Percent Composition, Empirical Formula and Molecular Formula

Percent Composition

$\frac{\text{g of one element}}{\text{total g all elements}}(100)$

From a practical point of view, find the molar mass. Put the mass of each element as the numerator, and the molar mass as the denominator.

Determine the % Composition of $Ca(OH)_2$

Ca 1x40.08=40.08
O 2x16.00=32.00
H 2x1.008= 2.016
74.10 g/mol

%Ca = 40.08(100)/74.10 = 54.09 % Ca
%O = 32.00(100)/74.10 = 43.18 % O
%H = 2.016(100)/74.10 = 2.72 % H
99.99%

Empirical and Molecular Formulas

Empirical Formula = the lowest whole number ratio of atoms in the molecule.

Molecular Formula = the actual whole number ratio of atoms in the molecule.

Examples

Compound	**Molecular Formula**	**Empirical Formula**
Water	H_2O	H_2O
Hydrogen Peroxide	H_2O_2	HO
Ethane	C_2H_6	CH_3
Benzene	C_6H_6	CH

Converting % Comp. To Empirical Formula

1. Write the % as grams.
2. G to mol for all elements.
3. Divide by the smallest # of moles.
4. Round to nearest whole # if within + or - .1 from whole number.
5. Multiply all elements by a factor to produce whole #'s (if needed).
6. Convert ratio to formula.

Find the empirical formula of a substance that is 75% C and 25% H.

75 g C| 1 mol C = 6.24 mol C
| 12.01 g C

25 g H| 1 mol H = 24.80 mol H
| 1.008 g H

6.24 mol C/6.24 mol = 1 C

24.80 mol H/6.24 mol = 3.97 H = 4 H

Empirical Formula is CH_4

Find the empirical formula of a compound that is 2.374% H, 14.14% C and 83.48% Cl.

2.374 g H | 1 mol H = 2.355 mol H
| 1.008 g H

14.14 g C | 1 mol C = 1.177 mol C
| 12.01 g C

83.48 g Cl | 1 mol Cl = 2.355 mol Cl
| 35.45 g Cl

2.355 mol H = 2 H
1.177 mol

1.177 mol C = 1 C
1.177 mol

2.355 mol Cl = 2 Cl
1.177 mol

Empirical Formula is CH_2Cl_2.

Determine the empirical formula of a compound that is 18.01% C, 2.267% H and 79.73% Cl.

18.01 g C | 1 mol C = 1.500 mol C
| 12.01 g C

2.267 g H | 1 mol H = 2.249 mol H
| 1.008 g H

79.73g Cl | 1 mol Cl = 2.249 mol Cl
| 35.45 g Cl

1.500 mol C/1.500 mol = 1 C

2.249 mol H/1.500 mol = 1.499 H

2.249 mol Cl/1.500 mol = 1.499 Cl

Multiply all values by 2 to get whole numbers.

2 C, 2.998 H = 3 H & 2.998 Cl = 3 Cl

Empirical formula is $C_2H_3Cl_3$

1 C

1.333 H

1.333 Cl

Multiply all values by 3 to get whole numbers.

3 C, 3.999 H = 4 H & 3.999 Cl = 4 Cl

Empirical formula is $C_3H_4Cl_4$

Molecular formula from empirical formula

The molecular formula is always a multiple of the empirical formula, and the molar mass of the real compound is always a multiple of the molar mass for just the empirical formula.

Hydrogen peroxide is H_2O_2 with a molar mass of 34.02 g/mol. The empirical formula is HO with a molar mass of 17.01 g/mol.

34.02/17.01 = 2 which is the ratio between the molecular formula and the empirical formula.

Empirical formula is CH. Molar mass of molecule is 78 g/mol. Find molecular formula.

- 78/13 = 6
- CH times 6 = C_6H_6.

- Molar mass of molecule is between 135 and 155. Empirical formula is CHO.
- What is molar mass of CHO?
- 29.02
- 135/29.02 = 4.65
- 155/29.02 = 5.34
- What is the whole number in this range? 5
- Molecular formula is 5 times CHO or $C_5H_5O_5$.

Hydrates

- Hydrates are solids with water trapped in the crystal in an organized pattern.
- The formula without the water is called the anhydrate, or it is "anhydrous".
- The formula of the hydrate includes a "•", number and H_2O.
- For example $MgSO_4 \cdot 2H_2O$

Hydrates

- Molar mass of the hydrate is the molar mass of the anhydrate plus the waters of hydration.
- Hydrate = $MgSO_4 \cdot 2H_2O$
- Anhydrate = $MgSO_4$
- 2 waters of hydration
- Molar mass of $MgSO_4$ = 120.38
- Add 2 x 18.02 = 36.04 to 120.38 to get 156.42

Mg = 24.31 = 24.31
S = 32.07 = 32.07
O = 4 x 16.00 = 64.00
=120.38

% of water

Mass of waters of hydration x 100
Molar mass of the hydrate

36.04 (100) = 23% water
156.42