Name _____
Team No. _____ **Section** _____

ALE 11. Molar Mass, Empirical Formula, & Percent Composition

How much does one mole of a compound weigh?

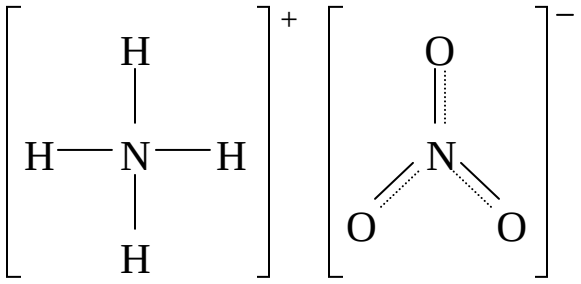
The Model: Molar Masses

(Reference: Section 3.1 in *Silberberg 5th ed.*)

Molar Mass of X = mass in grams of 1 mole of formula units of X

Key Questions

1. The formula unit of ammonium nitrate may be represented by what is shown on the right.



2. What is the "molecular formula" of ammonium nitrate? _____
3. Within 1 mole of ammonium nitrate formula units how many moles of
   - hydrogen atoms are there? _____ mol H
   - nitrogen atoms are there? _____ mol N
   - oxygen atoms are there? _____ mol O
4. What is the molar mass (the mass in grams of one mole of *atoms*—i.e. the atomic mass in grams) for each of the following? Consult the Periodic Table and report the molar masses to 2 decimal places using the units of molar mass, g/mol.
   - hydrogen, H _____
   - nitrogen, N _____
   - oxygen, O _____

a. What is the mass (in grams) of exactly 4 moles of hydrogen *atoms*?

b. What is the mass (in grams) of exactly 2 moles of nitrogen *atoms*?

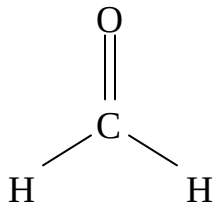
c. What is the mass (in grams) of exactly 3 moles of oxygen *atoms*?

d. If 4 moles of hydrogen atoms were chemically combined with 2 moles of nitrogen atoms and 3 moles of oxygen atoms, what would the total mass in grams be? (Assume 4, 2 and 3 moles are have no uncertainty—i.e. they are exact numbers)

e. What is the *molar mass* of ammonium nitrate (in g/mol)?

The Model: Empirical Formulas and Percent Composition

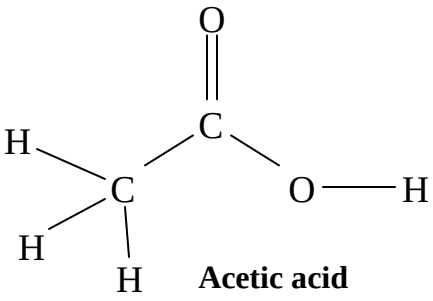
(Reference: Section 3.2 in *Silberberg 5th ed.*)



Formaldehyde

Molecular formula: CH_2O

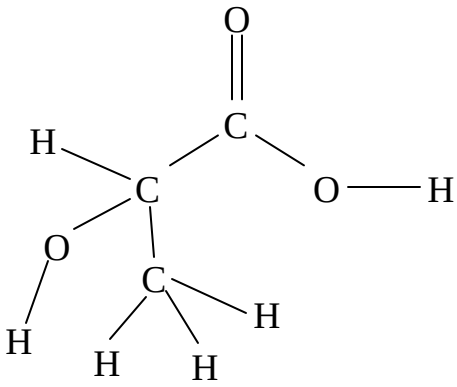
Empirical formula: CH_2O



Acetic acid

Molecular formula: $C_2H_4O_2$

Empirical formula: CH_2O



Lactic acid

Molecular formula: $C_3H_6O_3$

Empirical formula: CH_2O

Concerning Acetic Acid:

Element	No. in Formula	Molar Mass (g/mol)	Mass Contribution (g/mol)	Fraction of Molar Mass
C	2	12.01	(2 × 12.01 =) 24.02	(24.02 / 60.05 =) 0.4000
H	4	1.008	(4 × 1.008 =) 4.032	(4.032 / 60.05 =) 0.06714
O	2	16.00	(2 × 16.00 =) 32.00	(32.00 / 60.05 =) 0.5329

Molar Mass = (24.02 + 4.032 + 32.00 =) 60.05 g/mol

Therefore, acetic acid's ***percent composition*** is 40.00% C (carbon), 6.71% H (hydrogen), and 53.29% O (oxygen).

Exercise

5. In a manner similar to what was presented in the Model, above, determine the percent composition of lactic acid.

Key Questions

6a. Compare the percent compositions of acetic acid (in the Model) and lactic acid (Exercise 5). What can you conclude about a compound's empirical formula and its percent composition?

b. Without doing any calculations, what is the percent composition of formaldehyde?

7. If you know a compound's percent composition, do you automatically know what the compound's molecular formula is? If you do, explain how. If you do not, what is the missing piece of information that would be used to determine the molecular formula?

8. What is the molar mass of CH_2O (the empirical formula of formaldehyde, acetic acid, and lactic acid)?

9a. What is the molar mass of acetic acid divided by the molar of CH_2O equal to? (The molar mass of acetic acid is provided in the Model.)

b. If you multiply the stoichiometric subscripts of CH_2O (the empirical formula of acetic acid) by the answer of Question 9a to obtain a "new" formula, what formula do you get? To which compound does this formula belong?

10a. What is the molar mass of lactic acid divided by the molar mass of CH_2O equal to? (The molar mass of lactic acid should be found in your solution of Exercise 5.)

b. If you multiply the stoichiometric subscripts of CH_2O (the empirical formula of lactic acid) by the answer of Question 10a to obtain a "new" formula, what formula do you get? To which compound does this formula belong?

Exercises

11. a. An ionic substance is found to have the % composition by mass: 82.0% mercury, 4.9% carbon, and 13.1% oxygen. What is the empirical formula of the compound? *Hints*: Since the percent composition is a percent-by-mass, it might be a good idea to start off by making an assumption about how many grams of the substance is being considered—100 g of the substance makes the calculations simpler! Keep in mind that the subscripts in a formula are *ratios* of the *number of moles of the elements* in the compound. So you will want to convert from mass to moles for each element. Also keep in mind that all subscripts in the formula must be integers. Show all work using the factor-label method and atomic masses to two decimal places.

b. The molar mass of the compound is determined to be 489.2 g/mol. Use a calculation to show what the "molecular formula" of the compound must be. *Hint*: What is the relationship between the molar mass and the molar mass of the compound's empirical formula?

c. What is the correct unambiguous name of the compound? (Recall the names of the commonly-encountered polyatomic ions.)