Announcements for Monday, 07OCT2024

- Today’s Office Hours only until 2:30 PM
- Week 5 Homework Assignments available on eLearning
  - Graded and Timed Quiz 5 – “Periodic Trends” due **tomorrow at 6:00 PM (EDT)**

ANY GENERAL QUESTIONS? Feel free to see me after class!

Try These On Your Own

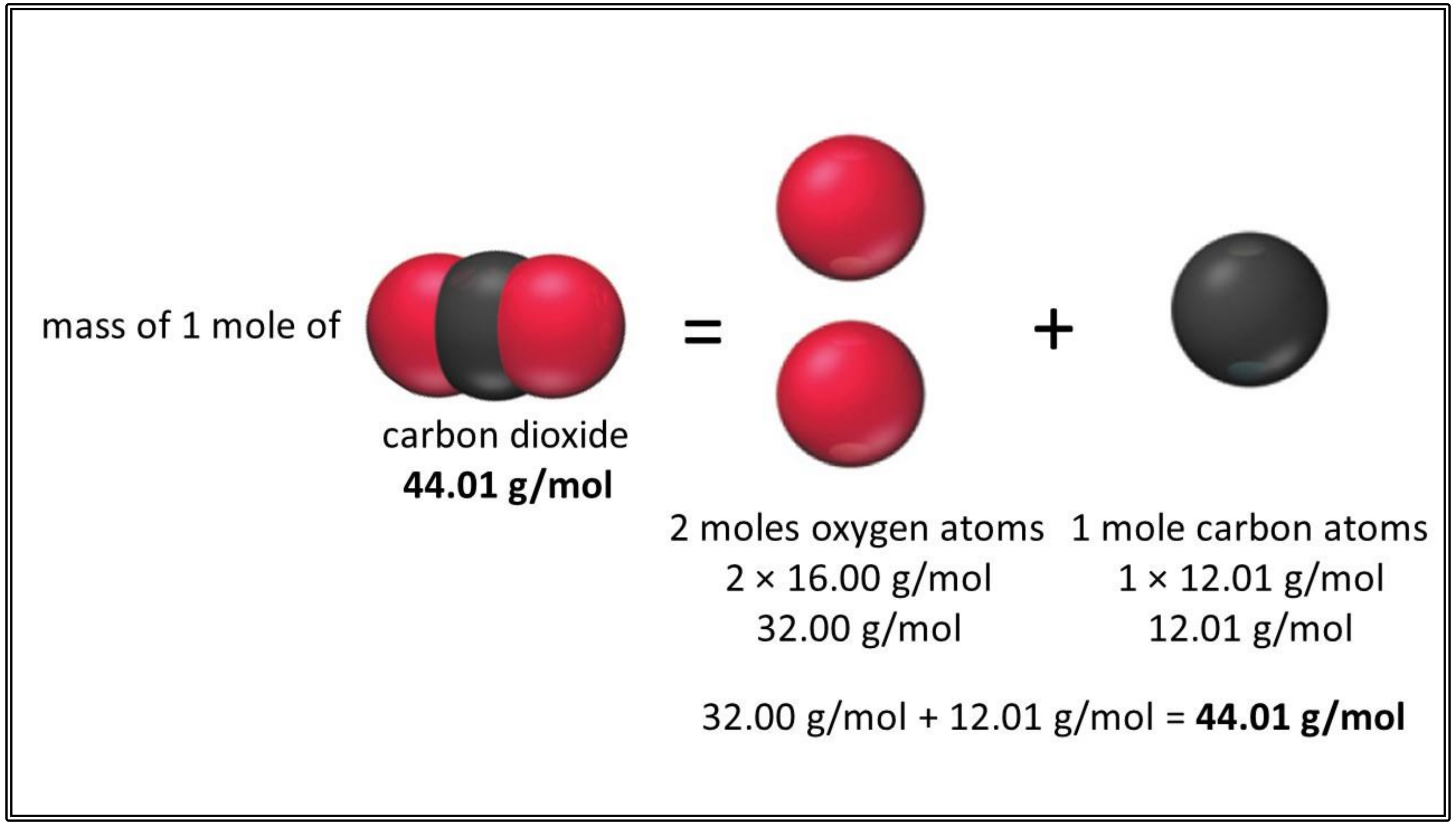
Give the formula or the name of the following:

- iodine heptachloride ICl_7
- dihydrogen monoxide H_2O
- nitrogen trihydride NH_3
- xenon tetrafluoride XeF_4
- As_4O_{10} tetraarsenic decoxide
- N_2O_5 dinitrogen pentoxide
- P_2I_4 diphosphorus tetraiodide
- NH_4NO_3 ammonium nitrate

ionic!!

Formula Mass/Molar Mass of a Compound

- **formula mass =** mass of a **single molecule** (or formula unit) in **amu**
  - add up the masses of all the atoms making up the molecule or formula unit
- **molar mass =** mass of 1 **mole of molecules** (i.e., 6.022×10^{23} molecules) or formula units in **grams**
  - add up the molar masses of all the atoms making up the molecule or formula unit



IMPORTANT! The chemical formula and molar mass of a compound are the sources of many conversion factors…

Formula Mass/Molar Mass of a Compound

- What is the molar mass of acetic acid ($C_2H_4O_2$)?

$$\underbrace{(2)(12.01\,\text{g/mol})}_{\text{molar mass carbon}} + \underbrace{(4)(1.008\,\text{g/mol})}_{\text{molar mass hydrogen}} + \underbrace{(2)(16.00\,\text{g/mol})}_{\text{molar mass oxygen}} = \mathbf{60.05\,g/mol}$$

- How many oxygen atoms are in 99.5 μg of acetic acid? **$2.00{\times}10^{18}$ O atoms**

starting unit mass acetic acid (μg) ⟶ ⟶ ⟶ **ending unit** # of oxygen atoms

$$99.5\ \mu\text{g acetic acid} \times \frac{1\ \text{g}}{10^6 \mu\text{g}} \times \underbrace{\frac{1\ \text{mol acetic acid}}{60.05\ \text{g}}}_{\text{molar mass glucose}} \times \frac{6.022\times10^{23}\ \text{acetic acid molecules}}{1\ \text{mol acetic acid}} \times \underbrace{\frac{2\ \text{oxygen atoms}}{1\ \text{acetic acid molecule}}}_{\text{from chemical formula}}$$

OR

$$99.5\ \mu\text{g acetic acid} \times \frac{1\ \text{g}}{10^6 \mu\text{g}} \times \frac{1\ \text{mol acetic acid}}{60.05\ \text{g}} \times \frac{2\ \text{mol oxygen atoms}}{1\ \text{mol acetic acid}} \times \frac{6.022\times10^{23}\ \text{oxygen atoms}}{1\ \text{mol oxygen atoms}}$$

Try These On Your Own

- What is the molar mass of glucose ($C_6H_{12}O_6$)?

- How many hydrogen atoms are in 88.0 ng glucose?

- How many molecules in 5.21 g glucose?

- A sample of glucose contains 5.55×10^{24} carbon atoms. What amount of glucose, in moles, is there?

- What amount of oxygen atoms, in moles, is in 25.0 g glucose?

- How many atoms in total are in 100.0 g glucose?

Mass Percent Composition

- like a chemical formula, it is a way of expressing the composition of a **compound**
  - ***must*** contain ***2 or more components/elements***
- recall how to calculate a regular percentage:

$$\frac{\text{part}}{\text{whole}} \times 100\%$$

- to calculate the ***mass*** % of an element in a compound:

$$\frac{\textbf{mass of the element}\text{ in 1 mole of compound}}{\textbf{mass of 1 mole of compound}} \times 100\%$$

- **What is the mass % of hydrogen in water (H_2O)?**

$$\frac{\mathbf{2 \times 1.008\ g}}{\mathbf{18.02\ g}} \times \mathbf{100\% = 11.19\%\ hydrogen\ by\ mass}$$

$$\mathbf{mass\ \%\ oxygen = 100 - 11.19 = 88.81\%\ oxygen\ by\ mass}$$

Mass Percent Composition *as a Conversion Factor*

The mass percent composition of **H_2O**:

11.19% hydrogen by mass and **88.81% oxygen** by mass

$$\frac{11.19\ \text{g hydrogen}}{88.81\ \text{g oxygen}} \qquad \frac{11.19\ \text{g hydrogen}}{100\ \text{g water}} \qquad \frac{88.81\ \text{g oxygen}}{100\ \text{g water}}$$

$$\frac{88.81\ \text{g oxygen}}{11.19\ \text{g hydrogen}} \qquad \frac{100\ \text{g water}}{11.19\ \text{g hydrogen}} \qquad \frac{100\ \text{g water}}{88.81\ \text{g oxygen}}$$

What mass of **water** is needed to provide 46.8 kg of **oxygen**?

$$46.8\ \text{kg oxygen} \times \frac{100\ \textbf{kg}\ \text{water}}{88.81\ \textbf{kg}\ \text{oxygen}} = 52.7\ \text{kg water}$$

Try This On Your Own

- Calculate the mass percent composition of all elements in 255 g of chromium(III) phosphate trihydrate

Some Practical Skills Connected with Mass Percent Composition

- You should be able to determine the mass percent composition of a compound given the compound's chemical formula.

  "Determine the mass composition of all the elements in $C_6H_{12}O_6$"

- You should be able to use mass percent information as conversion factors to determine the mass of an element in a given sample of compound (and vice versa).

  "Water is 88.8% oxygen by mass. What mass of water contains 75.0 g hydrogen?"

We see that we can "convert" a chemical formula into a mass percentage. Can we do the opposite and establish a compound's chemical formula from its mass percent composition?

Yes…sort of

Experimentally Determining Chemical Formulas – an Overview

in the lab, different complementary techniques are used to establish the chemical formula of an unknown compound

- decomposing a compound into constituent elements to get mass % data OR
- combustion analysis

- from the mass percent composition, only the ***empirical formula*** of a compound can be *directly* determined

- mass spectrometry
  - a technique that allows us to determine the molar mass/formula mass of a compound

★ the molar mass, combined with an empirical formula, can be used to determine the ***molecular formula*** of a compound

Determining Empirical Formula from Mass Data

The Goal: figure out the total number of atoms of each element in the compound and express the ratio of atoms in lowest whole-number possible

- masses need to be converted into amounts/numbers of atoms since an empirical formula is a **ratio of amounts** *not a ratio of masses*

mass percentage of compound → masses of each component → moles of each component → express ratio in lowest whole-number

Determining Empirical Formula from Mass Data (continued)

The mass percent composition of a compound is 81.71% C and 18.29% H.
Determine the empirical formula

Assume 100 g of compound

$$81.71 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 6.80 \text{ mol C}$$

$$18.29 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 18.1 \text{ mol H}$$

$$C_{\frac{6.80}{6.80}} H_{\frac{18.1}{6.80}}$$

$$C_{1} H_{2.66}$$

$\times 3$ $\times 3$

$$\boxed{C_3H_8}$$

Fractional Subscript	Multiply by This
0.20	5
0.25	4
0.33	3
0.40	5
0.50	2
0.66	3
0.75	4
0.80	5

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Try This

25.00 g of a pure ionic compound composed of Mg, C, and O contains 1.785×10^{23} magnesium ions and 3.56 g carbon. Determine the empirical formula of this compound and name it.

$$1.785 \times 10^{23}\ \text{Mg} \times \frac{1\ \text{mol Mg}}{6.022 \times 10^{23}\ \text{Mg}} = 0.2964\ \text{mol Mg} \times \frac{24.31\ \text{g}}{1\ \text{mol Mg}} = 7.206\ \text{g Mg}$$

$$3.56\ \text{g C} \times \frac{1\ \text{mol C}}{12.01\ \text{g C}} = 0.2964\ \text{mol C}$$

$$25.00\ \text{g sample} - 7.206\ \text{g Mg} - 3.56\ \text{g C} = 14.23\ \text{g O} \times \frac{1\ \text{mol O}}{16.00\ \text{g O}} = 0.8894\ \text{mol O}$$

$$\text{Mg}_{\frac{0.2964}{0.2964}}\ \text{C}_{\frac{0.2964}{0.2964}}\ \text{O}_{\frac{0.8894}{0.2964}}$$

$$1 \qquad 1 \qquad 3$$

$$\text{MgCO}_3\ \ \text{magnesium carbonate}$$