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Unit 5
Chemical Formula Relationships

OBJECTIVES FOR UNIT 5

- Molecular and formula mass
- Calculate molecular and formula masses
- Value & meaning of Avogadro's number
- Calculate with molar mass
- Calculate mass percent
- Empirical and Molecular Formulas

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Roald Hoffmann, 1981 Nobel Laureate
in Chemistry
Speaks of the beauty of molecules

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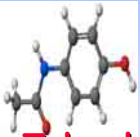
MOLECULAR AND FORMULA
MASS

What is the atom's mass?

What about having atomic masses for
compounds?

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**MOLECULAR AND FORMULA
MASS EXAMPLES**




$C_8H_9NO_2$

Tylenol

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**MOLECULAR AND FORMULA
MASS EXAMPLES**




Rust Fe_2O_3

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**COMPOUND WITH A POLYATOMIC
ION: FORMULA MASS EXAMPLES**

Example: $Mg(OH)_2$, magnesium hydroxide is an antacid (known as milk of magnesia).




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The Mole

Chemistry is a quantitative science—we need a “counting unit.”


What is a mole?
To the chemistry illiterate, a mole is a furry brown animal that burrows through the ground and ruins a lot of nicely groomed lawns.

To the chemist, a mole IS JUST A NUMBER:
 6.02×10^{23} , which amounts to
602,000,000,000,000,000,000,000



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Amedeo Avogadro




1776-1856

Back in the 19th century an Italian scientist, Amedeo Avogadro hypothesized that equal volumes of gases, under the same conditions of temperature and pressure contain the same number of molecules. Later this number of molecules was determined to be 6.02×10^{23} . Today, chemists still rely on the quantity known as the MOLE, which contains Avogadro's number of formula unit.

There is Avogadro's number of particles in a mole of any substance.


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 **Why Do We Need The MOLE?**

- How about... 602,000,000,000,000,000,000,000 atoms to be exact. Do you think it is possible to see this amount? Certainly.
- The basic idea: atoms, molecules, and particles are so small that it would be impossible to place one on a balance to get its mass.
- Therefore, we place 602,000,000,000,000,000,000,000 atoms or 602,000,000,000,000,000,000,000 molecules or 602,000,000,000,000,000,000,000 particles on a balance and get their masses.
- And SURPRISE... These masses are the same number as THE ATOMIC MASSES found on the periodic table.

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One-mole Amounts





Look... We can see one mole of magnesium...
Or 24.3 grams of Mg. **THIS IS THE SAME NUMBER
AS THE ATOMIC MASS OF Mg! WOW!**

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Mole Examples

 Place 6.02×10^{23} atoms of gold on a balance and you have _____ of gold.


 Place 6.02×10^{23} molecules of water on a balance and you have _____ of water.

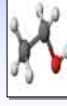
 Place 6.02×10^{23} particles of NaCl (salt) on a balance and you have _____ of salt.

Now it is your turn to conjure up some moles!!

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Molar Mass Example

 C_2H_5OH , Ethanol, or Ethyl alcohol that is common alcohol for consumption.



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MOLECULAR WEIGHT AND MOLAR MASS

Molecular weight = sum of the atomic weights of all atoms in the molecule. UNITS OF **amu**

Molar mass = molecular weight in UNITS OF **grams/moles**

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Molar Mass



Aspirin, $C_9H_8O_4$ 180.2 g/mol
Copper (II) chloride, $CuCl_2 \cdot 2 H_2O$ 170.5 g/mol
Iron (III) oxide, Fe_2O_3 159.7 g/mol
 H_2O 18.02 g/mol


Figure 3.14 One-mole quantities of some compounds. (Charles D. Winter)

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MOLE CALCULATIONS

Using the molar mass of substances, conversions between grams (the amount in mass) of substance and moles (the amount in quantity) of a substance and atoms (or molecules or particles) of a substance.

[mass (grams)] $\xrightarrow{+ \text{molar mass}}$ [moles] $\xrightarrow{\times 6.02 \times 10^{23}}$ [atoms, molecules, particles]
[mass (grams)] $\xleftarrow{\times \text{molar mass}}$ [moles] $\xleftarrow{+ 6.02 \times 10^{23}}$ [atoms, molecules, particles]



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PROBLEM: What amount of Mg is represented by 0.200 g? How many atoms?

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How many **moles** of alcohol are there in a "standard" can of beer if there are 21.3 g of C_2H_6O ?

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How many **molecules** of alcohol are there in a "standard" can of beer if there are 21.3 g of C_2H_6O ?

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How many **atoms of C** are there in a "standard" can of beer if there are 21.3 g of C_2H_6O ?

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Determining Chemical Formulas #3
Mass Percent

 • Understanding mass percent may be helpful the next time you take a trip to the flower shop to buy fertilizers. Most fertilizers contain phosphorus, nitrogen, and potassium. The packages usually list these elements as percents. What does this mean?


MASS PERCENT of a compound is a calculation for determining the percent mass each element contributes to the overall mass of the compound.

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

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Percent Composition
(Mass Percent of Each Element)

$H_3C_6H_5O_7$, Citric acid that is a common acid found in fruit. Calculate the mass percent of citric acid.



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Formula Determination
Empirical Formulas



In the previous example of fertilizers, percents of elements were given. What does that tell us about the compound or compounds that are present in that fertilizer?


What is it exactly that you will be putting on your roses and vegetables?

Interestingly, we can determine chemical formulas from percentages and masses of elements given. The only problem is the formula that we determine may not be the actual formula for that particular compound. The only formula that can be determined is the **EMPIRICAL FORMULA**.

An **EMPIRICAL FORMULA** is the simplest ratio of atoms in a compound.

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Write The Empirical Formula for Each Compound




Olive oil is composed of many fatty acid components. What makes it popular is its polyunsaturated acids such as:

- $C_{18}H_{32}O_2$, Linoleic acid.

An important carbohydrate in our body is glucose, a simple sugar.

$C_6H_{12}O_6$



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How to Experimentally Determine an Empirical Formula #4

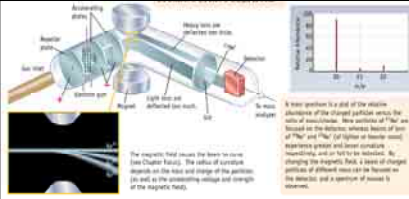
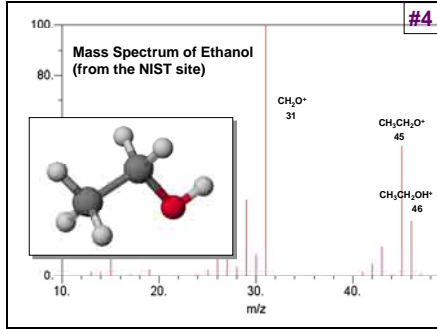


Figure 2.5 Mass spectrometer.

Mass spectrometer

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Example Calculation of Empirical Formula

- Nicotine, a chemical commonly found in cigarettes, contains: 74.0% C, 8.70% H, and 17.3% N.



But, is this the formula for nicotine?

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Molecular Formula Determination - Nicotine

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Table 3.1
Molecular Models of Two Compounds That Have the Empirical Formula CH
Although benzene and acetylene have the same empirical formula, they do not have the same molecular formula or structure.

Compound	Empirical Formula	Molecular Formula	Molecular Model
Acetylene	CH	C ₂ H ₂	
Benzene	CH	C ₆ H ₆	

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Determining the Formula of a Hydrocarbon by Combustion

