Avagadro's Number and The Mole

The amount of a substance which contains as many atoms (or other unit) as there are in 12 grams of carbon-12 is called a **mole**. (symbol mol) There are 6.022×10^{23} atoms of carbon in 12 grams of carbon-12. 6.022×10^{23} is referred to as **Avagadro's number.** (symbol N) Avagadro was an Italian chemist during the early 1800's. Avagadro's number can refer to any unit. When used one mole of an item will contain 6.022×10^{23} units of that item. Think of it like a measurement, like a dozen or a case.

For example: **1 mole = 6.022×10^{23} units**
a mole of donuts contains 6.022×10^{23} donuts
a mole of H_2O contains 6.022×10^{23} molecules of H_2O
a mole of copper contains 6.022×10^{23} atoms of copper
a mole of nails contains 6.022×10^{23} nails

Because we can't weigh a single atom we "count" atoms (or molecules) by weighing large amounts of them on a balance. The **molar mass,** or formula mass, of a substance is its weight in grams of one mole. (expressed grams/mole) For a single element the atomic mass is its molar mass, the molar mass of carbon is 12 g/mol. Use the following directions to determine the molar (formula) mass of a compound.

Calculating Molar Mass

1. multiply atomic mass of each element by number of atoms of that element in the formula (shown by the subscript)
2. Find the sum of all the atomic masses – this is formula mass (unit is a.m.u.)
3. Express the formula mass in grams (unit is g/mol). This is molar mass

For example: What is the molar mass of a H_2O molecule?
H = 1.01 amu x 2 = 2.02 g/mol
O = 16.00 amu x1 = 16.00 g/mol
Molar Mass of H_2O = 18.02 g/mol

- What is the molar mass of $Al(NO_3)_3$?

Al = 26.98 amu x 1 = 26.98 g/mol
N = 14.01 amu x 3 = 42.09 g/mol
O = 16.00 amu x 9 = 144.00 g/mol
Molar Mass of $Al(NO_3)_3$ = 213.07 g/mol

There are times when we can't mass the item we are measuring. Then we have to measure the molar volume. To do this we need to know that a mole of any gas occupies 22.4 liters at STP.

For example: **1 mole = 22.4 L = # of grams/mole**

- Find the number of liters in 12.00 grams of helium at STP.
  Each mole of helium weighs 4.00 grams. Use conversion factors to determine the answer:
  $12.00\text{g} \times \frac{1\text{mole}}{4.00\text{g}} \times \frac{22.4\text{ L}}{1\text{ mole}} = 67.2\text{ L}$

- Find the number of grams in 11.2 L of water vapor.

$$11.2\text{L} \times \frac{1\text{ mole}}{22.4\text{ L}} \times \frac{18.02\text{g}}{1\text{ mole}} = 9.01\text{ g of water vapor}$$

Practice: Complete the following molar mass and volume questions. (use conversion factors and unit cancellation)

1. grams in 2.5 moles of calcium

2. atoms in 200 L of fluorine atoms

3. grams in 4 moles of Al

4. grams and moles in 3.10×10^4 atoms of sulfur

5. grams in 6.0 L of oxygen gas

6. atoms in 35 grams of water

7. moles and grams in 3.011×10^{16} atoms of zinc

8. grams and moles in 6.022×10^{23} atoms of silicon

9. liters in 0.500 moles of chlorine gas

10. moles in 180 grams of calcium bicarbonate

Percent Composition

As John Dalton had predicted in his atomic theory of matter there is a definite ratio of elements in a compound. When compared to the formula mass the mass of each element can be expressed as a percentage. Use the following directions to help you determine the percent composition from a formula or from the masses of each element.

Calculating % Composition

1. calculate formula mass
2. divide the total atomic mass of each element by the formula mass and multiply by 100

For example: What is the percent composition of water?

From our previous work we know the formula mass of water is 18.02 grams.

% H(2) = 2.02 g ÷ 18.02 g x 100 = 11% hydrogen
% O = 16.00g ÷ 18.02g x 100 = 89% oxygen

Find the percent composition for CH_2O (first determine formula mass).

%C = 12.01g ÷ 30.03g x 100 = 40%
% H(2) = 2.02g ÷ 30.03g x 100 = 7%
% O = 16.00g ÷ 30.03g x 100 = 53%

Practice: Determine the percent composition for the following compounds.

1. HCl
   %H =
   % Cl =

2. $AgNO_3$
   % Ag =
   % N =
   % O =

3. $BaCrO_4$
   % Ba =
   % Cr =
   % O =

4. $ZnSO_4$
   % Zn =
   % S =
   % O =

5. $KClO_4$
   % K =
   % Cl =
   % O =

6. $Fe(OH)_3$
   % Fe =
   % O =
   % H =

Name: _____ **Period:** ___ **Date:** _____

Homework: Avagadros Number and the Mole

Show your work on a separate sheet of paper.

Determine the molar (formula) mass for the following.

1. HNO_3

2. Fe_2O_3

3. H_3PO_4

4. Ammonium nitrate

5. Rubidium sulfite

Complete the following molar mass and volume questions.
(use conversion factors and unit cancellation)

6. Molecules in 46.6 grams of sodium phosphite

7. Moles and grams in 12.04×10^{23} molecules of silver bromide

8. Moles in 20.45 grams of calcium sulfate

9. Moles in 250.2 grams of iron (III) oxide

10. Molecules in 25.9 grams of sulfur dioxide

11. Liters in 68.3 grams of hydrogen sulfide gas

12. Molecules in 48.0 liters of chlorine gas

13. Grams in 4.86×10^{19} molecules of mercurous sulfide

14. Moles in 50.4 grams of zince oxide

15. Liters in 60.0 grams of neon

Calculate the percent composition of the following.

16. CH_3NH_2 (methylamine)

17. C_6H_6 (benzene)

18. AgCl (silver chloride)

19. NaOH (sodium hydroxide)

20. C_3H_8 (propane)

21. $CuSO_4$ (copper (II) sulfate)

22. $C_2H_6O_2$ (ethandiol)

23. $CHCl_3$ (chloroform)

24. Br_3HSi (tribromosilane)

25. HNO_3 (aq) (nitric acid)

Complete the following multiple choice questions.

____ 26. Which of the following elements is the base for the scale used for expressing atomic mass?
a. hydrogen-1 b. carbon-12 c. oxygen-16 d. helium-2

____ 27. A mole of O_2 gas contains 6.022×10^{23}:
a. atoms b. molecules c. pieces d. grams

____ 28. How many liters are in one mole of gas at STP?
a. 11.2L b. 22.4L c. 44.6L d. 33.3L

____ 29. Which of the following contains 4 moles of oxygen?
a. O_2 b. H_2SO_3 c. CO_2 d. $KMnO_4$

____ 30. The molar mass of a compound depends on:
a. avagadro's number
b. its empirical formula
c. the total of the masses of the elements in the compound
d. the number of atoms in a mole