Chemical Quantities

Chapter 10

The Mole: A Measurement of Matter

- Section 10.1

10.1 The Mole: A Measurement of Matter

Connecting to Your World

Every year, contestants from all over the world travel to Harrison Hot Springs in British Columbia, Canada, to compete in the world championship sand sculpture contest.

Each contestant creates a beautiful work of art out of millions of tiny grains of sand. You could measure the amount of sand in a sculpture by counting the grains of sand. But wouldn't it be much easier to weigh the sand? In this section, you'll discover how chemists measure the amount of a substance using a unit called a mole.

10.1 The Mole: A Measurement of Matter

Measuring Matter

- Often measure the amount of matter by 1 of 3 ways:
  - Count
  - Mass
  - Volume

- We can create conversion factors
  - 1 gallon of gas = $3.00 or
  - $3.00/gallon (Think of "/" as "per" or divided by)
  - How much gas can I buy for $15?

SAMPLE PROBLEM 10.1

Finding Mass from a Count

What is the mass of 90 average-sized apples if 1 dozen of the apples has a mass of 2.0 kg?

1 Analyze ***List the knowns and the unknown.***

2 Calculate ***Solve for the unknown.***

3 Evaluate ***Does the result make sense?***

10.1 The Mole: A Measurement of Matter

What is a mole?

- **Avogadro's number**–
  - 6.02×10^{23},
  - =number of "representative particles" in a mole.

- **Representative particles**–
  - refers to the species present in a substance: usually
    - atoms,
    - molecules, or
    - formula units.

10.1 The Mole: A Measurement of Matter

- **Mole (mol)–**
  - 6.02×10^{23} = "representative particles" of that substance
  - the SI unit for measuring the amount of a substance.

10.1 The Mole: A Measurement of Matter

Table 10.1

Representative Particles and Moles

Substance	Representative particle	Chemical formula	Representative particles in 1.00 mole
Atomic nitrogen	Atom	N	6.02×10^{23}
Nitrogen gas	Molecule	N_2	6.02×10^{23}
Water	Molecule	H_2O	6.02×10^{23}
Calcium ion	Ion	Ca^{2+}	6.02×10^{23}
Calcium fluoride	Formula unit	CaF_2	6.02×10^{23}
Sucrose	Molecule	$C_{12}H_{22}O_{11}$	6.02×10^{23}

10.1 The Mole: A Measurement of Matter

- Converting Number of Particles to Moles

$$\text{moles} = \text{representative particles} \times \frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ representative particles}}$$

SAMPLE PROBLEM 10.2

Converting Number of Atoms to Moles

Magnesium is a light metal used in the manufacture of aircraft, automobile wheels, tools, and garden furniture. How many moles of magnesium is 1.25×10^{23} atoms of magnesium?

1 Analyze ***List the knowns and the unknown.***

2 Calculate ***Solve for the unknown.***

3 Evaluate ***Does the result make sense?***

10.1 The Mole: A Measurement of Matter

- Converting Moles to Number of Particles

$$\text{representative particles} = \text{moles} \times \frac{6.02 \times 10^{23}\ \text{representative particles}}{1\ \text{mole}}$$

SAMPLE PROBLEM 10.3

Converting Moles to Number of Atoms

Propane is a gas used for cooking and heating. How many atoms are in 2.12 mol of propane (C_3H_8)?

1 Analyze *List the knowns and the unknown.*

2 Calculate *Solve for the unknown.*

3 Evaluate *Does the result make sense?*

10.1 The Mole: A Measurement of Matter

The Mass of a Mole of an Element

- The Atomic mass of an element (expressed in grams) is the mass of a mole of the element.

- **Molar mass**–
  - term used to refer to the mass of a mole of any substance.
    - Example:
      - 1 mol of Hg = 200.6 g
      - 1mol of C= 12.0g
    - 1mole = atomic mass of an element or compound

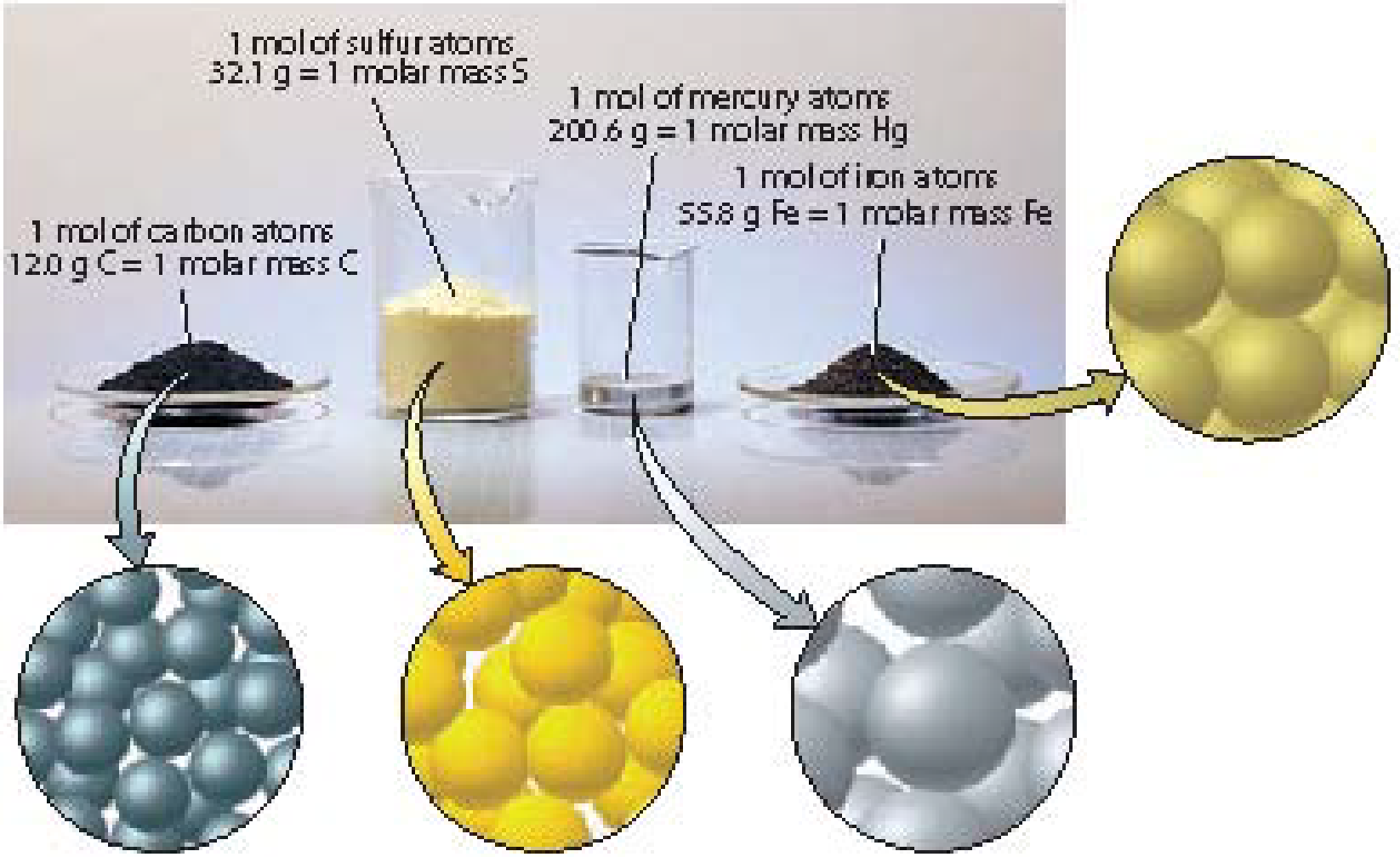
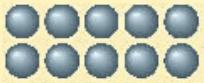
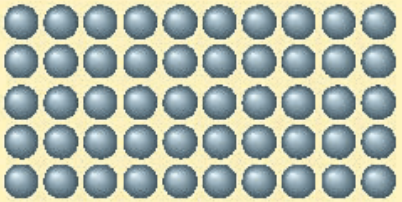

1 mol of sulfur atoms
32.1 g = 1 molar mass S
1 mol of mercury atoms
200.6 g = 1 molar mass Hg
1 mol of iron atoms
55.8 g Fe = 1 molar mass Fe
1 mol of carbon atoms
12.0 g C = 1 molar mass C

Table 10.2

CARBON ATOMS		HYDROGEN ATOMS		MASS RATIO
Number	Mass (amu)	Number	Mass (amu)	$\frac{\text{Mass carbon}}{\text{Mass hydrogen}}$
	12		1	$\frac{12\text{ amu}}{1\text{ amu}} = \frac{12}{1}$
	24 [2 × 12]		2 [2 × 1]	$\frac{24\text{ amu}}{2\text{ amu}} = \frac{12}{1}$
	120 [10 × 12]		10 [10 × 1]	$\frac{120\text{ amu}}{10\text{ amu}} = \frac{12}{1}$
	600 [50 × 12]		50 [50 × 1]	$\frac{600\text{ amu}}{50\text{ amu}} = \frac{12}{1}$
Avogadro's number	$(6.02 \times 10^{23}) \times (12)$	Avogadro's number	$(6.02 \times 10^{23}) \times (1)$	$\frac{(6.02 \times 10^{23}) \times (12)}{(6.02 \times 10^{23}) \times (1)} = \frac{12}{1}$

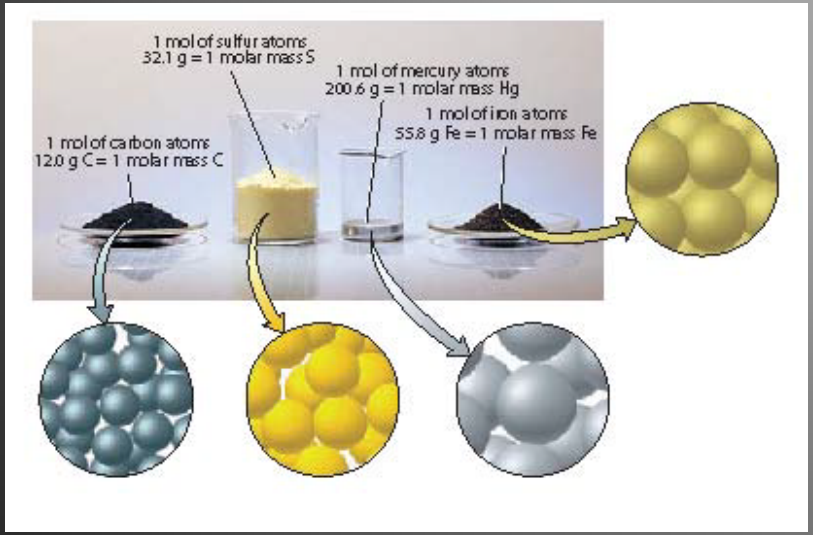
10.1 The Mole: A Measurement of Matter

Mass of a mole of a Compound

- To calculate the molar mass of a compound–
  - find the number of grams of each element in one mole of the compound,
  - add the masses of the elements in the compound.

    - Example
      - Molar mass of H_2O:
        - Atm. Mass H=1g (x2) = 2g
        - Atm. Mass O = 16g
        - **Molar mass H_2O = 18g**

10.1 The Mole: A Measurement of Matter



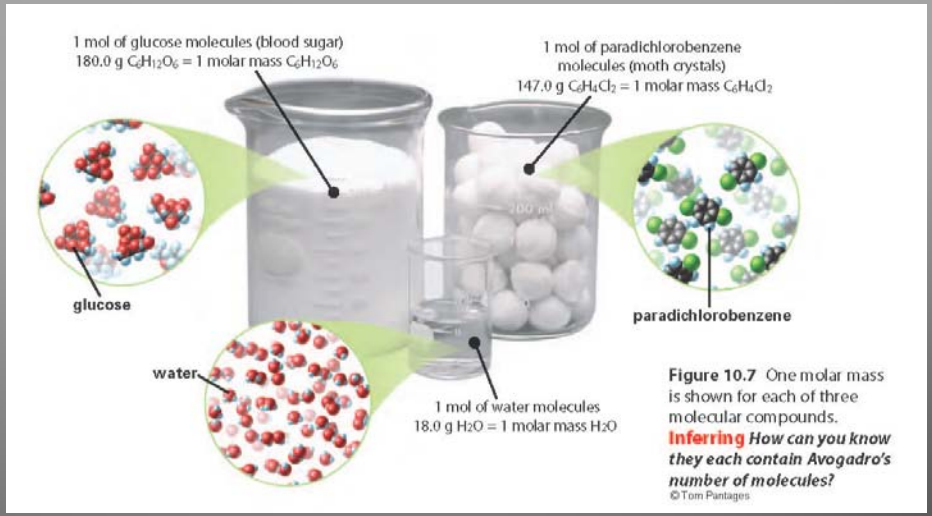


Figure 10.7 One molar mass is shown for each of three molecular compounds.
Inferring ***How can you know they each contain Avogadro's number of molecules?***

©Courtesy of NASA

SAMPLE PROBLEM 10.4

Finding the Molar Mass of a Compound

The decomposition of hydrogen peroxide (H_2O_2) provides sufficient energy to launch a rocket. What is the molar mass of hydrogen peroxide?

1 Analyze *List the knowns and the unknown.*

2 Calculate *Solve for the unknown.*

3 Evaluate *Does the result make sense?*

Mole to mass and mole to volume ratios

- Section 10.2

10.2 Mole-Mass and Mole-Volume Relationships

Connecting to Your World

Guess how many jelly beans are in the container and win a prize! You decide to enter the contest and you win. Was it just a lucky guess? Not exactly. You estimated the length and diameter of a jelly bean to find its approximate volume. Then you estimated the dimensions of the container to obtain its volume. You did the arithmetic and made your guess. In a similar way, chemists use the relationships between the mole and quantities such as mass, volume, and number of particles to solve chemistry problems. In this section you will find out how the mole and mass are related.

10.2 Mole–Mass and Mole–Volume Relationship

Mole to mass relationships

- Use the molar mass of an element or compound to convert between the mass of a substance and the moles of a substance.

- Moles to mass conversion

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

SAMPLE PROBLEM 10.5

Converting Moles to Mass

The aluminum satellite dishes in Figure 10.8 are resistant to corrosion because the aluminum reacts with oxygen in the air to form a coating of aluminum oxide (Al_2O_3). This tough, resistant coating prevents any further corrosion. What is the mass of 9.45 mol of aluminum oxide?

1 Analyze *List the known and the unknown.*

2 Calculate *Solve for the unknown.*

3 Evaluate *Does the result make sense?*

10.2 Mole–Mass and Mole–Volume Relationship

- Mass to moles conversion:

$$\text{moles} = \text{mass (grams)} \times \frac{1 \text{ mole}}{\text{mass (grams)}}$$

SAMPLE PROBLEM 10.6

Converting Mass to Moles

When iron is exposed to air, it corrodes to form red-brown rust. Rust is iron(III) oxide (Fe_2O_3). How many moles of iron(III) oxide are contained in 92.2 g of pure Fe_2O_3?

1 Analyze *List the known and the unknown.*

2 Calculate *Solve for the unknown.*

3 Evaluate *Does the result make sense?*

10.2 Mole–Mass and Mole–Volume Relationship

10.2 Mole–Mass and Mole–Volume Relationship

The Mole–Volume Relationship

- **Avogadro's hypothesis**–
  - states that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.

- **Standard temperature and pressure (STP)–**
  - means a temperature of **0°C** and,
  - a pressure of **101.3kPa**, or **1 atmosphere** (atm)
    - kPa = kilopascal

- At STP,
  - **1 mol** or 6.02 x 10^{23} representative particles, of any gas occupies a volume of **22.4 Liters**

- **Molar volume**–
  - the quantity **22.4L** of a gas.

10.2 Mole–Mass and Mole–Volume Relationship

- 22.4L applies <u>only at STP</u>

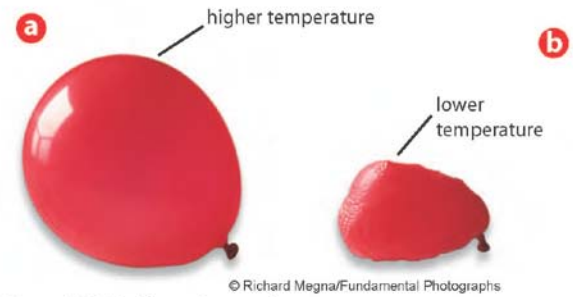


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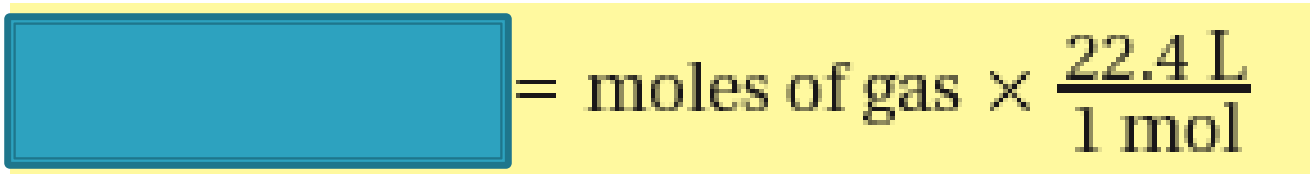
Figure 10.10 The volume of a gas varies with temperature and pressure. **a** The volume of the gas in the balloon on the left is larger because its temperature is higher. **b** The air in the "empty" water bottle on the left has a larger volume because it is at a lower pressure.

- If we change Temperature or pressure, volume will change

10.2 Mole–Mass and Mole–Volume Relationship

- **Calculating Volume at STP**



SAMPLE PROBLEM 10.7

Calculating the Volume of a Gas at STP

Sulfur dioxide (SO_2) is a gas produced by burning coal. It is an air pollutant and one of the causes of acid rain. Determine the volume, in liters, of 0.60 mol SO_2 gas at STP.

1 Analyze ***List the knowns and the unknown.***

2 Calculate ***Solve for the unknown.***

3 Evaluate ***Does the result make sense?***

10.2 Mole–Mass and Mole–Volume Relationship

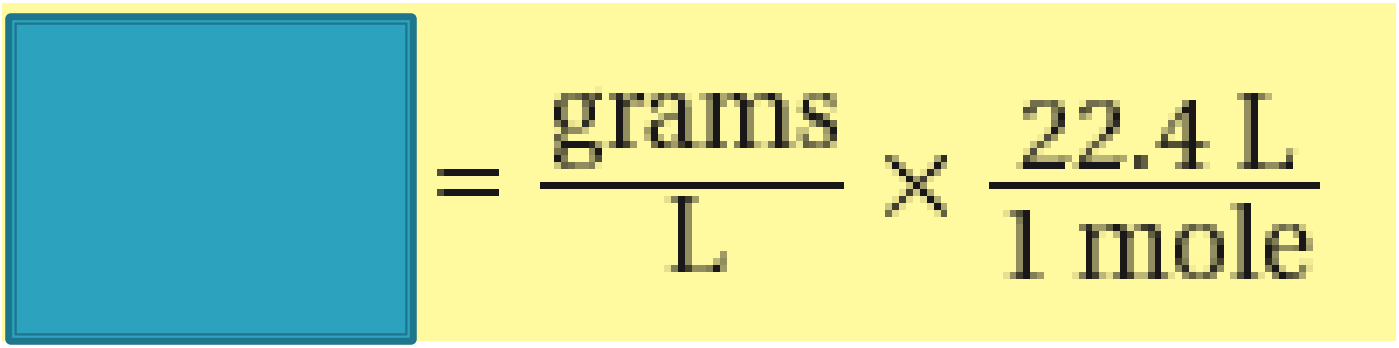
Calculating Molar Mass from Density

- Mass units
  - Grams (g)
- Molar mass units
  - g/mole
- Density units
  - Mass/volume, usually
    - g/L

- Density tell us if a substance will float or sink in another substance
  - Applies to solids, liquids & gases

10.2 Mole–Mass and Mole–Volume Relationship

- molar mass = density at STP × molar volume at STP



SAMPLE PROBLEM 10.8

Calculating the Molar Mass of a Gas at STP

The density of a gaseous compound containing carbon and oxygen is found to be 1.964 g/L at STP. What is the molar mass of the compound?

1 Analyze ***List the knowns and the unknown.***

2 Calculate ***Solve for the unknown.***

3 Evaluate ***Does the result make sense?***

10.2 Mole–Mass and Mole–Volume Relationship

- The Mole Road Map (p. 303)

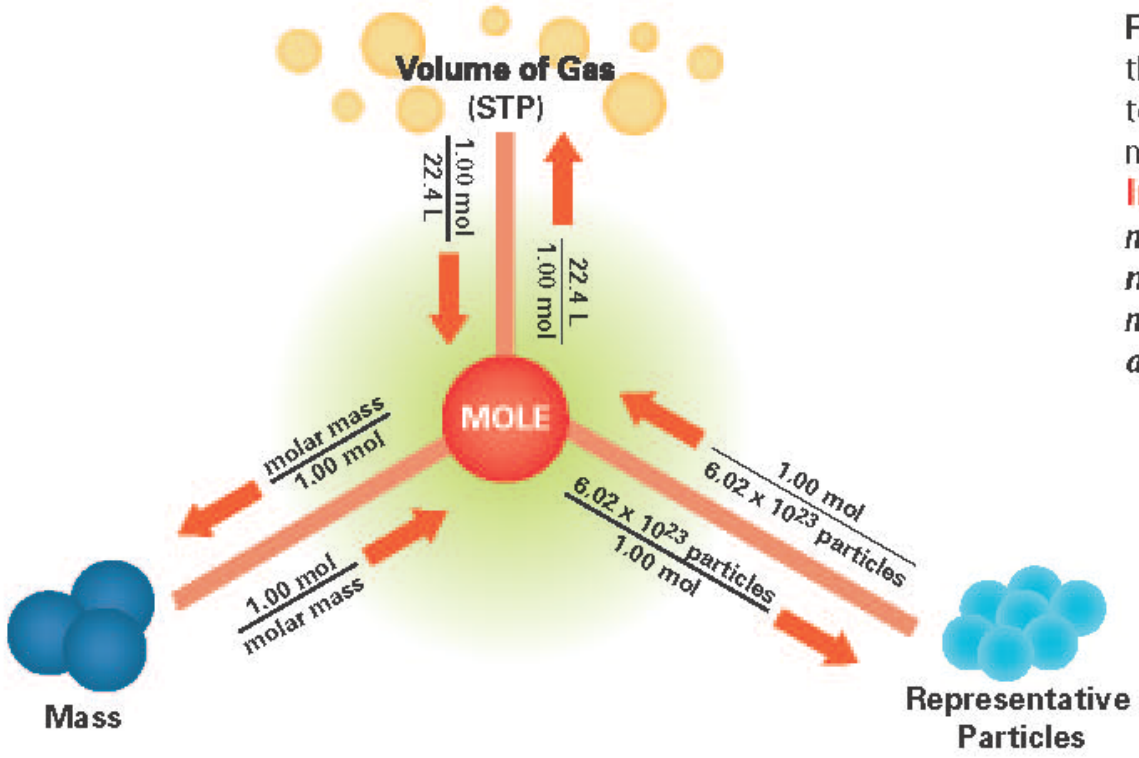


Figure 10.12 The map shows the conversion factors needed to convert among volume, mass, and number of particles. **Interpreting Diagrams** ***How many conversion factors are needed to convert from the mass of a gas to the volume of a gas at STP?***

Percent Composition and Chemical Formulas

- Section 10.3

10.3 Percent Composition and Chemical Formulas

Connecting to Your World Is your shirt made of 100 percent cotton or wool, or is the fabric a combination of two or more fibers? A tag sewed into the seam of the shirt usually tells you what fibers were used to make the cloth and the percent of each. It helps to know the percents of the components in the shirt because they affect how warm it is, whether it will need to be ironed, and how it should be cleaned. In this section you will learn how the percents of the elements in a compound are important in chemistry.

10. 3 Percent Composition and Chemical Formulas

Percent composition–

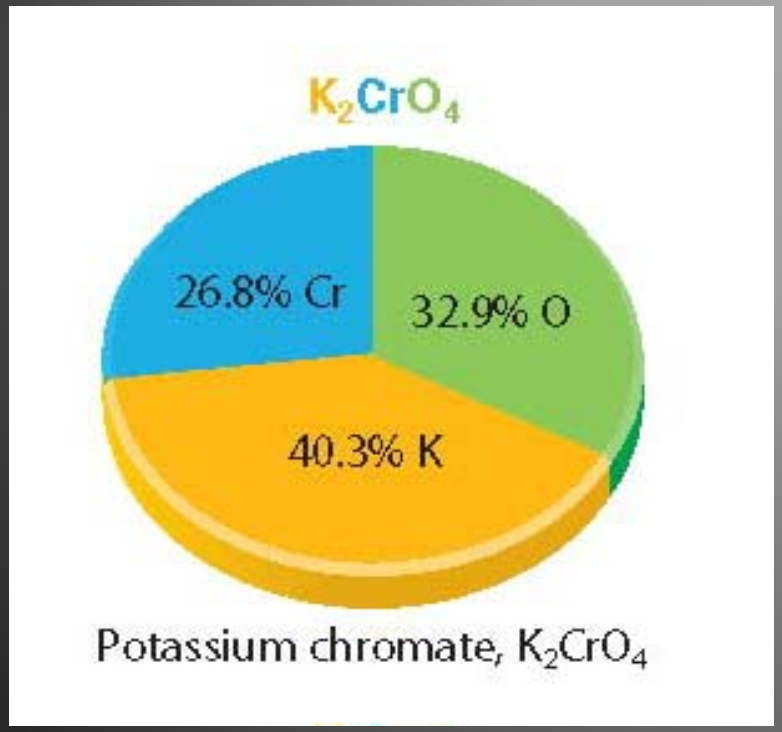
- the percent by mass of each element in a compound.
  - Equal to mass (in g) of an element divided by,
  - The mass (in g) of the compound x100%

"part"

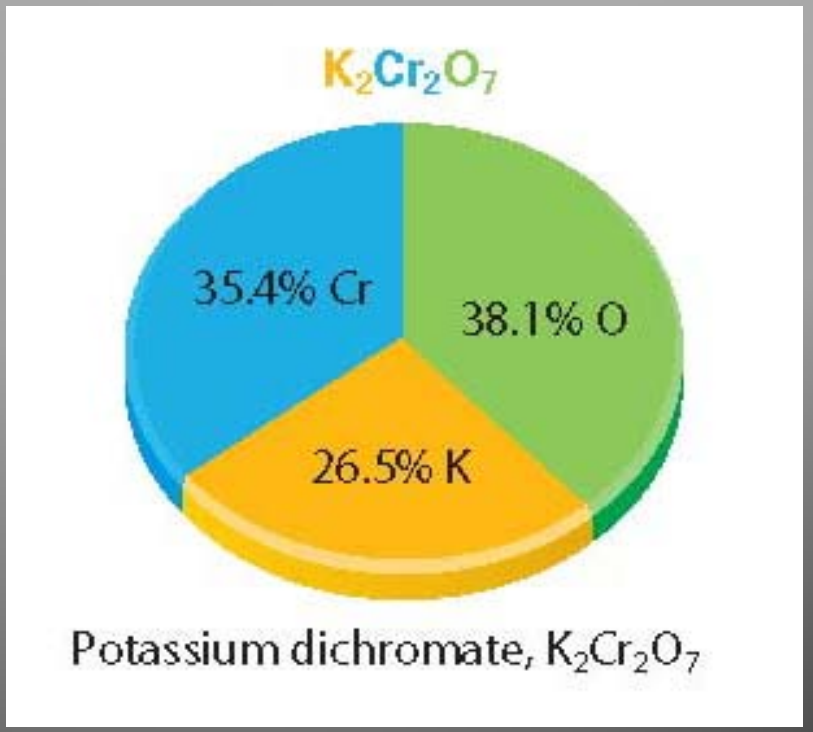
'WHOLE'

$$\% \text{ mass of element} = \frac{\text{mass of element}}{\text{mass of compound}} \times 100\%$$

10. 3 Percent Composition and Chemical Formulas



Potassium chromate, K_2CrO_4



Potassium dichromate, $K_2Cr_2O_7$

SAMPLE PROBLEM 10.9

Calculating Percent Composition from Mass Data

When a 13.60-g sample of a compound containing only magnesium and oxygen is decomposed, 5.40 g of oxygen is obtained. What is the percent composition of this compound?

1 Analyze *List the knowns and the unknowns.*

2 Calculate *Solve for the unknown.*

3 Evaluate *Does the result make sense?*

10. 3 Percent Composition and Chemical Formulas

Percent Composition from the Chemical Formula

$$\% \text{ mass} = \frac{\text{mass of element in 1 mol compound}}{\text{molar mass of compound}} \times 100\%$$

SAMPLE PROBLEM 10.10

Calculating the Percent Composition from a Formula

Propane (C_3H_8), the fuel commonly used in gas grills, is one of the lighter compounds obtained from petroleum. Calculate the percent composition of propane.

1 Analyze *List the knowns and the unknowns.*

2 Calculate *Solve for the unknowns.*

3 Evaluate *Does the result make sense?*

10. 3 Percent Composition and Chemical Formulas

Percent Composition as a Conversion factor

- If C_3H_8 is
  - 81.8% C
  - 18% H

- How many g of C and H would be present in an 82g sample of C_3H_8?

10. 3 Percent Composition and Chemical Formulas

- **Empirical formula**–
  - gives the lowest whole number ratio of the atoms of the elements in a compound.
    - Ex:
      - Mg_2S_2→ MgS
      - CH_4, CO_2, H_2O

SAMPLE PROBLEM 10.11

Determining the Empirical Formula of a Compound

A compound is analyzed and found to contain 25.9% nitrogen and 74.1% oxygen. What is the empirical formula of the compound?

1 Analyze *List the knowns and the unknown.*

2 Calculate *Solve for the unknown.*

3 Evaluate *Does the result make sense?*

10. 3 Percent Composition and Chemical Formulas

- **Molecular Formula**–
  - simple whole number multiple of its empirical formula.
  - Not necessarily the lowest
    - Ex: C_2H_2, C_6H_6, $C_6H_{12}O_6$

SAMPLE PROBLEM 10.12

Finding the Molecular Formula of a Compound

Calculate the molecular formula of a compound whose molar mass is 60.0 g/mol and empirical formula is CH_4N.

1 Analyze *List the knowns and the unknown.*

2 Calculate *Solve for the unknown.*

3 Evaluate *Does the result make sense?*

10. 3 Percent Composition and Chemical Formulas

- Assignment:
  - For tomorrow-Read Lab p. 304
  - Ch. 10 test Friday