U6LM2B-WS- Empirical and Molecular Formulas   Name: ______KEY_______

1. The empirical formula of a compound is also called the **simplest** formula. It represents the **relative or smallest whole-number ratio of atoms in a cmpd.**

2. The molecular formula represents the **actual number of atoms of each element in a molecule of the compound.**

3. The empirical formula and the molecular formula are mathematically related as follows:

   Molecular formula = **n x empirical formula.**

4. Can the molecular formula be the same as the empirical formula? Explain.
   Yes. The molecular and empirical formula may be the same when the molecular formula does not have subscripts that can be reduced (ex: formaldeyhyde,CH_2O). They are different in any case where the molecular formula may be reduced to a smaller whole-number ratio of elements (ex: acetic acid, $C_2H_4O_2$ has the same empirical formula as formaldehyde, CH_2O).

5. The molecular formula for glucose is $C_6H_{12}O_6$.
   a. What is its empirical formula? **CH_2O**
   b. The molecular formula of glucose, $C_6H_{12}O_6$ = **6 x CH_2O**
   c. The molecular weight of glucose is **180 $^g/_{mol}$.** It is equal to **6 x 30 $^g/_{mol}$.**

6. The molecular formula of benzene is C_6H_6.
   a. What is its empirical formula? **CH**
   b. The molecular formula of benzene, C_6H_6 = **6 x CH**

7. The empirical formula of a compound is NH, and its molecular weight is 30.0 amu.

   What is its molecular formula? **N_2H_2**

   NH =15 $^g/_{mol}$.

   n = 30.0 $^g/_{mol}$ ÷ 15.0 $^g/_{mol}$ = 2   ∴   2 x NH = **N_2H_2**

8. The empirical formula of a compound is CH_3. Its molecular weight is 30.0 amu.

   What is its molecular formula? **C_2H_6**

   CH_3 =15 $^g/_{mol}$.

   n = 30.0 $^g/_{mol}$ ÷ 15.0 $^g/_{mol}$ = 2   ∴   2 x CH_3 = C_2H_6

9. A compound is 81.7% carbon and 18.3% hydrogen.

   a. What is its empirical formula? **C_3H_8**

      Assume 100g of the compound to simplify the problem.

      81.7g C x (1 mol C / 12.01g C) = 6.803 mol C … divide both by 6.803 to reduce the ratio = 1 mol C

      18.3g H x (1mol H / 1.01g H) = 18.12 mol H … to 2.663 mol H

      Multiplying by 3 will give the smallest whole number ratio: 3 ($C_1H_{2.663}$) = C_3H_8

   b. The formula weight of this compound is 44.0 amu. Is the molecular formula different than the empirical formula? **No.** The mass of the empirical formula above is 44.0 g/mol, so the empirical and molecular formulas are the same.

10. Butyric acid is 54.5% carbon, 9.09% hydrogen and 36.4% oxygen.

   a. What is its empirical formula? **C_2H_4O**

      54.5g C x (1 mol C / 12.01g C) = 4.538 mol C … divide all by 2.275 to reduce the ratio = 1.995 mol C

      9.09g H x (1mol H / 1.01g H) = 9.000 mol H … to 3.956 mol H

      36.4g O x (1mol H / 16.00g H) = 2.275 mol O … to 1 mol O

      This gives the smallest whole number ratio: C_2H_4O

   b. Its molar mass is 88.0 g/mol. What is the molecular formula of butyric acid? **$C_4H_8O_2$**

      Empirical molar mass = 44. g/mol n = 88.0 $^g/_{mol}$ ÷ 44.0 $^g/_{mol}$ = 2 ∴ 2 x C_2H_4O = $C_4H_8O_2$

11. Isopropyl alcohol contains C, H, and O. When we burn 11.63 g of this compound, the products are 25.5 g CO_2 and 14.0 g H_2O.

	$C_xH_yO_z$ + O_2 →	CO_2	+	H_2O
	11.63g	25.5g		14.0g
Convert to moles:	? ? ?	0.5795mol		0.7778mol

   a. What is the empirical formula? **C_3H_8O**

      You can assume all the moles of C and all the moles of H came from the isopropanol.

      0.5795 mol C x (12.01g C / 1 mol C) = 6.96g carbon

      0.7778 mol H_2O x (2 mol H / 1 mol H_2O) = **1.5556mol H** …x (1.01 g H / 1 mol H) = 1.57 g hydrogen

      11.63g total – (6.96g C + 1.57g H) = 3.10g oxygen … (1 mol O / 16.00g O) = **0.1937 mol O**

      Dividing all moles by 0.1937 to reduce the ratio gives: C_3H_8O

   b. The molar mass of the alcohol is 60.0 g/mol. What is its molecular formula? **C_3H_8O**

      The molar mass of the empirical formula C_3H_8O *is* 60.0 g/mol, so the molecular formula is the same.

12. The complete combustion of a 0.5728 g sample of a compound that contains only C, H, and O produced 0.840 g of carbon dioxide and 0.254 g of water. The molar mass of the compound was determined to be about 60.0 g/mol.

What is the molecular formula of this compound? **$C_2H_3O_2$**

	$CxHyOz$ + O_2 →	CO_2 +	H_2O
	0.5728g	0.840g	0.254g
Convert to moles:	? ? ?	0.01909mol	0.01410mol

0.01909 mol C x (12.01g C / 1 mol C) = 0.2293g carbon

0.01410 mol H_2O x (2 mol H / 1 mol H_2O) = **0.02819mol H** …x (1.01 g H / 1 mol H) = 0.02847 g hydrogen

0.5728g total – (0.2293g C + 0.02847g H) = 0.3151g oxygen … (1 mol O / 16.00g O) = **0.01969 mol O**

Dividing all moles by 0.01909 to reduce the ratio gives: $C_1H_{1.48}O_{1.06}$

Multiplying by 2 will give the smallest whole number ratio: 2 ($C_1H_{1.48}O_{1.06}$) = $C_2H_3O_2$

Empirical molar mass = 59 g/mol, which is approximately 60 g/mol ∴ the molecular formula is the same.