Announcements

Wednesday, September 23, 2009

MasteringChemistry due dates (all at 11:59 pm):

- Ch 3: Fri, Sep 25

Exam 1: next Mon, Sep 28.

- 20-25 multiple choice questions
- Short answer (naming, chemical equations)
- 2 show your work problems

For exam practice:

- Practice exams on webpage
- End-of-chapter problems (check answers in back of book)
- Rework MasteringChemistry exercises for practice (without using hints)

Mass percent as a conversion factor

If you're given a mass percent, you can use it as a conversion factor between the element and the compound

whole sample

A 3.5 kg sample is found to contain 2.6% Pb. How many grams of lead are present?

Mass percent = per 100 grams

100 g sample : 2.6 g Pb ← conversion factor

$$3.5\,\cancel{kg\ sample} \times \frac{1000\,\cancel{g\ sample}}{1\,\cancel{kg\ sample}} \times \frac{2.6\,g\,Pb}{100\,\cancel{g\ sample}} = \boxed{91\,g\,Pb}$$

Conversion factors from chemical formulas

Chemical formulas give the ratio of atoms in a compound

- This can also be used to construct **mole ratios**

1 mol $Fe_2(SO_4)_3$ contains: 2 mol Fe

3 mol S

12 mol O

assume 1 mol of compound

use subscripts in chemical formula

How many O atoms are in 8.6 mol $Fe_2(SO_4)_3$?

$$8.6\ \cancel{\text{mol } Fe_2(SO_4)_3} \times \frac{12\ \cancel{\text{mol O}}}{1\ \cancel{\text{mol } Fe_2(SO_4)_3}} \times \frac{6.022E23\ \text{O atoms}}{1\ \cancel{\text{mol O}}} = \boxed{6.2E25\ \text{O atoms}}$$

How many grams S are in 2.50 mol $Fe_2(SO_4)_3$?

$$2.50\ \cancel{\text{mol } Fe_2(SO_4)_3} \times \frac{3\ \cancel{\text{mol S}}}{1\ \cancel{\text{mol } Fe_2(SO_4)_3}} \times \frac{32.07\text{ g S}}{1\ \cancel{\text{mol S}}} = \boxed{241\text{ g S}}$$

How many grams Fe are in 18.25 g $Fe_2(SO_4)_3$?

to convert from mass compound to g element, use

mass cpd → mol cpd → mol element → mass element

(g) MM mol ratio MM (g)

$$18.25\ \cancel{\text{g } Fe_2(SO_4)_3} \times \frac{1\ \cancel{\text{mol } Fe_2(SO_4)_3}}{399.91\ \cancel{\text{g } Fe_2(SO_4)_3}} \times \frac{2\ \cancel{\text{mol Fe}}}{1\ \cancel{\text{mol } Fe_2(SO_4)_3}} \times \frac{55.85\text{ g Fe}}{1\ \cancel{\text{mol Fe}}} = \boxed{5.097\text{ g Fe}}$$

Determining a chemical formula from element masses

You are given:

- the elements present in a compound
- masses OR mass percentages of elements

You can calculate:

- The empirical formula

A compound made of C, H, and O is found to contain 68.8% C, 5.0% H, and 26.2% O. What is the empirical formula?

1. If given percentages, convert them to grams per 100 g sample. If you're missing one element's mass, subtract from a given total mass.

   68.8 g C , 5.0 g H , 26.2 g O

2. Convert each mass to moles using the molar mass of elements

   $$68.8\text{ g C} \times \frac{1\text{ mol C}}{12.01\text{ g C}} = 5.729\text{ mol C}$$

   $$5.0\text{ g H} \times \frac{1\text{ mol H}}{1.008\text{ g H}} = 4.9603\text{ mol H}$$

   $$26.2\text{ g O} \times \frac{1\text{ mol O}}{16.00\text{ g O}} = 1.6375\text{ mol O}$$

3. Use moles to make a formula, divide by smallest numbe

   $$C_{\frac{5.729}{1.6375}} H_{\frac{4.9603}{1.6375}} O_{\frac{1.6375}{1.6375}} \cong C_{3.5}H_3O$$

4. Make the subscripts whole numbers by multiplying all by 2, 3, 4, or 5. $C_{3.5}H_3O \times 2 = \boxed{C_7H_6O_2}$

Calculating molecular formulas

You are given:
- empirical formula
- molar mass

You can calculate:
- molecular formula

Molecular formulas are always whole-number multiples of empirical formulas

$(CH_2)_3 = C_3H_6$

Molecular: C_3H_6 Empirical: CH_2

1 : 2

$(CH_2) \times n = C_nH_{2n}$ - For this molecule, $n = 3$

$$\frac{C_3H_6 \text{ formula mass} = \cancel{47.028}\ 42.078 \text{ g/mol}}{CH_2 \text{ formula mass} = 14.026 \text{ g/mol}} = n = 3$$

Mass spectrometry can be used to determine molar mass of a compound experimentally.

A compound with empirical formula of CH_2O has a molar mass of 60.05 g/mol. What is its molecular formula?

$$n = \frac{\text{molar mass}}{\text{empirical formula mass}} = \frac{60.05 \text{ g/mol}}{30.026 \text{ g/mol}}$$

$= 2$

emp.

$CH_2O \times 2 = \boxed{C_2H_4O_2}$

Combustion analysis

Combustion: compound + $O_2 \rightarrow CO_2 + H_2O$

You are given:
- masses of CO_2 and H_2O produced
- which elements are in the sample
- total sample mass (if elements other than C and H present)

You can calculate:
- empirical formula
- (molecular formula if a molar mass is given)

total sample mass

A 4.30 mg sample containing C, H, and O produces 8.59 mg CO_2 and 3.52 mg H_2O upon combustion. What is its empirical formula?

1. Convert masses of CO_2 and H_2O to mol C and mol H

$$8.59 \text{ mg } CO_2 \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{1 \text{ mol C}}{1 \text{ mol } CO_2} = \boxed{1.952E-4 \text{ mol C}}$$

$$3.52 \text{ mg } H_2O \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol } H_2O}{18.016 \text{ g } H_2O} \times \frac{2 \text{ mol H}}{1 \text{ mol } H_2O} = \boxed{3.908E-4 \text{ mol H}}$$

2. If elements other than C and H, calculate masses of C and H, subtract from the total to get mass of other element, and calculate moles of the other element.

$$1.952E-4 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 2.344E-3 \text{ g C}$$

$$3.098E-4 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 3.939E-4 \text{ g H}$$

$$4.30E-3 \text{ g total} - (2.344E-3 \text{ g} + 3.939E-4 \text{ g}) = 1.562E-3 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}}$$

$\boxed{9.763E-5 \text{ mol O}}$

3. Use moles of each element to calculate the empirical formula as before.

$$C_{\frac{1.95E-4}{9.76E-5}} H_{\frac{3.90E-4}{9.76E-5}} O_{\frac{9.76E-5}{9.76E-5}} = \boxed{C_2H_4O}$$

Difficult combustion problem

A 6.54 mg sample of a compound containing C, H, N, and O produced 8.29 mg CO_2, 4.53 mg H_2O, and 1.76 mg N_2 upon combustion. Its molar mass was found to be 208.2 g/mol. What is the molecular formula of this compound?

$$8.29\text{ mg }CO_2 \times \frac{1\text{ mmol }CO_2}{44.01\text{ mg}} \times \frac{1\text{ mmol C}}{1\text{ mmol }CO_2} = \underline{0.18837\text{ mmol C}}\ (1.8837E{-4}\text{ mol})$$

$$\times \frac{12.01\text{ mg}}{1\text{ mmol}} = 2.2623\text{ mg C}\ (2.2623E{-3}\text{ g})$$

$$4.53\text{ mg }H_2O \times \frac{1\text{ mmol }H_2O}{18.016\text{ mg }H_2O} \times \frac{2\text{ mmol H}}{1\text{ mmol }H_2O} = \underline{0.50289\text{ mmol H}}$$

$$\times \frac{1.008\text{ mg H}}{1\text{ mmol H}} = 0.50691\text{ mg H}$$

$$1.76\text{ mg }N_2 \times \frac{1\text{ mmol }N_2}{28.02\text{ mg }N_2} \times \frac{2\text{ mmol N}}{1\text{ mmol }N_2} = \underline{0.12562\text{ mmol N}}$$

$$\times \frac{14.01\text{ mg}}{1\text{ mmol}} = 1.76\text{ mg N}$$

$$\underset{(\text{tot})}{6.54\text{ mg}} - (2.2623\text{ mg C} - 0.50691\text{ mg H} - 1.76\text{ mg N})$$

$$= 2.01079\text{ mg O} \times \frac{1\text{ mmol}}{16.00\text{ mg}} = \underline{0.12567\text{ mmol O}}\ (1.2567E{-4}\text{ mol O})$$

$$C_{\frac{0.188}{0.126}} H_{\frac{0.503}{0.126}} N_{\frac{0.126}{0.126}} O_{\frac{0.126}{0.126}} = C_{1.5}H_4NO$$

$$= C_3H_8N_2O_2$$

molar mass → $\dfrac{208.2\text{ g/mol}}{104.1\text{ g/mol}} \approx 2$ ← emp. formula mass

$$\text{molecular formula} = (C_3H_8N_2O_2)_2 = \boxed{C_6H_{16}N_4O_4}$$

Chemical equations

A **<u>chemical equation</u>** represents a chemical reaction with chemical formulas.

Phase/state labels:
- (*s*) solid
- (*l*) liquid
- (*g*) gas
- (*aq*) aqueous (dissolved in H_2O)

NaCl(aq) = saltwater

NaCl (l) molten NaCl

<u>Reactants</u>: substances that will react (on left side of equation)

<u>Products</u>: substances resulting from reaction (on right side of equation)

Write the chemical equation with phase labels:

Solid calcium reacts with chlorine gas to produce solid calcium chloride:

Ca^{2+} Cl^-

$$Ca(s) + \underset{\text{diatomic element}}{Cl_2(g)} \longrightarrow CaCl_2(s)$$

Balancing chemical equations: add coefficients in front of formulas so that the number of each type of atom is the same on the reactants side and products side

1. Only add coefficients, never change subscripts
2. Save elements (O_2, Cl_2, Na, etc) for last
3. Multiply fractions through so coefficients are simplest whole numbers
4. Count polyatomic ions together if they don't react, but count atoms if the polyatomic ion does react

$\underline{2}$ C_4H_{10} + $\underline{\cancel{13/2}\ 13}$ O_2 → $\underline{\cancel{4}\ 8}$ CO_2 + $\underline{\cancel{5}\ 10}$ H_2O

C : $\cancel{4}$ 8   C : $\cancel{1}$ $\cancel{4}$ 8

H : $\cancel{10}$ 20   H : $\cancel{2}$ $\cancel{10}$ 20

O : $\cancel{2}$ $\cancel{13}$ 26   O : $\cancel{3}$ $\cancel{9}$ $\cancel{13}$ 26

$\underline{4}$ Fe + $\underline{3}$ O_2 → $\underline{2}$ Fe_2O_3 least common multiple

Write a balanced chemical equation:
Sodium^{+} carbonate^{2-} solid reacts with aluminum^{3+} chloride^{-} to form aluminum^{3+} carbonate^{2-} and sodium^{+} chloride^{-}.

Na^+ / CO_3^{2-}

$3Na_2CO_3 + 2AlCl_3 \rightarrow Al_2(CO_3)_3 + 6NaCl$