Moles and stoichiometry practice problems (from Chapter 3 in Brady, Russell, and Holum's *Chemistry, Matter and its Changes, 3rd Ed.*)

Concept of mole/molar ratio

1) How many moles of sodium atoms correspond to 1.56×10^{21} atoms of sodium?

2) How many moles of Al atoms are needed to combine with 1.58 mol of O atoms to make aluminum oxide, Al_2O_3?

3) How many moles of Al are in 2.16 mol of Al_2O_3?

4) Aluminum sulfate, $Al_2(SO_4)_3$, is a compound used in sewage treatment plants.
   a. Construct a pair of conversion factors that relate moles of aluminum to moles of sulfur for this compound
   b. Construct a pair of conversion factors that relate moles of sulfur to moles of $Al_2(SO_4)_3$
   c. How many moles of Al are in a sample of this compound if the sample also contains 0.900 mol S?
   d. How many moles of S are in 1.16 mol $Al_2(SO_4)_3$?

5) How many moles of H_2 and N_2 can be formed by the decomposition of 0.145 mol of ammonia, NH_3?

6) What is the total number of atoms in 0.260 mol of glucose, $C_6H_{12}O_6$?

7) What is the mass of 1.00 mol of each of the following elements?

   a. Sodium
   b. Sulfur
   c. Chlorine

8) Determine the mass in grams of each of the following:
   a. 1.35 mol Fe
   b. 24.5 mol O
   c. 0.876 mol Ca
   d. 1.25 mol $Ca_3(PO_4)_2$
   e. 0.625 mol $Fe(NO_3)_3$
   f. 0.600 mol C_4H_{10}
   g. 1.45 mol $(NH_4)_2CO_3$

9) Calculate the number of moles of each compound:
   a. 21.5 g $CaCO_3$
   b. 1.56 g NH_3
   c. 16.8 g $Sr(NO_3)_2$
   d. 6.98 mg Na_2CrO_4

Percent composition and empirical formulas

10) Calculate the percentage composition by mass of each element in the following compounds:
   a. NaH_2PO_4

b. $NH_4H_2PO_4$
c. $(CH_3)_2CO$

11) Phencyclidine is $C_{17}H_{25}N$. A sample suspected of being this illicit drug was found to have a percentage composition of 83.71% C, 10.42% H, and 5.61% N. Do these data acceptably match the theoretical data for phencyclidine?

12) How many grams of O are combined with $7.14x10^{21}$ atoms of N in the compound N_2O_5?

13) Quantitative analysis of a sample of sodium pertechnetate with a mass of 0.896g found 0.111g Na and 0.477g technetium (Tc). The remainder was oxygen. Calculate the empirical formula of sodium pertechnetate, $Na_xTc_yO_z$.

14) A substance was found to be composed of 22.9% Na, 21.5% B, and 55.7% O. What is the empirical formula of this compound?

15) When 0.684 g of an organic compound containing only C, H, and O was burned in oxygen 1.312g CO_2 and 0.805g H_2O were obtained. What is the empirical formula of the compound?

Balancing equations

16) Write the equation that expresses in acceptable chemical shorthand the following statement: "Iron can be made to react with molecular oxygen (O_2) to give iron oxide with the formula Fe_2O_3"

17) Balance the following reactions:
a. $Ca(OH)_2 + HCl \rightarrow CaCl_2 + H_2O$
b. $AgNO_3 + CaCl_2 \rightarrow Ca(NO_3)_2 + AgCl$
c. $Fe_2O_3 + C \rightarrow Fe + CO_3$
d. $NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2$
e. $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$
f. $Mg(OH)_2 + HBr \rightarrow MgBr_2 + H_2O$
g. $Al_2O_3 + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2O$
h. $KHCO_3 + H_3PO_4 \rightarrow K_2HPO_4 + H_2O + CO_2$
i. $C_9H_{10}O + O_2 \rightarrow CO_2 + H_2O$

Stoichiometry/limiting reactants

18) Chlorine is used by textile manufacturers to bleach cloth. Excess chlorine is destroyed by its reaction with sodium thiosulfate, $Na_2S_2O_3$:

$$Na_2S_2O_{3(aq)} + 4Cl_{2(g)} + 5H_2O_{(aq)} \rightarrow 2NaHSO_{4(aq)} + 8HCl_{(aq)}$$

a. How many moles of $Na_2S_2O_3$ are needed to react with 0.12mol of Cl_2?
b. How many moles of HCl can form from 0.12mol of Cl_2?
c. How many moles of H_2O are required for the reaction of 0.12mol of Cl_2?
d. How many moles of H_2O react if 0.24mol HCl is formed?

19) The incandescent white of a fireworks display is caused by the reaction of phosphorous with O_2 to give P_4O_{10}.
a. Write the balanced chemical equation for the reaction.

b. How many grams of O_2 are needed to combine with 6.85g of P?
c. How many grams of P_4O_{10} can be made from 8.00g of O_2?
d. How many grams of P are needed to make 7.46g P_4O_{10}?

20) In *dilute* nitric acid, HNO_3, copper metal dissolves according to the following equation:

$$3Cu_{(s)} + 8HNO_{3(aq)} \rightarrow 3Cu(NO_3)_{2(aq)} + 2NO_{(g)} + 4H_2O_{(aq)}$$

How many grams of HNO_3 are needed to dissolve 11.45g of Cu?

21) The reaction of powdered aluminum and iron(II)oxide,

$$2Al_{(s)} + Fe_2O_{3(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(l)}$$

produces so much heat the iron that forms is molten. Because of this, railroads use the reaction to provide molten steel to weld steel rails together when laying track. Suppose that in one batch of reactants 4.20mol Al was mixed with 1.75mol Fe_2O_3.

a. Which reactant, if either, was the limiting reactant?
b. Calculate the mass of iron (in grams) that can be formed from this mixture of reactants.

22) Silver nitrate, $AgNO_3$, reacts with iron(III) chloride, $FeCl_3$, to give silver chloride, AgCl, and iron(III) nitrate, $Fe(NO_3)_3$. A solution containing 18.0g $AgNO_3$ was mixed with a solution containing 32.4g $FeCl_3$. How many grams of which reactant *remains* after the reaction is over?

Theoretical and percent yield

23) Barium sulfate, $BaSO_4$, is made by the following reaction:

$$Ba(NO_3)_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaNO_{3(aq)}$$

An experiment was begun with 75.00g of $Ba(NO_3)_2$ and an excess of Na_2SO_4. After collecting and drying the product, 63.45g $BaSO_4$ was obtained. Calculate the theoretical yield and percent yield of $BaSO_4$.

24) Aluminum sulfate can be made by the following reaction:

$$2AlCl_{3(aq)} + 3H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 6HCl_{(aq)}$$

It is quite soluble in water, so to isolate it the solution has to be evaporated to dryness. This drives off the volatile HCl, but the residual solid has to be treated to a little over 200°C to drive off all the water. In one experiment, 25.0g of $AlCl_3$ was mixed with 30.0g H_2SO_4. Eventually, 28.46g of pure $Al_2(SO_4)_3$ was isolated. Calculate the percent yield.

Answers

1) 2.59×10^{-3}mol Na atoms
2) 1.05mol Al
3) 4.32mol Al
4) a. 2mol Al/3mol S b. 3mol S/1mol $Al_2(SO_4)_3$ c. 0.600mol Al d. 3.48mol S
5) 0.0725mol N_2 and 0.218mol H_2
6) 3.76×10^{24} atoms
7) a. 23.0g Na b. 32.1g S c. 35.3g Cl
8) a. 75.4g Fe b. 392g O c. 35.1g Ca d. 388g $Ca_3(PO_4)_2$
   e. 151g $Fe(NO_3)_2$ f. 34.9g C_4H_{10} g. 139g $(NH_4)_2CO_3$
9) a. 0.215mol b. 0.0916mol c. 0.0794mol d. 4.31×10^{-8}mol
10) a. 19.2% Na, 1.68% H, 25.8% P, 53.3% O

b. 12.2% N, 5.26% H, 26.9% P, 55.6%O
c. 62.0% C, 10.4% H, 27.6% O

11) Theoretical data (83.89% C, 10.35% H, 5.76% N) are consistent with experimental results.
12) 0.474g O
13) $NaTcO_4$
14) $Na_2B_4O_7$
15) C_2H_6O
16) $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
17)
    a. $Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$
    b. $2AgNO_3 + CaCl_2 \rightarrow Ca(NO_3)_2 + 2AgCl$
    c. $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_3$
    d. $2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$
    e. $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$
    f. $Mg(OH)_2 + 2HBr \rightarrow MgBr_2 + 2H_2O$
    g. $Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$
    h. $2KHCO_3 + H_3PO_4 \rightarrow K_2HPO_4 + 2H_2O + 2CO_2$
    i. $C_9H_{10}O + 14O_2 \rightarrow 9CO_2 + 10H_2O$
18) a. 0.030mol $Na_2S_2O_3$ b. 0.24mol HCl c. 0.15mol H_2O
    d. 0.15mol H_2O
19) a. $4P + 5O_2 \rightarrow P_4O_{10}$ b. 8.85g O_2 c. 14.2g P_4O_{10} d. 3.26g P
20) 30.31g HNO_3
21) a. limiting reactant is Fe_2O_3 b. 195g Fe is formed
22) 26.7g of $FeCl_3$ are left over
23) theoretical yield = 66.98g $BaSO_4$, % yield = 94.73%
24) % yield = 88.74%