Using Moles with Formulas

Name: ____________________________

Date: _______________

Hour: _____

Information: Percent Composition

Sometimes it is needful to know the composition of a compound. For example, 39.3% of the mass of sodium chloride is due to sodium. The other 60.7% of the mass is from chlorine. So, in a 100 g sample of sodium chloride, there are 39.3 g of sodium and 60.7 g of chlorine. This type of data is known as percent composition. The percent composition tells you the percentage by mass of an element in a compound. There is a convenient formula for finding the percent composition of an element in a compound:

$$\text{percent composition of element "X"} = \frac{\overbrace{\text{mass of x in one mole of the compound}}^{\text{(obtained from periodic table)}}}{\underbrace{\text{mass of one mole of the compound}}_{\text{(obtained from periodic table)}}} \bullet 100$$

Let us look at how the percent composition of calcium (Ca) in calcium chloride ($CaCl_2$) was determined.

$$\text{percent composition of Ca} = \frac{\text{mass of Ca in one mole of } CaCl_2}{\text{mass of one mole of } CaCl_2} \bullet 100$$

$$\text{percent composition of Ca} = \frac{\overbrace{40.1\text{ g}}^{\text{from periodic table for calcium}}}{\underbrace{111.1\text{ g}}_{\text{from periodic table for calcium + 2 chlorines; } 40.1 + 2(35.5) = 111.1}} \bullet 100 = 36.1\%$$

As another example, consider calculating the percent composition of nitrogen in Ca_3N_2:

$$\text{percent composition of N} = \frac{\overbrace{28.0\text{ g}}^{\text{From periodic table for 2 nitrogen atoms: } 2(14.0)=28.0}}{\underbrace{148.3\text{ g}}_{\text{from periodic table for 3 calcium + 2 nitrogen atoms } 3(40.1) + 2(14.0) = 148.3}} \bullet 100 = 18.9\%$$

Critical Thinking Questions

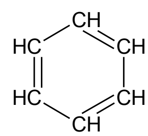
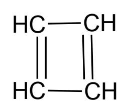
Note: For the following questions use 12.0 g/mol for the molar mass of carbon and 1.01 g/mol for the molar mass of hydrogen. These values can be found on the periodic table.

1. Verify that in C_4H_{10} the percent composition of carbon is approximately 82.6%.

2. Calculate the percent composition of sodium in Na_2S.

Information: Formulas and Percent Composition

Table 1: Percent composition and formulas of some compounds.

Name	Structural Formula	Molecular Formula	% Comp. of H	% Comp. of C
Hexene	$H_2C{=}CH{-}CH_2{-}CH_2{-}CH_2{-}CH_3$	C_6H_{12}	14.4	85.6
Propene	$H_2C{=}CH{-}CH_3$			
Benzene		C_6H_6		
Cyclobutadiene			7.8	
1,5-hexadi-yne	$HC{\equiv}C{-}CH_2{-}CH_2{-}C{\equiv}CH$			

Critical Thinking Questions

3. Verify that the percent composition of C and H given for hexene in Table 1 are correct.

4. Fill in the blanks in Table 1 by determining the percent composition and the molecular formulas of each compound.

5. Can you determine a compound's structural formula if you are given the molecular formula? Explain.

6. What is true about the percent composition of two different compounds that each have the same ratio of carbon to hydrogen?

7. Can you determine a molecule's molecular formula solely from the percent composition? Explain.

8. It is possible to complete the following table using only the information in Table 1 without the aid of a calculator or periodic table. Try it! (Hint: consider question #6.)

Molecular Formula	% Composition of H	% Composition of C
C_8H_8		
$C_{10}H_{20}$		

Information: Empirical Formulas

An empirical formula is a formula that describes the lowest whole-number ratio of elements in a compound. An example of an empirical formula is CH, which is the empirical formula for benzene whose molecular formula was given in Table 1.

Critical Thinking Questions

9. What is the empirical formula of a compound whose percent composition is 92.2% carbon and 7.8% hydrogen? (See question 8 and Table 1)

10. Verify that the empirical formula for hexene (see Table 1) is CH_2.

Information: Calculating the Empirical Formula

When you know the percent composition of each element in a compound, you can calculate the empirical formula of that compound. The following example will illustrate how to do this.

Example 1: A certain compound is 30.4% nitrogen and 69.6% oxygen by mass. What is the empirical formula of the compound?

Step #1: Divide each percentage by the molar mass from the periodic table:

For Nitrogen: $\frac{30.4}{14.0} = 2.17$ For Oxygen: $\frac{69.6}{16.0} = 4.35$

From the periodic table for nitrogen and oxygen

Step #2: Find the ratio of nitrogen to oxygen. To do this, find the smallest answer obtained in step #1. In this example, the smallest answer is 2.17. Now divide each of your answers to step #1 by this smallest number. In this example, you should divide each answer by 2.17:

For Nitrogen: $\frac{2.17}{2.17} = 1.00$ For Oxygen: $\frac{4.35}{2.17} = 2.00$

Step #3: Write the formula. The answers from step #2 are the subscripts in the formula! The formula is NO_2.

If in step #2 you get something like Nitrogen = 1.00 and Oxygen = 2.50 then the formula you write in step #3 would be $NO_{2.5}$. This doesn't make sense because all subscripts must be whole numbers. You would need to double *each* subscript. The formula would be $N_{1x2}O_{2.5x2}$ = $\mathbf{N_2O_5}$.

Critical Thinking Questions

11. Find the empirical formula for a compound that contains 82.4% nitrogen and 17.6% hydrogen.

Information: Calculating the Molecular Formula from the Empirical Formula

Remember that the empirical formula is just a simplification of the molecular formula. For example, consider the empirical formula NO. There are several possible molecular formulas including: N_2O_2, N_3O_3, N_4O_4, etc. Which one is it? Notice that the possible formula N_2O_2 is made up of two of the empirical formulas, NO. Similarly, N_3O_3 is made up of three of the empirical formulas, NO. How do we know which empirical formula is correct? All you need is the molar mass or molecular mass of the molecular formula.

Critical Thinking Questions

12. The empirical formula for a certain compound is NO. The <u>molar mass</u> of the compound is 60.0 g/mol.
    a) What is the molar mass of the empirical formula? (Use the periodic table.)

    b) Divide the molar mass of the compound (given in the question) by the molar mass of the empirical formula found in part a.

    c) Your answer to part b tells you how many empirical formulas are in the molecular formula. You now should be able to write the correct molecular formula, which is N_2O_2. Verify that the correct molecular formula is N_2O_2.

13. a) What is the empirical formula of a compound whose percent composition by mass is 85.7% carbon and 14.3% hydrogen?

    b) If the compound has a molar mass of 56 g/mol, what is the molecular formula? (Follow the steps from question 12abc.)