Chapter 3 Suggested end-of-chapter problems with solutions

28. What is the difference between the molar mass and the empirical formula mass of a compound? When are these masses the same, and when are they different? When different, how is the molar mass related to the empirical formula mass?

34. What does it mean to say a reactant is present "in excess" in a process? Can the limiting reactant be present in excess? Does the presence of an excess of a reactant affect the mass of products expected for a reaction?

40. Assume silicon has three major isotopes in nature as shown in the table below. Fill in the missing information.

Isotope	**Mass** (u)	**Abundance**
^{28}Si	27.98	______
^{29}Si	______	4.70%
^{30}Si	29.97	3.09%

42. The element silver (Ag) has two naturally occurring isotopes: ^{109}Ag and ^{107}Ag with a mass of 106.905 u. Silver consists of 51.82% ^{107}Ag and has an average atomic mass of 107.868 u. Calculate the mass of ^{109}Ag.

64. Bauxite, the principal ore used in the production of aluminum, has a molecular formula of $Al_2O_3 \cdot 2H_2O$. The $\cdot H_2O$ in the formula are called waters of hydration. Each formula unit of the compound contains two water molecules.

a. What is the molar mass of bauxite?

b. What is the mass of aluminum in 0.58 mole of bauxite?

c. How many atoms of aluminum are in 0.58 mole of bauxite?

d. What is the mass of 2.1×10^{24} formula units of bauxite?

66. What amount (moles) is represented by each of these samples?

a. 20.0 mg caffeine, $C_8H_{10}N_4O_2$

b. 2.72×10^{21} molecules of ethanol, C_2H_5OH

c. 1.50 g of dry ice, CO_2

71. Chloral hydrate ($C_2H_3Cl_3O_2$) is a drug formerly used as a sedative and hypnotic. It is the compound used to make "Mickey Finns" in detective stories.

a. Calculate the molar mass of chloral hydrate.

b. What amount (moles) of $C_2H_3Cl_3O_2$ molecules are in 500.0 g chloral hydrate?

c. What is the mass in grams of 2.0×10^{-2} mole of chloral hydrate?

d. What number of chlorine atoms are in 5.0 g chloral hydrate?

e. What mass of chloral hydrate would contain 1.0 g Cl?

f. What is the mass of exactly 500 molecules of chloral hydrate?

78. Hemoglobin is the protein that transports oxygen in mammals. Hemoglobin is 0.347% Fe by mass, and each hemoglobin molecule contains four iron atoms. Calculate the molar mass of hemoglobin.

88. Determine the molecular formula of a compound that contains 26.7% P, 12.1% N, and 61.2% Cl, and has a molar mass of 580 g/mol.

94. A compound contains only carbon, hydrogen, and oxygen. Combustion of 10.68 mg of the compound yields 16.01 mg CO_2 and 4.37 mg H_2O. The molar mass of the compound is 176.1 g/mol. What are the empirical and molecular formulas of the compound?

96. Give the balanced equation for each of the following.

a. The combustion of ethanol (C_2H_5OH) forms carbon dioxide and water vapor. A combustion reaction refers to a reaction of a substance with oxygen gas.

b. Aqueous solutions of lead(II) nitrate and sodium phosphate are mixed, resulting in the precipitate formation of lead(II) phosphate with aqueous sodium nitrate as the other product.

c. Solid zinc reacts with aqueous HCl to form aqueous zinc chloride and hydrogen gas.

d. Aqueous strontium hydroxide reacts with aqueous hydro-bromic acid to produce water and aqueous strontium bromide.

102. Balance the following equations:

a. $Cr(s) + S_8(s) \rightarrow Cr_2S_3(s)$

b. $NaHCO_3(s) \xrightarrow{\text{Heat}} Na_2CO_3(s) + CO_2(g) + H_2O(g)$

c. $KClO_3(s) \xrightarrow{\text{Heat}} KCl(s) + O_2(g)$

d. $Eu(s) + HF(g) \rightarrow EuF_3(s) + H_2(g)$

108. One of relatively few reactions that takes place directly between two solids at room temperature is

$$Ba(OH)_2 \cdot 8H_2O(s) + NH_4SCN(s) \rightarrow$$
$$Ba(SCN)_2(s) + H_2O(l) + NH_3(g)$$

In this equation, the $\cdot\, 8H_2O$ in $Ba(OH)_2 \cdot 8H_2O$ indicates the presence of eight water molecules. This compound is called barium hydroxide octahydrate.

a. Balance the equation.

b. What mass of ammonium thiocyanate (NH_4SCN) must be used if it is to react completely with **6.5 g** barium hydroxide octahydrate?

110. Aspirin ($C_9H_8O_4$) is synthesized by reacting salicylic acid ($C_7H_6O_3$) with acetic anhydride ($C_4H_6O_3$). The balanced equation is

$$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + HC_2H_3O_2$$

a. What mass of acetic anhydride is needed to completely consume 1.00×10^2 g salicylic acid?

b. What is the maximum mass of aspirin (the theoretical yield) that could be produced in this reaction?

118. Consider the following unbalanced equation:

$$Ca_3(PO_4)_2(s) + H_2SO_4(aq) \rightarrow CaSO_4(s) + H_3PO_4(aq)$$

What masses of calcium sulfate and phosphoric acid can be produced from the reaction of 1.0 kg calcium phosphate with 1.0 kg concentrated sulfuric acid (98% H_2SO_4 by mass)?

28. Molar mass corresponds to the molecular formula, where the molecular mass (commonly called molecular weight) in atomic units leads to a molar mass that has the same numeric value but the unit of grams.

There appears to be a mistake in this question when it asks us to compare "molar mass" to "empirical formula mass". What they mean by the latter is "molar mass corresponding to the empirical formula". Otherwise, "formula mass" (empirical or not) is a quantity similar to molecular mass, and has atomic mass units (not grams, like molar masses do).

Molar mass corresponding to the empirical formula would be smaller than the molar mass corresponding to the molecular formula by an integer factor, because the empirical formula contains elements in the simplest ratio (1:2 instead of 6:12), which is achieved by dividing the number of atoms by the largest common factor. For example, $C_6H_{12}O_6$ has the empirical formula CH_2O, and the molar mass corresponding to that is 6 times smaller than the ordinary molar mass which corresponds to the molecular formula.

34. A reactant being in excess means that there is more of it than is needed. An excess reactant by definition cannot be limiting. The expected amounts of products are determined by the limiting reactant. Therefore excess reactants cannot affect the expected mass of the products.

40. We can find the abundance of ^{28}Si by realizing that the sum of all isotopic abundances of an element must add up to 100%.

Abundance of $^{28}Si = 100.00 - 4.70 - 3.09 = 92.21\%$

Once we have all the abundances, we can find the isotope mass of one isotope as long as we know the isotopic masses of all the other isotopes as well as the average atomic mass of the element:

Atomic mass of Si = 28.0855 u

$$28.0855 = (0.9221)(27.98) + (0.0470)x + (0.0309)(29.97)$$

$$\Rightarrow x = 29.01 \text{ u}$$

42.) With problems that relate isotopic masses and abundances to the atomic mass of the element, we can find the unknown as long as there is only one unknown.
Here, even though there are superficially two unknowns (abundance of ^{109}Ag and the isotopic mass of ^{109}Ag), the abundance is actually known because the two abundances must add up to 100%.
Abundance of $^{109}Ag = 100 - (\text{Abundance of } ^{107}Ag) = 100 - 51.82 = 48.18\%$
So now we can solve for the isotopic mass of ^{109}Ag

$$107.868 = (0.5182)(106.905) + (0.4818)x \Rightarrow x = 108.9 \text{ u}$$

64.

(a) Molar mass of $Al_2O_3 \cdot 2H_2O$:

$(2)(26.982) + (3)(15.999) + 2[(2)(1.008) + (1)(15.999)]$

$= 137.991\ g/mol$

(b) $0.58\ mol\ Al_2O_3 \cdot 2H_2O \times \frac{2\ mol\ Al}{1\ mol\ Al_2O_3 \cdot 2H_2O} \times \frac{26.982\ g\ Al}{1\ mol\ Al} = 31\ g\ Al$

(c) $0.58\ mol\ Al_2O_3 \cdot 2H_2O \times \frac{2\ mol\ Al}{1\ mol\ Al_2O_3 \cdot 2H_2O} \times \frac{6.022 \times 10^{23}\ Al\ atoms}{1\ mol\ Al}$

$= 7.0 \times 10^{23}$ Al atoms

(d) Note that we cannot talk about "molecules" of bauxite because it is an ionic compound. But we can think about "formula units" in calculations just as if they are molecules. So, 1 mol of bauxite contains 6.022×10^{23} formula units.

$2.1 \times 10^{24}\ formula\ units \times \frac{1\ mol\ Al_2O_3 \cdot 2H_2O}{6.022 \times 10^{23}\ formula\ units} \times \frac{137.991\ g\ Al_2O_3 \cdot 2H_2O}{1\ mol\ Al_2O_3 \cdot 2H_2O}$

$= 4.8 \times 10^{2}\ g\ Al_2O_3 \cdot 2H_2O$

66.

(a) To go from mass to moles, we need the molar mass

Molar mass of $C_8H_{10}N_4O_2 = 8(12.01) + 10(1.01) + 4(14.01) + 2(16.00)$

$= 194.22\ g/mol$

$20.0\ mg \times \frac{10^{-3}\ g}{1\ mg} \times \frac{1\ mol}{194.22\ g} = 1.03 \times 10^{-4}\ mol$

(b) To connect no. of molecules and no. of moles, we need Avogadro's Number, but we don't need molar mass.

$2.72 \times 10^{21}\ molecules \times \frac{1\ mol}{6.022 \times 10^{23}\ molecules} = 4.52 \times 10^{-3}\ mol$

(c) Molar mass of $CO_2 = 12.01 + 2(16.00) = 44.01\ g/mol$

$1.50\ g\ CO_2 \times \frac{1\ mol\ CO_2}{44.01\ g\ CO_2} = 3.41 \times 10^{-2}\ mol\ CO_2$

71.

(a) $2(12.01)+3(1.01)+3(35.45)+2(16.00)=165.40\ g/mol$

(b) $500.0\ g \times \dfrac{1\ mol}{165.40\ g} = 3.023\ mol$

(c) $2.0\times10^{-2}\ mol \times \dfrac{165.40\ g}{1\ mol} = 3.3\ g$

(d) $5.0\ g\ C_2H_3Cl_3O_2 \times \dfrac{1\ mol\ C_2H_3Cl_3O_2}{165.40\ g\ C_2H_3Cl_3O_2} \times \dfrac{6.022\times10^{23}\ molecules}{1\ mol\ C_2H_3Cl_3O_2} \times \dfrac{3\ Cl\ atoms}{1\ molecule}$

$= 5.5\times10^{22}\ Cl\ atoms$

(e) $1.0\ g\ Cl \times \dfrac{1\ mol\ Cl}{35.45\ g\ Cl} \times \dfrac{1\ mol\ C_2H_3Cl_3O_2}{3\ mol\ Cl} \times \dfrac{165.40\ g\ C_2H_3Cl_3O_2}{1\ mol\ C_2H_3Cl_3O_2} = 1.6\ g\ C_2H_3Cl_3O_2$

(f) $500\ molecules \times \dfrac{1\ mol}{6.022\times10^{23}\ molecules} \times \dfrac{165.40\ g}{1\ mol} = 1.37\times10^{-19}\ g$

78.

0.347 % Fe means that there is 0.347 g of Fe in 100 g of hemoglobin.

4 atoms of Fe in each molecule of hemoglobin means that $4\times55.85=223.4\ u$ of Fe is present in each molecule and that $4\times55.85=223.4\ g$ of Fe is present in each mole of hemoglobin

From the Law of Constant Proportion:

$$\frac{0.347\ g\ Fe}{100\ g\ hemoglobin} = \frac{223.4\ g\ Fe}{\text{molar mass of hemoglobin}}$$

$$\Rightarrow \text{molar mass of hemoglobin} = \frac{(223.4)(100)}{(0.347)} = 6.44\times10^4\ g/mol$$

Or by dimensional analysis, where we start with 100 g of hemoglobin (by the way, 100 g comes from %, per 100 grams, so it is exact, with infinite sig. figs) per 0.347 g Fe (rather than 0.347 g Fe per 100 g hemoglobin) because we want a quantity where grams of hemoglobin is in the numerator (grams per mole)

$$\frac{100\ g\ hemoglobin}{0.347\ g\ Fe} \times \frac{223.4\ g\ Fe}{1\ mole\ hemoglobin} = 6.44\times10^4\ \frac{g\ hemoglobin}{1\ mole\ hemoglobin}$$

88. When masses of constituent elements are given as percentages, it's natural and convenient to use a sample mass of 100 g (exact). We can find the empirical formula from the masses alone.

mass of P = (0.267)(100) = 26.7 g

moles of P = $26.7\text{ g P} \times \dfrac{1\text{ mol P}}{30.97\text{ g P}} = 0.8621\text{ mol}$

mass of N = (0.121)(100) = 12.1 g

moles of N = $12.1\text{ g N} \times \dfrac{1\text{ mol N}}{14.01\text{ g N}} = 0.8637\text{ mol}$

mass of Cl = (0.612)(100) = 61.2 g

moles of Cl = $61.2\text{ g Cl} \times \dfrac{1\text{ mol Cl}}{35.45\text{ g Cl}} = 1.726\text{ mol}$

To find the empirical formula, we divide each mol amount by the smallest mol amount

P: $\dfrac{0.8621}{0.8621} = 1$ N: $\dfrac{0.8637}{0.8621} \simeq 1$ Cl: $\dfrac{1.726}{0.8621} \simeq 2$

$\Rightarrow$ empirical formula: $PNCl_2$

$\Rightarrow$ molar mass of empirical formula = $(1)(30.97)+(1)(14.01)+(2)(35.45) = 115.88\ \frac{g}{mol}$

$$\frac{\text{no. of atoms in molecular formula}}{\text{no. of atoms in empirical formula}} = \frac{\text{molar mass of molecular formula}}{\text{molar mass of empirical formula}}$$

$\dfrac{580}{115.88} \simeq 5$ $\Rightarrow$ molecular formula: $P_5N_5Cl_{10}$

Or, we could use the molar mass as sample mass and bypass the finding of empirical formula (because we are given the molar mass info)

$$\left.\begin{aligned} \text{moles of P} &= \frac{(0.267)(580)}{30.97} = 5 \\ \text{moles of N} &= \frac{(0.121)(580)}{14.01} = 5 \\ \text{moles of Cl} &= \frac{(0.612)(580)}{35.45} = 10 \end{aligned}\right\} \Rightarrow P_5N_5Cl_{10}$$

94. We have to find out the amounts of C, H, and O from the products. Remember that Oxygen in the products comes from the air as well as the reactant being burned, so its quantity in the reactant must be calculated indirectly from the amounts of C and H along with the mass of the reactant.

C: $16.01\ mg\ CO_2 \times \frac{10^{-3}\ g}{1\ mg} \times \frac{12.01\ g\ C}{44.01\ g\ CO_2} = 4.369 \times 10^{-3}\ g\ C$

H: $4.37\ mg\ H_2O \times \frac{10^{-3}\ g}{1\ mg} \times \frac{2.02\ g\ H}{18.02\ g\ H_2O} = 4.89 \times 10^{-4}\ g\ H$

O: $mass_C + mass_H + mass_O = mass_{compound}$

$mass_O = 10.68 \times 10^{-3}\ g - (4.369 \times 10^{-3} + 4.89 \times 10^{-4}) = 5.822 \times 10^{-3}\ g\ O$

Now that we have all the masses, we need to go to moles if we are to find out anything about formulas

C: $4.369 \times 10^{-3}\ g\ C \times \frac{1\ mol\ C}{12.01\ g\ C} = 3.638 \times 10^{-4}\ mol\ C$

H: $4.89 \times 10^{-4}\ g\ H \times \frac{1\ mol\ H}{1.01\ g\ H} = 4.84 \times 10^{-4}\ mol\ H$

O: $5.822 \times 10^{-3}\ g\ O \times \frac{1\ mol\ O}{16.00\ g\ O} = 3.639 \times 10^{-4}\ mol\ O$

Empirical formula is found by dividing each mol quantity by the smallest one

C: $\frac{3.638 \times 10^{-4}}{3.638 \times 10^{-4}} = 1$

H: $\frac{4.84 \times 10^{-4}}{3.638 \times 10^{-4}} = 1.33$

O: $\frac{3.639 \times 10^{-4}}{3.638 \times 10^{-4}} = 1$

multiply by 3 to make integers $\Rightarrow$ C: 3, H: 4, O: 3

$\boxed{C_3H_4O_3}$ empirical formula

molar mass of empirical formula $= (3)(12.01) + (4)(1.01) + (3)(16.00) = 88.07\ g/mol$

molar mass is $176.1\ g/mol$ $\quad \frac{176.1}{88.07} \simeq 2 \Rightarrow \boxed{C_6H_8O_6}$ molecular formula

96\. (a) $C_2H_5OH + ?O_2 \longrightarrow ?CO_2 + ?H_2O$

Start with C since it happens in one reactant and one product (we could have started with H as well). We will assume 1 mol of C_2H_5OH and find coefficients relative to that. If needed we can revise that later.

$C_2H_5OH + ?\,O_2 \longrightarrow 2CO_2 + ?H_2O$

Next we balance H

$C_2H_5OH + ?\,O_2 \longrightarrow 2CO_2 + 3H_2O$

We have 7 oxygens in the products, and 1 oxygen in C_2H_5OH. The six oxygens needed would be supplied by 3 O_2 molecules

$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$

(b) $Pb(NO_3)_2\,(aq) + \quad Na_3PO_4\,(aq) \longrightarrow Pb_3(PO_4)_2\,(s) + \quad NaNO_3(aq)$

We should treat the oxyanions NO_3^- and PO_4^{3-} as entities to keep track of (as if they were atoms) since they don't change in this reaction (they might in other reactions).

3 Pb in products, so put 3 in front of $Pb(NO_3)_2(aq)$

$3Pb(NO_3)_2(aq) + \,?\,Na_3PO_4(aq) \longrightarrow Pb_3(PO_4)_2(s) + \,?\,NaNO_3(aq)$

Now we have 6 NO_3^- groups in reactants, so put 6 in front of $NaNO_3$

$3Pb(NO_3)_2(aq) + \,?\,Na_3PO_4(aq) \longrightarrow Pb_3(PO_4)_2(s) + 6NaNO_3(aq)$

6 Na^+ in the products means we need to put 2 in front of Na_3PO_4

$3Pb(NO_3)_2(aq) + 2Na_3PO_4(aq) \longrightarrow Pb_3(PO_4)_2(s) + 6NaNO_3(aq)$

PO_4^{3-} groups are also balanced. The above equation is now balanced.

(c) $Zn(s) + \,?\,HCl(aq) \longrightarrow \,?\,ZnCl_2\,(aq) + \,?\,H_2(g)$

2 Cl atoms in products, so put 2 in front of HCl to balance, which also balances H

$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2\,(aq) + H_2(g)$

(d) $Sr(OH)_2\,(aq) + \,?\,HBr(aq) \longrightarrow \,?\,H_2O\,(l) + \,?\,SrBr_2\,(aq)$

2 Br atoms in products, so put 2 in front of HBr to balance. (We observed that Sr was balanced already)

$Sr(OH)_2(aq) + 2HBr\,(aq) \rightarrow \,?\,H_2O\,(l) + SrBr_2(aq)$

2 oxygens in reactants, so put 2 in front of H_2O to balance, which also balances H

$Sr(OH)_2(aq) + 2HBr(aq) \longrightarrow 2H_2O\,(l) + SrBr_2\,(aq)$

102.

(a) $? Cr(s) + ? S_8(s) \longrightarrow ? Cr_2S_3(s)$

If we start with a coefficient of 1 (implied) for Cr_2S_3, $Cr(s)$ on the reactant side needs a coefficient of 2

$$2Cr(s) + ?S_8(s) \longrightarrow Cr_2S_3(s)$$

The only way to have 3 S atoms on the reactant side is to use a fractional coefficient of $\frac{3}{8}$ in front of $S_8(s)$.

$$2Cr(s) + \frac{3}{8}S_8(s) \longrightarrow Cr_2S_3(s)$$

If we want to get rid of fractional coefficients we multiply all coefficients by 8

$$16\,Cr(s) + 3\,S_8(s) \longrightarrow 8\,Cr_2S_3(s)$$

(b) $? NaHCO_3(s) \longrightarrow ? Na_2CO_3(s) + ? CO_2(g) + ? H_2O(g)$

Na occurs in one reactant and only one product, so it's a good atom to start balancing with.

$$2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

It turns out H, C, and O are also balanced if we just stick with one CO_2 and one H_2O on the product side.

(c) $KClO_3(s) \longrightarrow ?\ KCl(s) + ?\ O_2(g)$

K and Cl are already balanced. We can balance O by using a fractional coefficient of $\frac{3}{2}$ for O_2

$$KClO_3(s) \longrightarrow KCl(s) + \frac{3}{2}O_2(g)$$

We can get rid of the fractional coefficient by multiplying all coefficients by 2 (if we want to, or are asked to)

$$2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$$

(d) $Eu(s) + ?\ HF(g) \longrightarrow ?EuF_3(s) + ?\ H_2(g)$

Eu is balanced. Next we can handle H or F. If we try to balance H next, either by choosing 2HF or $\frac{1}{2}H_2$, it will leave F unbalanced, which would lead to some ugly fraction for EuF_3, and by extension Eu(s), modifying an element that was already balanced, and with ugly numbers too.
On the other hand, if we proceed with F, H_2 gets a fractional coefficient (which is commonly tolerated for gaseous species) but that is the end of the balancing.

$$Eu(s) + 3HF(g) \longrightarrow EuF_3(s) + \frac{3}{2}H_2(g)$$

or

$$2Eu(s) + 6HF(g) \longrightarrow 2EuF_3(s) + 3H_2(g)$$

108.

(a) $Ba(OH)_2 \cdot 8H_2O(s) + ?\ NH_4SCN(s) \rightarrow ?\ Ba(SCN)_2(s) + ?\ H_2O(l) + ?\ NH_3(g)$

It is useful to pay attention to what is going on in the reaction.

* SCN^- (thiocyanate) is staying intact, because we see it occur on both sides. There is a chance some of the SCN^- might be doing more, but it's worth trying to see if the simple case is true.
* H_2O also occurs on both sides of the reaction, as "crystal water" on the reactant side, and ordinary water on the product side. While there is a chance that some of the crystal waters might have done more than simply get freed up from $Ba(OH)_2$, it's worth trying to see if the simple case is true.
* It looks like the OH^- (hydroxide) groups grabbed an H^+ from the NH_4^+ (ammonium) groups and became H_2O, adding onto the freed up crystal waters

- We need two SCN^- groups on the reactant side to balance
- That leads to two NH_4^+ groups to give one H^+ each to the two OH^- groups, which become two H_2O molecules in addition to the 8 freed up crystal waters.

$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4SCN(s) \rightarrow Ba(SCN)_2(s) + 10H_2O(l) + 2NH_3(g)$$

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b) We need molar masses to go from grams to mols and back

$\underbrace{\text{m.m.}}_{\text{molar mass}}(NH_4SCN) = (2)(14.01) + (4)(1.01) + 32.07 + 12.01 = 76.14\text{g/mol}$

$\text{m.m.}(Ba(OH)_2 \cdot 8H_2O) = 137.3 + (2)(16.00 + 1.01) + (8)[(2)(1.01) + 16.00]$
$= 315.48\ \text{g/mol}$

$$6.5\text{g } Ba(OH)_2 \cdot 8H_2O \times \frac{1\text{ mol } Ba(OH)_2 \cdot 8H_2O}{315.48\text{ g } Ba(OH)_2 \cdot 8H_2O} \times \frac{2\text{ mol } NH_4SCN}{1\text{ mol } Ba(OH)_2 \cdot 8H_2O} \times \frac{76.14\text{g } NH_4SCN}{1\text{ mol } NH_4SCN}$$

$= 3.1\text{g } NH_4SCN$

110. $C_7H_6O_3 + C_4H_6O_3 \longrightarrow C_9H_8O_4 + HC_2H_3O_2$

salicylic acid, acetic anhydride, Aspirin

To use stoichiometry, we need to go from grams to mols first, and then we go back to grams if needed. So we need molar masses.

$\underbrace{m.m.}_{\text{molar mass}}(C_7H_6O_3) = (7)(12.01) + (6)(1.01) + (3)(16.00) = 138.13\ g/mol$

$m.m.(C_4H_6O_3) = (4)(12.01) + (6)(1.01) + (3)(16.00) = 102.10\ g/mol$

$m.m.(C_9H_8O_4) = (9)(12.01) + (8)(1.01) + (4)(16.00) = 180.17\ g/mol$

(a) $1.00 \times 10^2\ g\ C_7H_6O_3 \times \frac{1\ mol\ C_7H_6O_3}{138.13\ g\ C_7H_6O_3} \times \frac{1\ mol\ C_4H_6O_3}{1\ mol\ C_7H_6O_3} \times \frac{102.10\ g\ C_4H_6O_3}{1\ mol\ C_4H_6O_3} = 73.9\ g\ C_4H_6O_3$

(b) $1.00 \times 10^2\ g\ C_7H_6O_3 \times \frac{1\ mol\ C_7H_6O_3}{138.13\ g\ C_7H_6O_3} \times \frac{1\ mol\ C_9H_8O_4}{1\ mol\ C_7H_6O_3} \times \frac{180.17\ g\ C_9H_8O_4}{1\ mol\ C_9H_8O_4} = 130.\ g\ C_9H_8O_4$

118.

First we need to balance the reaction equation

$$? \, Ca_3(PO_4)_2(s) + \, ? \, H_2SO_4(aq) \rightarrow \, ? \, CaSO_4(s) + \, ? \, H_3PO_4(aq)$$

Note that PO_4^{3-} and SO_4^{2-} groups "travel" together, and we can keep track of them as entities.

We can start by balancing Ca, and propagate the consequences (3 in front of $CaSO_4$ dictates 3 in front of H_2SO_4 to balance the SO_4^{2-} groups, etc.)

$$Ca_3(PO_4)_2(s) + 3H_2SO_4(aq) \rightarrow 3CaSO_4(s) + 2H_3PO_4(aq)$$

We are given the masses of reactants, which we need to convert to mols, and also find out which one is limiting because we are not simply looking for an amount of reactant just enough to completely react with the other one; we are given two arbitrary masses, which usually results in one or the other reactant is limiting.

m.m. of $Ca_3(PO_4)_2 = (3)(40.08) + 2[30.97 + (4)(16.00)] = 310.18$ g/mol

m.m. of $H_2SO_4 = (2)(1.01) + (1)(32.07) + (4)(16.00) = 98.09$ g/mol

m.m. of $CaSO_4 = 40.08 + 32.07 + (4)(16.00) = 136.15$ g/mol

m.m. of $H_3PO_4 = (3)(1.01) + 30.97 + (4)(16.00) = 98.00$ g/mol

mols of $Ca_3(PO_4)_2 = 1.0 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol}}{310.18 \text{ g}} = 3.2$ mol

Mols of H_2SO_4 needed to react w/ 3.2 mol $Ca_3(PO_4)_2$:

$$3.2 \text{ mol } Ca_3(PO_4)_2 \times \frac{3 \text{ mol } H_2SO_4}{1 \text{ mol } Ca_3(PO_4)_2} = 9.6 \text{ mol } H_2SO_4$$

H_2SO_4 is in excess because we have 10. mols of H_2SO_4

$\Rightarrow Ca_3(PO_4)_2$ is the limiting reactant

$$3.2 \text{ mol } Ca_3(PO_4)_2 \times \frac{3 \text{ mol } CaSO_4}{1 \text{ mol } Ca_3(PO_4)_2} \times \frac{136.15 \text{ g } CaSO_4}{1 \text{ mol } CaSO_4} = 1.3 \times 10^3 \text{ g } CaSO_4$$

$$3.2 \text{ mol } Ca_3(PO_4)_2 \times \frac{2 \text{ mol } H_3PO_4}{1 \text{ mol } Ca_3(PO_4)_2} \times \frac{98.00 \text{ g } H_3PO_4}{1 \text{ mol } H_3PO_4} = 6.3 \times 10^2 \text{ g } H_3PO_4$$