times 10^{22} \text{ molecules } C_6H_{14}$$

EVALUATE

Are the units correct?

Yes; the answer has the correct units of molecules of C_6H_{14} .

Is the number of significant figures correct?

Yes; three significant figures is correct.

Is the answer reasonable?

Yes; multiplying Avogadro's number by 0.05 would yield a product that is a factor of 10 less with a value of 3×10^{22} .

Problem Solving *continued*

Practice

1. Calculate the number of molecules in each of the following amounts:

a. 4.99 mol of methane, CH_4 **ans: 3.00×10^{24} molecules CH_4**

b. 0.005 20 mol of nitrogen gas, N_2 **ans: 3.13×10^{21} molecules N_2**

c. 1.05 mol of phosphorus trichloride, PCl_3 **ans: 6.32×10^{23} molecules PCl_3**

d. 3.5×10^{-5} mol of vitamin C, ascorbic acid, $\text{C}_6\text{H}_8\text{O}_6$ **ans: 2.1×10^{19} molecules $\text{C}_6\text{H}_8\text{O}_6$**

Problem Solving *continued*

USING FORMULA UNITS OF IONIC COMPOUNDS

Ionic compounds do not exist as molecules. A crystal of sodium chloride, for example, consists of Na^+ ions and Cl^- ions in a 1:1 ratio. Chemists refer to a combination of one Na^+ ion and one Cl^- ion as one formula unit of NaCl . A mole of an ionic compound consists of 6.022×10^{23} formula units. The mass of one formula unit is called the formula mass. This mass is used in the same way atomic mass or molecular mass is used in calculations.

Practice

1. Calculate the number of formula units in the following amounts:

a. 1.25 mol of potassium bromide, KBr **ans: 7.53×10^{23} formula units KBr**

b. 5.00 mol of magnesium chloride, MgCl_2 **ans: 3.01×10^{24} formula units MgCl_2**

c. 0.025 mol of sodium carbonate, Na_2CO_3 **ans: 1.5×10^{22} formula units Na_2CO_3**

d. 6.82×10^{-6} mol of lead(II) nitrate, $\text{Pb}(\text{NO}_3)_2$ **ans: 4.11×10^{18} formula units $\text{Pb}(\text{NO}_3)_2$**

Problem Solving *continued*

CONVERTING NUMBER OF MOLECULES OR FORMULA UNITS TO AMOUNT IN MOLES

In Sample Problem 3, you determined the amount in moles of the element lithium. Suppose that you are asked to determine the amount in moles of copper(II) hydroxide in 3.34×10^{34} formula units of $\text{Cu}(\text{OH})_2$. You can follow the same plan as you did in Sample Problem 3.

Practice

1. Calculate the amount in moles of the following numbers of molecules or formula units:

a. 3.34×10^{34} formula units of $\text{Cu}(\text{OH})_2$ **ans: 5.55×10^{10} mol $\text{Cu}(\text{OH})_2$**

b. 1.17×10^{16} molecules of H_2S **ans: 1.94×10^{-8} mol H_2S**

c. 5.47×10^{21} formula units of nickel(II) sulfate, NiSO_4 **ans: 9.08×10^{-3} mol NiSO_4**

d. 7.66×10^{19} molecules of hydrogen peroxide, H_2O_2 **ans: 1.27×10^{-4} mol H_2O_2**

Problem Solving *continued***Sample Problem 7**

What is the mass of a sample consisting of 1.00×10^{22} formula units of MgSO_4 ?

Solution**ANALYZE**

What is given in the problem? **number of magnesium sulfate formula units**

What are you asked to find? **mass of magnesium sulfate in grams**

Items	Data
Number of formula units of magnesium sulfate	1.00×10^{22} formula units
Avogadro's number—the number of formula units of magnesium sulfate per mole	6.022×10^{23} formula units/mol
Molar mass of magnesium sulfate	120.37 g/mol
Mass of magnesium sulfate	? g

PLAN

What steps are needed to convert from formula units of MgSO_4 to grams of MgSO_4 ?

First, you must convert the number of formula units of MgSO_4 to amount of MgSO_4 by using Avogadro's number. Then you can use the molar mass of MgSO_4 to convert amount in moles to mass of MgSO_4 .

$$\begin{array}{l}
 \text{Number of MgSO}_4 \text{ formula units} \xrightarrow{\text{multiply by the inverse of Avogadro's number}} \text{Amount of MgSO}_4 \text{ in mol} \xrightarrow{\text{multiply by the molar mass of MgSO}_4} \text{Mass of MgSO}_4 \text{ in g} \\
 \\
 \text{formula units MgSO}_4 \times \frac{1}{6.022 \times 10^{23} \text{ formula units MgSO}_4} \times \frac{120.37 \text{ g MgSO}_4}{1 \text{ mol MgSO}_4} = \text{g MgSO}_4
 \end{array}$$

Problem Solving *continued***COMPUTE**

$$1.00 \times 10^{22} \text{ formula units MgSO}_4 \times \frac{1 \text{ mol MgSO}_4}{6.022 \times 10^{23} \text{ formula units MgSO}_4} \times \frac{120.37 \text{ g MgSO}_4}{1 \text{ mol MgSO}_4} = 2.00 \text{ g MgSO}_4$$

EVALUATE

Are the units correct?

Yes; the answer has the correct units of grams of MgSO₄.

Is the number of significant figures correct?

Yes; the number of significant figures is correct because data were given to three significant figures.

Is the answer reasonable?

Yes; 2 g of MgSO₄ is about 1/60 of the molar mass of MgSO₄. Therefore, 2.00 g MgSO₄ will contain about 1/60 of an Avogadro's number of formula units.

Practice

1. Calculate the mass of each of the following quantities:

a. 2.41×10^{24} molecules of hydrogen, H₂ **ans: 8.08 g H₂**

b. 5.00×10^{21} formula units of aluminum hydroxide, Al(OH)₃ **ans: 0.648 g Al(OH)₃**

c. 8.25×10^{22} molecules of bromine pentafluoride, BrF₅ **ans: 24.0 g BrF₅**

d. 1.20×10^{23} formula units of sodium oxalate, Na₂C₂O₄ **ans: 26.7 g Na₂C₂O₄**

Problem Solving *continued*

CONVERTING MOLECULES OR FORMULA UNITS OF A COMPOUND TO MASS

In Sample Problem 4, you converted a given mass of boron to the number of boron atoms present in the sample. You can now apply the same method to convert mass of an ionic or molecular compound to numbers of molecules or formula units.

Practice

1. Calculate the number of molecules or formula units in each of the following masses:

a. 22.9 g of sodium sulfide, Na_2S **ans: 1.77×10^{23} formula units Na_2S**

b. 0.272 g of nickel(II) nitrate, $\text{Ni}(\text{NO}_3)_2$ **ans: 8.96×10^{20} formula units $\text{Ni}(\text{NO}_3)_2$**

c. 260 mg of acrylonitrile, CH_2CHCN **ans: 3.0×10^{21} molecules CH_2CHCN**

Problem Solving *continued***Additional Problems**

- Calculate the number of moles in each of the following masses:
 - 0.039 g of palladium
 - 8200 g of iron
 - 0.0073 kg of tantalum
 - 0.006 55 g of antimony
 - 5.64 kg of barium
 - 3.37×10^{-6} g of molybdenum
- Calculate the mass in grams of each of the following amounts:
 - 1.002 mol of chromium
 - 550 mol of aluminum
 - 4.08×10^{-8} mol of neon
 - 7 mol of titanium
 - 0.0086 mol of xenon
 - 3.29×10^4 mol of lithium
- Calculate the number of atoms in each of the following amounts:
 - 17.0 mol of germanium
 - 0.6144 mol of copper
 - 3.02 mol of tin
 - 2.0×10^6 mol of carbon
 - 0.0019 mol of zirconium
 - 3.227×10^{-10} mol of potassium
- Calculate the number of moles in each of the following quantities:
 - 6.022×10^{24} atoms of cobalt
 - 1.06×10^{23} atoms of tungsten
 - 3.008×10^{19} atoms of silver
 - 950 000 000 atoms of plutonium
 - 4.61×10^{17} atoms of radon
 - 8 trillion atoms of cerium
- Calculate the number of atoms in each of the following masses:
 - 0.0082 g of gold
 - 812 g of molybdenum
 - 2.00×10^2 mg of americium
 - 10.09 kg of neon
 - 0.705 mg of bismuth
 - 37 μg of uranium

Problem Solving *continued*

- 6.** Calculate the mass of each of the following:
- 8.22×10^{23} atoms of rubidium
 - 4.05 Avogadro's numbers of manganese atoms
 - 9.96×10^{26} atoms of tellurium
 - 0.000 025 Avogadro's numbers of rhodium atoms
 - 88 300 000 000 000 atoms of radium
 - 2.94×10^{17} atoms of hafnium
- 7.** Calculate the number of moles in each of the following masses:
- 45.0 g of acetic acid, CH_3COOH
 - 7.04 g of lead(II) nitrate, $\text{Pb}(\text{NO}_3)_2$
 - 5000 kg of iron(III) oxide, Fe_2O_3
 - 12.0 mg of ethylamine, $\text{C}_2\text{H}_5\text{NH}_2$
 - 0.003 22 g of stearic acid, $\text{C}_{17}\text{H}_{35}\text{COOH}$
 - 50.0 kg of ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$
- 8.** Calculate the mass of each of the following amounts:
- 3.00 mol of selenium oxybromide, SeOBr_2
 - 488 mol of calcium carbonate, CaCO_3
 - 0.0091 mol of retinoic acid, $\text{C}_{20}\text{H}_{28}\text{O}_2$
 - 6.00×10^{-8} mol of nicotine, $\text{C}_{10}\text{H}_{14}\text{N}_2$
 - 2.50 mol of strontium nitrate, $\text{Sr}(\text{NO}_3)_2$
 - 3.50×10^{-6} mol of uranium hexafluoride, UF_6
- 9.** Calculate the number of molecules or formula units in each of the following amounts:
- 4.27 mol of tungsten(VI) oxide, WO_3
 - 0.003 00 mol of strontium nitrate, $\text{Sr}(\text{NO}_3)_2$
 - 72.5 mol of toluene, $\text{C}_6\text{H}_5\text{CH}_3$
 - 5.11×10^{-7} mol of α -tocopherol (vitamin E), $\text{C}_{29}\text{H}_{50}\text{O}_2$
 - 1500 mol of hydrazine, N_2H_4
 - 0.989 mol of nitrobenzene $\text{C}_6\text{H}_5\text{NO}_2$
- 10.** Calculate the number of molecules or formula units in each of the following masses:
- 285 g of iron(III) phosphate, FePO_4
 - 0.0084 g of $\text{C}_5\text{H}_5\text{N}$
 - 85 mg of 2-methyl-1-propanol, $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$
 - 4.6×10^{-4} g of mercury(II) acetate, $\text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2$
 - 0.0067 g of lithium carbonate, Li_2CO_3

Problem Solving *continued*

- 11.** Calculate the mass of each of the following quantities:
- 8.39×10^{23} molecules of fluorine, F_2
 - 6.82×10^{24} formula units of beryllium sulfate, $BeSO_4$
 - 7.004×10^{26} molecules of chloroform, $CHCl_3$
 - 31 billion formula units of chromium(III) formate, $Cr(CHO_2)_3$
 - 6.3×10^{18} molecules of nitric acid, HNO_3
 - 8.37×10^{25} molecules of freon 114, $C_2Cl_2F_4$
- 12.** Precious metals are commonly measured in troy ounces. A troy ounce is equivalent to 31.1 g. How many moles are in a troy ounce of gold? How many moles are in a troy ounce of platinum? of silver?
- 13.** A chemist needs 22.0 g of phenol, C_6H_5OH , for an experiment. How many moles of phenol is this?
- 14.** A student needs 0.015 mol of iodine crystals, I_2 , for an experiment. What mass of iodine crystals should the student obtain?
- 15.** The weight of a diamond is given in carats. One carat is equivalent to 200. mg. A pure diamond is made up entirely of carbon atoms. How many carbon atoms make up a 1.00 carat diamond?
- 16.** 8.00 g of calcium chloride, $CaCl_2$, is dissolved in 1.000 kg of water.
- How many moles of $CaCl_2$ are in solution? How many moles of water are present?
 - Assume that the ionic compound, $CaCl_2$, separates completely into Ca^{2+} and Cl^- ions when it dissolves in water. How many moles of each ion are present in the solution?
- 17.** How many moles are in each of the following masses?
- 453.6 g (1.000 pound) of sucrose (table sugar), $C_{12}H_{22}O_{11}$
 - 1.000 pound of table salt, $NaCl$
- 18.** When the ionic compound NH_4Cl dissolves in water, it breaks into one ammonium ion, NH_4^+ , and one chloride ion, Cl^- . If you dissolved 10.7 g of NH_4Cl in water, how many moles of ions would be in solution?
- 19.** What is the total amount in moles of atoms in a jar that contains 2.41×10^{24} atoms of chromium, 1.51×10^{23} atoms of nickel, and 3.01×10^{23} atoms of copper?
- 20.** The density of liquid water is 0.997 g/mL at 25°C.
- Calculate the mass of 250.0 mL (about a cupful) of water.
 - How many moles of water are in 250.0 mL of water? Hint: Use the result of (a).
 - Calculate the volume that would be occupied by 2.000 mol of water at 25°C.
 - What mass of water is 2.000 mol of water?

Problem Solving *continued*

- 21.** An Avogadro's number (1 mol) of sugar molecules has a mass of 342 g, but an Avogadro's number (1 mol) of water molecules has a mass of only 18 g. Explain why there is such a difference between the mass of 1 mol of sugar and the mass of 1 mol of water.
- 22.** Calculate the mass of aluminum that would have the same number of atoms as 6.35 g of cadmium.
- 23.** A chemist weighs a steel cylinder of compressed oxygen, O_2 , and finds that it has a mass of 1027.8 g. After some of the oxygen is used in an experiment, the cylinder has a mass of 1023.2 g. How many moles of oxygen gas are used in the experiment?
- 24.** Suppose that you could decompose 0.250 mol of Ag_2S into its elements.
- How many moles of silver would you have? How many moles of sulfur would you have?
 - How many moles of Ag_2S are there in 38.8 g of Ag_2S ? How many moles of silver and sulfur would be produced from this amount of Ag_2S ?
 - Calculate the masses of silver and sulfur produced in (b).

- c. $60.4 \text{ kg}; 1.88 \times 10^4 \text{ dm}^3$
- d. $0.94 \text{ g/cm}^3; 5.3 \times 10^{-4} \text{ m}^3$
- e. $2.5 \times 10^3 \text{ kg}; 2.7 \times 10^6 \text{ cm}^3$
- 7. 2.8 g/cm^3
- 8. a. $0.72 \text{ }\mu\text{m}$
b. $2.5 \times 10^3 \text{ atoms}$
- 9. 1300 L/min
- 10. $1.3 \times 10^6 \text{ cal/h}$
- 11. 5.44 g/cm^3
- 12. $2.24 \times 10^4 \text{ cm}^3$
- 13. $32\,000 \text{ uses}$
- 14. 2500 L
- 15. 9.5 L/min

MOLE CONCEPT

1. a. $3.7 \times 10^{-4} \text{ mol Pd}$
b. 150 mol Fe
c. 0.040 mol Ta
d. $5.38 \times 10^{-5} \text{ mol Sb}$
e. 41.1 mol Ba
f. $3.51 \times 10^{-8} \text{ mol Mo}$
2. a. 52.10 g Cr
b. $1.5 \times 10^4 \text{ g}$ or 15 kg Al
c. $8.23 \times 10^{-7} \text{ g Ne}$
d. $3 \times 10^2 \text{ g}$ or 0.3 kg Ti
e. 1.1 g Xe
f. $2.28 \times 10^5 \text{ g}$ or 228 kg Li
3. a. $1.02 \times 10^{25} \text{ atoms Ge}$
b. $3.700 \times 10^{23} \text{ atoms Cu}$
c. $1.82 \times 10^{24} \text{ atoms Sn}$
d. $1.2 \times 10^{30} \text{ atoms C}$
e. $1.1 \times 10^{21} \text{ atoms Zr}$
f. $1.943 \times 10^{14} \text{ atoms K}$
4. a. 10.00 mol Co
b. 0.176 mol W
c. $4.995 \times 10^{-5} \text{ mol Ag}$
d. $1.6 \times 10^{-15} \text{ mol Pu}$
e. $7.66 \times 10^{-7} \text{ mol Rn}$
f. $1 \times 10^{-11} \text{ mol Ce}$
5. a. $2.5 \times 10^{19} \text{ atoms Au}$
b. $5.10 \times 10^{24} \text{ atoms Mo}$
c. $4.96 \times 10^{20} \text{ atoms Am}$
d. $3.011 \times 10^{26} \text{ atoms Ne}$
e. $2.03 \times 10^{18} \text{ atoms Bi}$
f. $9.4 \times 10^{16} \text{ atoms U}$
6. a. 117 g Rb
b. 223 g Mn
c. $2.11 \times 10^5 \text{ g Te}$
d. $2.6 \times 10^{-3} \text{ g Rh}$
e. $3.31 \times 10^{-8} \text{ g Ra}$
f. $8.71 \times 10^{-5} \text{ g Hf}$
7. a. $0.749 \text{ mol CH}_3\text{COOH}$
b. $0.0213 \text{ mol Pb(NO}_3)_2$
- c. $3 \times 10^4 \text{ mol Fe}_2\text{O}_3$
- d. $2.66 \times 10^{-4} \text{ mol C}_2\text{H}_5\text{NH}_2$
- e. $1.13 \times 10^{-5} \text{ mol C}_{17}\text{H}_{35}\text{COOH}$
- f. $378 \text{ mol (NH}_4)_2\text{SO}_4$
8. a. 764 g SeOBr_2
b. $4.88 \times 10^4 \text{ g CaCO}_3$
c. $2.7 \text{ g C}_{20}\text{H}_{28}\text{O}_2$
d. $9.74 \times 10^{-6} \text{ g C}_{10}\text{H}_{14}\text{N}_2$
e. $529 \text{ g Sr(NO}_3)_2$
f. $1.23 \times 10^{-3} \text{ g UF}_6$
9. a. $2.57 \times 10^{24} \text{ formula units WO}_3$
b. $1.81 \times 10^{21} \text{ formula units Sr(NO}_3)_2$
c. $4.37 \times 10^{25} \text{ molecules C}_6\text{H}_5\text{CH}_3$
d. $3.08 \times 10^{17} \text{ molecules C}_{29}\text{H}_{50}\text{O}_2$
e. $9.0 \times 10^{26} \text{ molecules N}_2\text{H}_4$
f. $5.96 \times 10^{23} \text{ molecules C}_6\text{H}_5\text{NO}_2$
10. a. $1.14 \times 10^{24} \text{ formula units FePO}_4$
b. $6.4 \times 10^{19} \text{ molecules C}_5\text{H}_5\text{N}$
c. $6.9 \times 10^{20} \text{ molecules (CH}_3)_2\text{CHCH}_2\text{OH}$
d. $8.7 \times 10^{17} \text{ formula units Hg(C}_2\text{H}_3\text{O}_2)_2$
e. $5.5 \times 10^{19} \text{ formula units Li}_2\text{CO}_3$
11. a. 52.9 g F_2
b. $1.19 \times 10^3 \text{ g}$ or 1.19 kg BeSO_4
c. $1.388 \times 10^5 \text{ g}$ or 138.8 kg CHCl_3
d. $9.6 \times 10^{-12} \text{ g Cr(CHO}_2)_3$
e. $6.6 \times 10^{-4} \text{ g HNO}_3$
f. $2.38 \times 10^4 \text{ g}$ or $23.8 \text{ kg C}_2\text{Cl}_2\text{F}_4$
12. 0.158 mol Au
 0.159 mol Pt
 0.288 mol Ag
13. $0.234 \text{ mol C}_6\text{H}_5\text{OH}$
14. 3.8 g I_2
15. $1.00 \times 10^{22} \text{ atoms C}$
16. a. $0.0721 \text{ mol CaCl}_2$
 $55.49 \text{ mol H}_2\text{O}$
b. $0.0721 \text{ mol Ca}^{2+}$
 0.144 mol Cl^-
17. a. $1.325 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}$
b. 7.762 mol NaCl
18. 0.400 mol ions
19. 4.75 mol atoms
20. a. $249 \text{ g H}_2\text{O}$
b. $13.8 \text{ mol H}_2\text{O}$
c. $36.1 \text{ mL H}_2\text{O}$
d. $36.0 \text{ g H}_2\text{O}$
21. The mass of a sugar molecule is much greater than the mass of a water molecule. Therefore, the mass of 1 mol of sugar molecules is much greater than the mass of 1 mol of water molecules.
22. 1.52 g Al

23. 0.14 mol O₂
 24. a. 0.500 mol Ag
 0.250 mol S
 b. 0.157 mol Ag₂S
 0.313 mol Ag
 0.157 mol S
 c. 33.8 g Ag
 5.03 g S

PERCENTAGE COMPOSITION

1. a. HNO₃
 1.60% H
 22.23% N
 76.17% O
 b. NH₃
 82.22% N
 17.78% H
 c. HgSO₄
 67.616% Hg
 10.81% S
 21.57% O
 d. SbF₅
 56.173% Sb
 43.83% F
 2. a. 7.99% Li
 92.01% Br
 b. 94.33% C
 5.67% H
 c. 35.00% N
 5.05% H
 59.96% O
 d. 2.15% H
 29.80% N
 68.06% O
 e. 87.059% Ag
 12.94% S
 f. 32.47% Fe
 13.96% C
 16.29% N
 37.28% S
 g. LiC₂H₃O₂
 10.52% Li
 36.40% C
 4.59% H
 48.49% O
 h. Ni(CHO₂)₂
 39.46% Ni
 16.15% C
 1.36% H
 43.03% O
 3. a. 46.65% N
 b. 23.76% S
 c. 89.491% Tl

- d. 39.17% O
 e. 79.95% Br in CaBr₂
 f. 78.767% Sn in SnO₂
 4. a. 1.47 g O
 b. 26.5 metric tons Al
 c. 262 g Ag
 d. 0.487 g Au
 e. 312 g Se
 f. 3.1×10^4 g Cl
 5. a. 40.55% H₂O
 b. 43.86% H₂O
 c. 20.70% H₂O
 d. 28.90% H₂O
 6. a. Ni(C₂H₃O₂)₂·4H₂O
 23.58% Ni
 b. Na₂CrO₄·4H₂O
 22.22% Cr
 c. Ce(SO₄)₂·4H₂O
 34.65% Ce
 7. 43.1 kg Hg
 8. malachite: 5.75×10^2 kg Cu
 chalcopyrite: 3.46×10^2 kg Cu
 malachite has a greater Cu content
 9. a. 25.59% V
 b. 39.71% Sn
 c. 22.22% Cl
 10. 319.6 g anhydrous CuSO₄
 11. 1.57 g AgNO₃
 12. 54.3 g Ag
 8.08 g S
 13. 23.1 g MgSO₄·7H₂O
 14. 3.27×10^2 g S

EMPIRICAL FORMULAS

1. a. BaCl₂
 b. BiO₃H₃ or Bi(OH)₃
 c. AlN₃O₉ or Al(NO₃)₃
 d. ZnC₄H₆O₄ or Zn(CH₃COO)₂
 e. NiN₂S₂H₈O₈ or Ni(NH₄)₂SO₄
 f. C₂HBr₃O₂ or CBr₃COOH
 2. a. CuF₂
 b. Ba(CN)₂
 c. MnSO₄
 3. a. NiI₂
 b. MgN₂O₆ or Mg(NO₃)₂
 c. MgS₂O₃, magnesium thiosulfate
 d. K₂SnO₃, potassium stannate
 4. a. As₂S₃
 b. Re₂O₇
 c. N₂H₄O₃ or NH₄NO₃
 d. Fe₂Cr₃O₁₂ or Fe₂(CrO₄)₃
 e. C₅H₉N₃
 f. C₆H₅F₂N or C₆H₃F₂NH₂