

ChemActivity 31

Empirical Formula

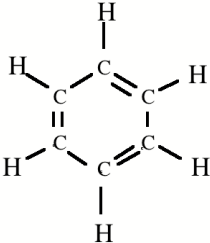
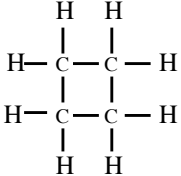
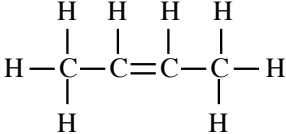
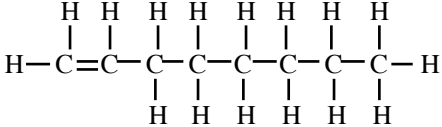
(Can a Molecule Be Identified by Its Percent Composition?)

Model: Percent Composition.

The **percent composition** (by mass) of an element in a molecule is the mass of the element in the molecule divided by the mass of the entire molecule times 100. Or, because the number of atoms (molecules) is proportional to the number of moles of atoms (molecules),

$$\text{percent composition of element } i = \frac{\text{mass of } i \text{ in one mole of the compound}}{\text{mass of one mole of the compound}} \times 100\%$$

Table 1. Percent composition (by mass) of some common organic molecules.

Name	Structural Formula	Molecular Formula	% Composition (by mass)	
			C	H
ethyne	$\text{HC}\equiv\text{CH}$	C_2H_2	92.26	7.74
benzene				
cyclobutane		C_4H_8		
2-butene			85.63	
1-octene				

Critical Thinking Questions

1. Verify that the % composition given for ethyne in Table 1 is correct.
2. Fill in the missing molecular formulas and % compositions in Table 1.
3. Is it possible, given the original data in Table 1, to determine the % composition by mass of H for 2-butene without using the equation given in the model? If so, how?
4. Based on the data in Table 1, is it possible to determine the *molecular* formula of a compound solely from its percent composition? Why or why not?
5. What feature related to composition do all compounds with the same % composition have?

Information

The **empirical formula** of a compound describes the relative number of each type of atom in the compound. It is given in terms of the smallest-possible-whole-number ratios (as subscripts). For example, the empirical formula of ethane, C_2H_6 , is CH_3 . (Note that the subscript "1" is omitted.)

Critical Thinking Questions

6. What feature related to the composition of a compound can be determined solely by percent composition?
7. Determine the empirical formula of each of the molecules in Table 1.

Exercises

1. The molecule 2-hexene has the molecular formula C_6H_{12} . Refer to Table 1 and determine the percent composition of H in this molecule.
2. Determine the percent composition of each element in acetic acid, CH_3COOH .
3. A molecule containing only nitrogen and oxygen contains (by mass) 36.8% N.
 - a) How many grams of N would be found in a 100 g sample of the compound?
How many grams of O would be found in the same sample?
 - b) How many moles of N would be found in a 100 g sample of the compound?
How many moles of O would be found in the same sample?
 - c) What is the ratio of the number of moles of O to the number of moles of N?
 - d) What is the empirical formula of the compound?
4. A compound used as a dry-cleaning fluid was analyzed and found to contain 18.00% C, 2.27% H, and 79.73% Cl. Determine the empirical formula of the fluid.
5. J. N. Spencer, G. M. Bodner, and L. H. Rickard, *Chemistry: Structure & Dynamics*, Fourth Edition, John Wiley & Sons, 2009. Chapter 1: Problems: 135, 137, 139, 145, 146, 149, 150, 152, 153, 155, 157, 165, 166, 169, 171.

Problems

1. Indicate whether the following statement is true or false and explain your reasoning.

All compounds with the same empirical formula are isomers of each other.
2. An unknown liquid contains 38.7% C and 51.6% O by mass. The remainder of the compound is H. What is the empirical formula of the compound?
3. A compound containing only P, O, and Zn is used as a dental cement. A sample of the cement is analyzed and gives 33.16% O and 16.04% P. Determine the empirical formula of the cement.