The Mole & Formulas

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Mole - Mass Relationships
Chemical Reactions
Stoichiometry

The Mole

- % Composition: Determining the Formula of an Unknown Compound
- Writing and Balancing Chemical Equations
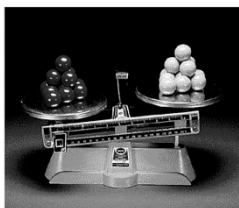- Calculating the amounts of Reactant and Product
- Limiting Reactant

The Mole

- *The number of carbon atoms in exactly 12 grams of pure ^{12}C. The number equals*

$$6.02 \times 10^{23}$$

- *1 mole of anything =* 6.02×10^{23} **units**

- 6.02×10^{23} *"units" of anything: atoms, people, stars, \$s, etc., etc. =* **1 mole**

Avogadro's Number

Avogadro's number equals 1 mole ....which equals

$$6.022 \times 10^{23} \text{ "units"}$$

Counting by Weighing

12 red marbles @ 7g each = 84g
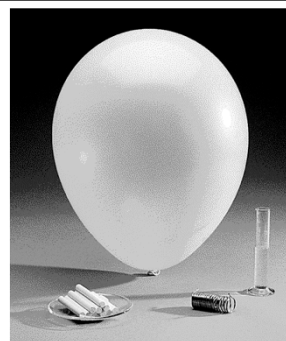**12 yellow marbles @4g each=48g**

55.85g Fe = 6.022 x 10^{23} atoms Fe
32.07g S = 6.022 x 10^{23} atoms S

Relative Masses of 1 Mole

$CaCO_3$
  100.09 g
Oxygen
  32.00 g
Copper
  63.55 g
Water
  18.02 g

Atomic and Molecular Weights
Mass Measurements

- ^1H weighs 1.6735 x 10^{-24} g and ^{16}O 2.6560 x 10^{-23} g.
- DEFINITION: mass of ^{12}C = exactly 12 amu.
- Using atomic mass units:
- 1 amu = 1.66054 x 10^{-24} g
- 1 g = 6.02214 x 10^{23} amu

QUESTION

What is the mass of one atom of copper in grams?

A. 63.5 g
B. 52.0 g
C. 58.9 g
D. 65. 4 g
E. 1.06 × 10^{-22} g

Atomic and Molecular Weights

- *Formula Weight a.k.a. Molecular Weight*
- *Formula weights (FW): sum of Atomic Weights (AW) for atoms in formula.*
- *FW (H_2SO_4) = 2AW(H) + AW(S) + 4AW(O)*
- *= 2(1.0 amu) + (32.0 amu) + 4(16.0)*
- *= 98.0 amu*

Atomic and Molecular Weights

- *Molecular weight (MW) is the weight of the molecular formula in amu.*
- *MW of sugar ($C_6H_{12}O_6$) = ?*

Molar Mass

- *A substance's **molar mass** (equal to the formula weight: atomic or molecular weight in grams) is the mass in grams of one mole of the element or compound.*

  - *C = 12.01 grams per mole (g/mol)*

  - *CO_2 = ??*

  - *44.01 grams per mole (g/mol)*
    12.01 + 2(16.00) = 44.01

QUESTION

What is the molar mass of ethanol (C_2H_5OH)?

A) 45.07 g/mol
B) 38.90 g/mol
C) 46.07 g/mol
D) 34.17 g/mol
E) 62.07 g/mol

QUESTION

For which compound does 0.256 mole weigh 12.8 g (experimental balance weight)?

A) C_2H_4O
B) CO_2
C) CH_3Cl
D) C_2H_6
E) None of these

QUESTION

How many grams are in a 6.94-mol sample of sodium hydroxide (*theoretically, not necessarily experimentally*)?

A) 40.0 g
B) 278 g
C) 169 g
D) 131 g
E) 34.2 g

Percent Composition

- *Mass percent of an element:*

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

- *For iron in (Fe_2O_3), iron (III) oxide = ?*

QUESTION

Which of the following compounds has the same percent composition by mass as styrene, C_8H_8?

A) Acetylene, C_2H_2
B) Benzene, C_6H_6
C) Cyclobutadiene, C_4H_4
D) α-ethyl naphthalene, $C_{12}H_{12}$
E) All of these

QUESTION

Morphine, derived from opium plants, has the potential for use and abuse. It's formula is $C_{17}H_{19}NO_3$. What percent, by mass, is the carbon in this compound?

A. 42.5%
B. 27.9%
C. 71.6%
D. This cannot be solved until the mass of the sample is given.

QUESTION

How many grams of potassium are in 12.5 g of K_2CrO_7?

A) 2.02 g
B) 8.80 g
C) 4.04 g
D) 78.2 g
E) 25.0 g

Formulas: Dalton's Law

• *Dalton's law of multiple proportions:*

When two elements form different compounds, the mass ratio of the elements in one compound is related to the mass ratio in the other by a small whole number.

Formulas: Multiple Proportions

Multiple Proportions

Formulas & Multiple Proportions
Components of acid rain, $SO_2(g)$ and $SO_3(g)$

- *Compound A contains:*
  1.000 g Sulfur & 1.500 g Oxygen
- *Compound B contains:*
  1.000 g Sulfur & 1.000 g Oxygen
- *Mass ratio A: 2 to 3; Mass ratio B: 1 to 1*
- *Adjusting for atomic mass differences: AW sulfur is 2x the AW oxygen; the atom ratios therefore are S_1O_3 and S_1O_2 respectively*
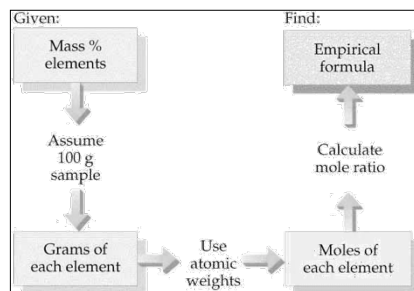
Formulas & Molecular Representations

- *molecular formula = C_6H_6 Benzene*
- *empirical formula = $CH = C_{6/6}H_{6/6}$*
- *molecular formula = (empirical formula)$_n$*
  [n = integer] $(CH)_6$

- *Other representations: Lewis Dot formulas, structural formulas, 2-D, 3-D*

Formulas & Molecular Representations

Representing Substances

Empirical Formulas from Analyses

Empirical Formula Determination

- 1. Use percent analysis.
  - Let 100 % = 100 grams of compound.
- 2. Determine the moles of each element.
  - (Element % = grams of element.)
- 3. Divide each value of moles by the smallest of the mole values.
- 4. Multiply each number by an integer to obtain all whole numbers.

QUESTION

The dye indigo is a compound with tremendous economic importance (blue jeans wouldn't be blue without it.) Indigo's percent composition is: 73.27% C; 3.84% H; 10.68%N and 12.21% O. What is the empirical formula of indigo?

A. C_6H_4NO
B. C_8H_3NO
C. C_8H_5NO
D. I know this should be whole numbers for each atom, but I do not know how to accomplish that.

Empirical & Molecular Formula Determination

The Molecular Formula is the important objective.

The Molar Mass (molecular weight) must be determined in order to reach this objective since the Molar Mass may not be equal to the Empirical formula's Mass.

The experimental process involves different processes as does the calculations.

Using mass percent data and molar mass is the most straightforward.
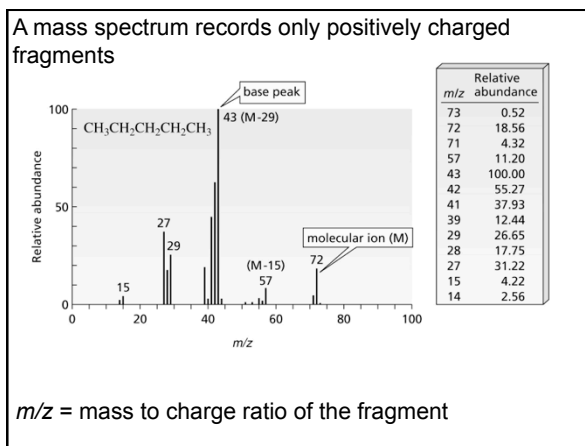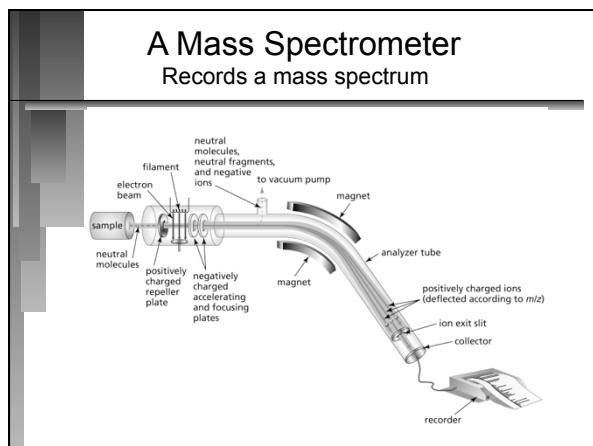
Combustion analysis is more involved.

SEE: COMPARISON of CALCULATIONS

Empirical & Molecular Formula Determination

Quinine:
- **C 74.05%, H 7.46%, N 8.63%, O 9.86%**
- **Molecular Weight = 324.42**
- **Molecular Formula = ?**

A Mass Spectrometer
Records a mass spectrum

A mass spectrum records only positively charged fragments

m/z	Relative abundance
73	0.52
72	18.56
71	4.32
57	11.20
43	100.00
42	55.27
41	37.93
39	12.44
29	26.65
28	17.75
27	31.22
15	4.22
14	2.56

m/z = mass to charge ratio of the fragment

QUESTION
http://chemconnections.org/pdb/Quinine.html

From the structures, determine the molecular formula of quinine.
A Carbon atom is at each angle.
Each C has 4 bonds (lines + Hs).
Hs are not always drawn in & must be added.

A)$C_{18}H_{24}NO_2$ B)$C_{20}H_{20}NO_3$ C)$C_{20}H_{24}N_2O_2$ D)$C_{20}H_{26}N_2O_2$

QUESTION

The empirical formula of styrene is CH; its molar mass is 104.1. What is the molecular formula of styrene?

A) C_2H_4
B) C_8H_8
C) $C_{10}H_{12}$
D) C_6H_6
E) None of these

QUESTION

Examine the condensed structural formulas shown below:

I) Acetic acid (main ingredient in vinegar), CH_3COOH

II) Formaldehyde (used to preserve biological specimens), $HCHO$

III) Ethanol (alcohol in beer and wine), CH_3CH_2OH

For which molecule(s) are the empirical formula(s) and the molecular formula(s) the same?

A) II   B) I and II   C) II and III   D) I, II, and III