

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

**Concept of mole/molar ratio**

- 1) How many moles of sodium atoms correspond to  $1.56 \times 10^{21}$  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,  $\text{Al}_2\text{O}_3$ ?
- 3) How many moles of Al are in 2.16 mol of  $\text{Al}_2\text{O}_3$ ?
- 4) Aluminum sulfate,  $\text{Al}_2(\text{SO}_4)_3$ , 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  $\text{Al}_2(\text{SO}_4)_3$
  - 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  $\text{Al}_2(\text{SO}_4)_3$ ?
- 5) How many moles of  $\text{H}_2$  and  $\text{N}_2$  can be formed by the decomposition of 0.145 mol of ammonia,  $\text{NH}_3$ ?
- 6) What is the total number of atoms in 0.260 mol of glucose,  $\text{C}_6\text{H}_{12}\text{O}_6$ ?
- 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  $\text{Ca}_3(\text{PO}_4)_2$
  - e. 0.625 mol  $\text{Fe}(\text{NO}_3)_3$
  - f. 0.600 mol  $\text{C}_4\text{H}_{10}$
  - g. 1.45 mol  $(\text{NH}_4)_2\text{CO}_3$
- 9) Calculate the number of moles of each compound:
  - a. 21.5 g  $\text{CaCO}_3$
  - b. 1.56 g  $\text{NH}_3$
  - c. 16.8 g  $\text{Sr}(\text{NO}_3)_2$
  - d. 6.98 mg  $\text{Na}_2\text{CrO}_4$

**Percent composition and empirical formulas**

- 10) Calculate the percentage composition by mass of each element in the following compounds:
  - a.  $\text{NaH}_2\text{PO}_4$

- b.  $\text{NH}_4\text{H}_2\text{PO}_4$   
 c.  $(\text{CH}_3)_2\text{CO}$

- 11) Phencyclidine is  $\text{C}_{17}\text{H}_{25}\text{N}$ . 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  $7.14 \times 10^{21}$  atoms of N in the compound  $\text{N}_2\text{O}_5$ ?
- 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,  $\text{Na}_x\text{Tc}_y\text{O}_z$ .
- 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  $\text{CO}_2$  and 0.805g  $\text{H}_2\text{O}$  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 ( $\text{O}_2$ ) to give iron oxide with the formula  $\text{Fe}_2\text{O}_3$ "
- 17) Balance the following reactions:
- $\text{Ca}(\text{OH})_2 + \text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}$
  - $\text{AgNO}_3 + \text{CaCl}_2 \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{AgCl}$
  - $\text{Fe}_2\text{O}_3 + \text{C} \rightarrow \text{Fe} + \text{CO}_3$
  - $\text{NaHCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O} + \text{CO}_2$
  - $\text{C}_4\text{H}_{10} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
  - $\text{Mg}(\text{OH})_2 + \text{HBr} \rightarrow \text{MgBr}_2 + \text{H}_2\text{O}$
  - $\text{Al}_2\text{O}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Al}_2(\text{SO}_4)_3 + \text{H}_2\text{O}$
  - $\text{KHCO}_3 + \text{H}_3\text{PO}_4 \rightarrow \text{K}_2\text{HPO}_4 + \text{H}_2\text{O} + \text{CO}_2$
  - $\text{C}_9\text{H}_{10}\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

### Stoichiometry/limiting reactants

- 18) Chlorine is used by textile manufacturers to bleach cloth. Excess chlorine is destroyed by its reaction with sodium thiosulfate,  $\text{Na}_2\text{S}_2\text{O}_3$ :
- $$\text{Na}_2\text{S}_2\text{O}_3(\text{aq}) + 4\text{Cl}_2(\text{g}) + 5\text{H}_2\text{O}(\text{aq}) \rightarrow 2\text{NaHSO}_4(\text{aq}) + 8\text{HCl}(\text{aq})$$
- How many moles of  $\text{Na}_2\text{S}_2\text{O}_3$  are needed to react with 0.12mol of  $\text{Cl}_2$ ?
  - How many moles of HCl can form from 0.12mol of  $\text{Cl}_2$ ?
  - How many moles of  $\text{H}_2\text{O}$  are required for the reaction of 0.12mol of  $\text{Cl}_2$ ?
  - How many moles of  $\text{H}_2\text{O}$  react if 0.24mol HCl is formed?
- 19) The incandescent white of a fireworks display is caused by the reaction of phosphorous with  $\text{O}_2$  to give  $\text{P}_4\text{O}_{10}$ .
- Write the balanced chemical equation for the reaction.

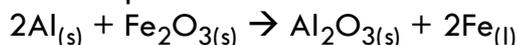
- b. How many grams of O<sub>2</sub> are needed to combine with 6.85g of P?
- c. How many grams of P<sub>4</sub>O<sub>10</sub> can be made from 8.00g of O<sub>2</sub>?
- d. How many grams of P are needed to make 7.46g P<sub>4</sub>O<sub>10</sub>?

20) In *dilute* nitric acid, HNO<sub>3</sub>, copper metal dissolves according to the following equation:



How many grams of HNO<sub>3</sub> are needed to dissolve 11.45g of Cu?

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



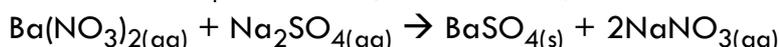
produces so much heat the iron that forms is molten. Because of this, railroads use the reaction to provide molten steel to weld steel rails together when laying track. Suppose that in one batch of reactants 4.20mol Al was mixed with 1.75mol Fe<sub>2</sub>O<sub>3</sub>.

- 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<sub>3</sub>, reacts with iron(III) chloride, FeCl<sub>3</sub>, to give silver chloride, AgCl, and iron(III) nitrate, Fe(NO<sub>3</sub>)<sub>3</sub>. A solution containing 18.0g AgNO<sub>3</sub> was mixed with a solution containing 32.4g FeCl<sub>3</sub>. How many grams of which reactant *remains* after the reaction is over?

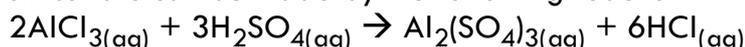
### Theoretical and percent yield

23) Barium sulfate, BaSO<sub>4</sub>, is made by the following reaction:



An experiment was begun with 75.00g of Ba(NO<sub>3</sub>)<sub>2</sub> and an excess of Na<sub>2</sub>SO<sub>4</sub>. After collecting and drying the product, 63.45g BaSO<sub>4</sub> was obtained. Calculate the theoretical yield and percent yield of BaSO<sub>4</sub>.

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



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<sub>3</sub> was mixed with 30.0g H<sub>2</sub>SO<sub>4</sub>. Eventually, 28.46g of pure Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> was isolated. Calculate the percent yield.

### Answers

- 1)  $2.59 \times 10^{-3}$  mol Na atoms
- 2) 1.05mol Al
- 3) 4.32mol Al
- 4) a. 2mol Al/3mol S      b. 3mol S/1mol Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>      c. 0.600mol Al      d. 3.48mol S
- 5) 0.0725mol N<sub>2</sub> and 0.218mol H<sub>2</sub>
- 6)  $3.76 \times 10^{24}$  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<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>
- e. 151g Fe(NO<sub>3</sub>)<sub>2</sub>      f. 34.9g C<sub>4</sub>H<sub>10</sub>      g. 139g (NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub>
- 9) a. 0.215mol      b. 0.0916mol      c. 0.0794mol      d.  $4.31 \times 10^{-8}$  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<sub>4</sub>

14) Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub>

15) C<sub>2</sub>H<sub>6</sub>O

16)  $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$

17)

a.  $\text{Ca}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{CaCl}_2 + 2\text{H}_2\text{O}$

b.  $2\text{AgNO}_3 + \text{CaCl}_2 \rightarrow \text{Ca}(\text{NO}_3)_2 + 2\text{AgCl}$

c.  $2\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Fe} + 3\text{CO}_3$

d.  $2\text{NaHCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O} + 2\text{CO}_2$

e.  $2\text{C}_4\text{H}_{10} + 13\text{O}_2 \rightarrow 8\text{CO}_2 + 10\text{H}_2\text{O}$

f.  $\text{Mg}(\text{OH})_2 + 2\text{HBr} \rightarrow \text{MgBr}_2 + 2\text{H}_2\text{O}$

g.  $\text{Al}_2\text{O}_3 + 3\text{H}_2\text{SO}_4 \rightarrow \text{Al}_2(\text{SO}_4)_3 + 3\text{H}_2\text{O}$

h.  $2\text{KHCO}_3 + \text{H}_3\text{PO}_4 \rightarrow \text{K}_2\text{HPO}_4 + 2\text{H}_2\text{O} + 2\text{CO}_2$

i.  $\text{C}_9\text{H}_{10}\text{O} + 14\text{O}_2 \rightarrow 9\text{CO}_2 + 10\text{H}_2\text{O}$

18) a. 0.030mol Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>

b. 0.24mol HCl

c. 0.15mol H<sub>2</sub>O

d. 0.15mol H<sub>2</sub>O

19) a.  $4\text{P} + 5\text{O}_2 \rightarrow \text{P}_4\text{O}_{10}$

b. 8.85g O<sub>2</sub>

c. 14.2g P<sub>4</sub>O<sub>10</sub>

d. 3.26g P

20) 30.31g HNO<sub>3</sub>

21) a. limiting reactant is Fe<sub>2</sub>O<sub>3</sub>

b. 195g Fe is formed

22) 26.7g of FeCl<sub>3</sub> are left over

23) theoretical yield = 66.98g BaSO<sub>4</sub>, % yield = 94.73%

24) % yield = 88.74%