

Key

1. Write and balance the following equations.

- a. Solid calcium carbide, CaC_2 , reacts with water to form an aqueous solution of calcium hydroxide and acetylene gas, C_2H_2 .



- b. When solid potassium chlorate is heated, it decomposes to form solid potassium chloride and oxygen gas.



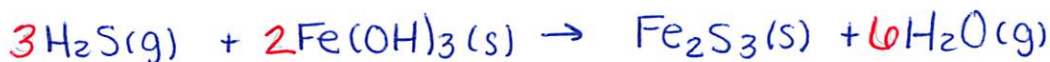
- c. Solid zinc metal reacts with sulfuric acid to form hydrogen gas and an aqueous solution of zinc sulfate.



- d. When liquid phosphorous trichloride is added to water, it reacts to form aqueous phosphorous acid and aqueous hydrochloric acid.

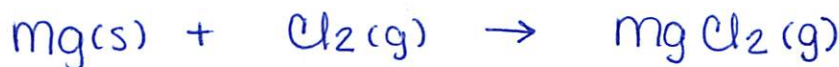


- e. When hydrogen sulfide gas is passed over hot iron (III) hydroxide, the resultant reaction produces solid iron (III) sulfide and steam.



2. Write a balanced chemical equation for the reaction that occurs when...

- a. $\text{Mg}(\text{s})$ reacts with $\text{Cl}_2(\text{g})$.



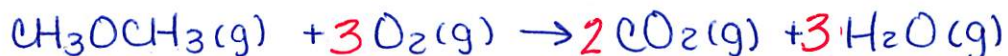
- b. Barium carbonate decomposes into barium oxide and carbon dioxide gas when heated.



- c. The hydrocarbon, styrene, $C_8H_8(l)$ completely combusts.



- d. Dimethylether, $CH_3OCH_3(g)$, completely combusts.



3. The molecular formula for allicin, the compound responsible for the characteristic of smell of garlic, is $C_6H_{10}OS_2$.

- a. What is the molar mass of allicin?

$$\begin{array}{lcl} C & 6 \times 12 \text{ g/mol} & = 72 \text{ g/mol} \\ H & 10 \times 1 \text{ g/mol} & = 10 \text{ g/mol} \\ O & 1 \times 16 \text{ g/mol} & = 16 \text{ g/mol} \\ S & 2 \times 32 \text{ g/mol} & = 64 \text{ g/mol} \end{array} = \boxed{162 \text{ g/mol}}$$

- b. How many moles of allicin are present in 3.00 mg of this substance?

$$3.00 \text{ mg} \left(\frac{1 \text{ g}}{1000 \text{ mg}} \right) \left(\frac{1 \text{ mol}}{162 \text{ g}} \right) = \boxed{1.85 \times 10^{-5} \text{ mol}}$$

- c. How many S atoms are present in 5.00 mg of allicin?

$$\begin{aligned} 5.00 \text{ mg } C_6H_{10}OS_2 & \left(\frac{1 \text{ g } C_6H_{10}OS_2}{1000 \text{ mg } C_6H_{10}OS_2} \right) \left(\frac{1 \text{ mol } C_6H_{10}OS_2}{162 \text{ g } C_6H_{10}OS_2} \right) \left(\frac{2 \text{ mol S}}{1 \text{ mol } C_6H_{10}OS_2} \right) \\ & = 6.17 \times 10^{-5} \text{ mol S} \left(\frac{6.02 \times 10^{23} \text{ atoms S}}{1 \text{ mol S}} \right) = \boxed{3.72 \times 10^{19} \text{ atoms S}} \end{aligned}$$

4. The allowable concentration level of vinyl chloride, C_2H_3Cl , in the atmosphere in a chemical plant is $2.0 \times 10^{-6} \text{ g/L}$. How many moles of vinyl chloride in each liter does this represent? How many molecules per liter?

moles of C_2H_3Cl

$$\frac{2.0 \times 10^{-6} \text{ g}}{\text{L}} \left(\frac{1 \text{ mol}}{62.5 \text{ g}} \right) = \boxed{3.2 \times 10^{-8} \frac{\text{mol}}{\text{L}}}$$

molecules of C_2H_3Cl

$$\frac{3.2 \times 10^{-8} \text{ mol}}{\text{L}} \left(\frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mol}} \right) = \boxed{1.9 \times 10^{16} \frac{\text{molecules}}{\text{L}}}$$

5. What is the molecular formula of each of the following compounds?

a. Empirical formula CH_2 , molar mass = 84 g/mol.

$$\frac{\text{CH}_2}{14 \text{ g/mol}} \quad \frac{84}{14} = 6 \quad \frac{\text{M.F.}}{6(\text{CH}_2)} = \boxed{\text{C}_6\text{H}_{12}}$$

b. Empirical formula, NH_2Cl , molar mass = 51.5 g/mol.

$$\frac{\text{NH}_2\text{Cl}}{51.5 \text{ g/mol}} \quad \frac{51.5}{51.5} = 1 \quad \frac{\text{M.F.}}{1(\text{NH}_2\text{Cl})} = \boxed{\text{NH}_2\text{Cl}}$$

6. A component of protein called serine has the percent composition is as follows, what is the empirical of serine? C = 34.95 % H = 6.844 % O = 46.56 % N = 13.59 %

$\frac{\text{C}}{34.95 \text{ g}}$	$\frac{\text{H}}{6.844 \text{ g}}$	$\frac{\text{O}}{46.56 \text{ g}}$	$\frac{\text{N}}{13.59 \text{ g}}$	$\frac{\text{EF}}{\text{C}_3\text{H}_7\text{O}_3\text{N}}$
$\frac{12 \text{ g/mol}}{12 \text{ g/mol}}$	$\frac{1.0 \text{ g/mol}}{1.0 \text{ g/mol}}$	$\frac{16 \text{ g/mol}}{16 \text{ g/mol}}$	$\frac{14 \text{ g/mol}}{14 \text{ g/mol}}$	
$= 2.9125 \text{ mol}$	$= 6.844 \text{ mol}$	$= 2.91 \text{ mol}$	$= .9707 \text{ mol}$	
$\frac{.9707 \text{ mol}}{.9707 \text{ mol}}$	$\frac{.9707 \text{ mol}}{.9707 \text{ mol}}$	$\frac{.9707 \text{ mol}}{.9707 \text{ mol}}$	$\frac{.9707 \text{ mol}}{.9707 \text{ mol}}$	
$= 3$	$= 7$	$= 3$	$= 1$	

7. Combustion of 3.903 g of a compound containing C, H, and O yields 9.848 g of CO_2 and 1.728 g of H_2O . What is the empirical formula?

$$9.848 \text{ g CO}_2 \left(\frac{1 \text{ mol CO}_2}{44 \text{ g CO}_2} \right) \left(\frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \right) \left(\frac{12 \text{ g C}}{1 \text{ mol C}} \right) = 2.686 \text{ g C}$$

$$1.728 \text{ g H}_2\text{O} \left(\frac{1 \text{ mol H}_2\text{O}}{18 \text{ g H}_2\text{O}} \right) \left(\frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \right) \left(\frac{1 \text{ g H}}{1 \text{ mol H}} \right) = .192 \text{ g H}$$

mass of O

$$3.903 \text{ g} - 2.686 \text{ g} - .192 \text{ g} = 1.025 \text{ g O}$$

$\frac{2.686 \text{ g C}}{12 \text{ g/mol}}$	$\frac{.192 \text{ g H}}{1 \text{ g/mol}}$	$\frac{1.025 \text{ g O}}{16 \text{ g/mol}}$	$\frac{\text{EF}}{\text{C}_7\text{H}_6\text{O}_2}$
$= .2238 \text{ mol}$	$= .192 \text{ mol}$	$= .0641 \text{ mol}$	
$\frac{.0641 \text{ mol}}{.0641 \text{ mol}}$	$\frac{.0641 \text{ mol}}{.0641 \text{ mol}}$	$\frac{.0641 \text{ mol}}{.0641 \text{ mol}}$	
$= (3.5) 2$	$= (3) 2$	$= (1) 2$	

8. Caffeine has C, H, O, and N. 1.00 mg of caffeine is combusted to form 1.813 mg of CO_2 , 0.4639 mg of H_2O , and .2885 mg of N_2 . Find the empirical formula.

$$1.813 \text{ mg CO}_2 \left(\frac{1 \text{ g CO}_2}{1000 \text{ mg CO}_2} \right) \left(\frac{1 \text{ mol CO}_2}{44 \text{ g CO}_2} \right) \left(\frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \right) \left(\frac{12 \text{ g C}}{1 \text{ mol C}} \right) = .0004945 \text{ g C}$$

$$.4639 \text{ mg H}_2\text{O} \left(\frac{1 \text{ g H}_2\text{O}}{1000 \text{ mg H}_2\text{O}} \right) \left(\frac{1 \text{ mol H}_2\text{O}}{18 \text{ g H}_2\text{O}} \right) \left(\frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \right) \left(\frac{1 \text{ g H}}{1 \text{ mol H}} \right) = .00005154 \text{ g H}$$

$$.2885 \text{ mg N}_2 \left(\frac{1 \text{ g N}_2}{1000 \text{ mg N}_2} \right) \left(\frac{1 \text{ mol N}_2}{28 \text{ g N}_2} \right) \left(\frac{2 \text{ mol N}}{1 \text{ mol N}_2} \right) \left(\frac{14 \text{ g N}}{1 \text{ mol N}} \right) = .0002885 \text{ g N}$$

$$\text{mass of O} = 1.00 \text{ mg} \left(\frac{1 \text{ g}}{1000 \text{ mg}} \right) = .001 \text{ g} - .0004945 \text{ g} - .00005154 \text{ g} - .0002885 \text{ g} = .0001655 \text{ g O}$$

$$\frac{.0004945 \text{ g C}}{12 \text{ g/mol}}$$

$$= .0000412 \text{ mol}$$

$$\frac{.0000412 \text{ mol}}{.0000103 \text{ mol}}$$

$$= 4$$

$$\frac{.0000515 \text{ g H}}{1 \text{ g/mol}}$$

$$= .0000515 \text{ mol}$$

$$\frac{.0000515 \text{ mol}}{.0000103 \text{ mol}}$$

$$= 5$$

$$\frac{.0002885 \text{ g N}}{14 \text{ g/mol}}$$

$$= .0000206 \text{ mol}$$

$$\frac{.0000206 \text{ mol}}{.0000103 \text{ mol}}$$

$$= 2$$

$$\frac{.0001655 \text{ g O}}{16 \text{ g/mol}}$$

$$= .0000103 \text{ mol}$$

$$\frac{.0000103 \text{ mol}}{.0000103 \text{ mol}}$$

$$= 1$$

$$\frac{\text{EF}}{\text{C}_4\text{H}_5\text{N}_2\text{O}}$$

9. Hydrofluoric acid, HF (aq), cannot be stored in glass bottles because compounds called silicates in the glass are attacked by the HF (aq). Sodium silicate (Na_2SiO_3), for example, reacts as follows:



- a. How many moles of HF are needed to react with 0.300 mol of Na_2SiO_3 ?

$$.300 \text{ mol Na}_2\text{SiO}_3 \left(\frac{8 \text{ mol HF}}{1 \text{ mol Na}_2\text{SiO}_3} \right) = 2.40 \text{ mol HF}$$

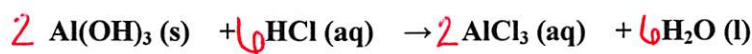
- b. How many grams of NaF form when 0.500 mol of HF reacts with excess Na_2SiO_3 ?

$$.500 \text{ mol HF} \left(\frac{2 \text{ mol NaF}}{8 \text{ mol HF}} \right) \left(\frac{42 \text{ g NaF}}{1 \text{ mol NaF}} \right) = 5.25 \text{ g NaF}$$

- c. What mass of Na_2SiO_3 can react with 0.800 g of HF ?

$$.800 \text{ g HF} \left(\frac{1 \text{ mol HF}}{20 \text{ g HF}} \right) \left(\frac{1 \text{ mol Na}_2\text{SiO}_3}{8 \text{ mol HF}} \right) \left(\frac{122 \text{ g Na}_2\text{SiO}_3}{1 \text{ mol Na}_2\text{SiO}_3} \right) = .61 \text{ g Na}_2\text{SiO}_3$$

10. Several brands of antacids use $\text{Al}(\text{OH})_3$ to react with stomach acid, which contains primarily HCl :



a. Balance the equation.

b. Calculate the number of grams of HCl that can react with 0.500 g of $\text{Al}(\text{OH})_3$.

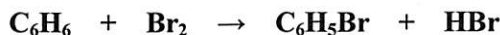
$$.500 \text{ g Al}(\text{OH})_3 \left(\frac{1 \text{ mol Al}(\text{OH})_3}{78 \text{ g Al}(\text{OH})_3} \right) \left(\frac{6 \text{ mol HCl}}{2 \text{ mol Al}(\text{OH})_3} \right) \left(\frac{36.5 \text{ g HCl}}{1 \text{ mol HCl}} \right) = \boxed{.702 \text{ g HCl}}$$

c. Calculate the masses of AlCl_3 and H_2O produced when 0.500 g of $\text{Al}(\text{OH})_3$ reacts.

$$.500 \text{ g Al}(\text{OH})_3 \left(\frac{1 \text{ mol Al}(\text{OH})_3}{78 \text{ g Al}(\text{OH})_3} \right) \left(\frac{2 \text{ mol AlCl}_3}{2 \text{ mol Al}(\text{OH})_3} \right) \left(\frac{133.5 \text{ g AlCl}_3}{1 \text{ mol AlCl}_3} \right) = \boxed{.856 \text{ g AlCl}_3}$$

$$.500 \text{ g Al}(\text{OH})_3 \left(\frac{1 \text{ mol Al}(\text{OH})_3}{78 \text{ g Al}(\text{OH})_3} \right) \left(\frac{6 \text{ mol H}_2\text{O}}{2 \text{ mol Al}(\text{OH})_3} \right) \left(\frac{18 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} \right) = \boxed{.346 \text{ g H}_2\text{O}}$$

11. When benzene (C_6H_6) reacts with bromine (Br_2), bromobenzene ($\text{C}_6\text{H}_5\text{Br}$) is obtained:



a. What is the theoretical yield of bromobenzene in this reaction when 30.0 g of benzene reacts with 65.0 of bromine?

Find limiting reactant.

$$30.0 \text{ g C}_6\text{H}_6 \left(\frac{1 \text{ mol C}_6\text{H}_6}{78 \text{ g C}_6\text{H}_6} \right) \left(\frac{1 \text{ mol C}_6\text{H}_5\text{Br}}{1 \text{ mol C}_6\text{H}_6} \right) = .385 \text{ mol C}_6\text{H}_5\text{Br}$$

$$65.0 \text{ g Br}_2 \left(\frac{1 \text{ mol Br}_2}{160 \text{ g Br}_2} \right) \left(\frac{1 \text{ mol C}_6\text{H}_5\text{Br}}{1 \text{ mol C}_6\text{H}_6} \right) = .406 \text{ mol C}_6\text{H}_5\text{Br}$$

Limiting
Reactant
is
 C_6H_6

$$.385 \text{ mol C}_6\text{H}_5\text{Br} \left(\frac{157 \text{ g C}_6\text{H}_5\text{Br}}{1 \text{ mol C}_6\text{H}_5\text{Br}} \right) = \boxed{60.4 \text{ g C}_6\text{H}_5\text{Br}}$$

- b. If the actual yield of bromobenzene was 42.3 g, what is the % yield?

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{42.3 \text{ g}}{60.4 \text{ g}} \times 100 = \boxed{70.0\%}$$

12. Dimethylhydrazine, $(\text{CH}_3)_2\text{NNH}_2$, was used as a fuel for the Apollo Lunar Descent Module, with N_2O_4 being used as the oxidant. The products of the reaction are H_2O , N_2 , and CO_2 .

- a. Write a balanced equation for the reaction?



- b. If 150. kg of $(\text{CH}_3)_2\text{NNH}_2$ react with 460. kg of N_2O_4 , what is the theoretical yield of N_2 ?

$$150. \text{ kg } (\text{CH}_3)_2\text{NNH}_2 \left(\frac{1000 \text{ g } (\text{CH}_3)_2\text{NNH}_2}{1 \text{ kg } (\text{CH}_3)_2\text{NNH}_2} \right) \left(\frac{6 \text{ mol } \text{N}_2}{1 \text{ mol } (\text{CH}_3)_2\text{NNH}_2} \right) = 900000 \text{ mol } \text{N}_2$$

$$460. \text{ kg } \text{N}_2\text{O}_4 \left(\frac{1000 \text{ g } \text{N}_2\text{O}_4}{1 \text{ kg } \text{N}_2\text{O}_4} \right) \left(\frac{6 \text{ mol } \text{N}_2}{2 \text{ mol } \text{N}_2\text{O}_4} \right) = 1380000 \text{ mol } \text{N}_2$$

Limiting Reactant is $(\text{CH}_3)_2\text{NNH}_2$

$$900000 \text{ mol } \text{N}_2 \left(\frac{28 \text{ g } \text{N}_2}{1 \text{ mol } \text{N}_2} \right) = \boxed{25200000 \text{ g } \text{N}_2}$$

- c. If a 30.0 kg yield of N_2 gas represents a 68% yield, what mass of N_2O_4 would have been used up in the reaction?

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}}$$

$$.68 = \frac{30 \text{ kg}}{x}$$

$$x = \frac{30 \text{ kg}}{.68}$$

$$x = 44.1 \text{ kg}$$

(theoretical yield)

$$44.1 \text{ kg } \text{N}_2 \left(\frac{1000 \text{ g } \text{N}_2}{1 \text{ kg } \text{N}_2} \right) \left(\frac{2 \text{ mol } \text{N}_2\text{O}_4}{6 \text{ mol } \text{N}_2} \right) \left(\frac{92 \text{ g } \text{N}_2\text{O}_4}{1 \text{ mol } \text{N}_2\text{O}_4} \right)$$

$$= 1352400 \text{ g } \text{N}_2\text{O}_4$$