Stoichiometry

1. If 544 g of zinc metal and a surplus of copper (II) nitrate are reacted, how many grams of copper metal will be produced?

Zinc + copper (II) nitrate → zinc nitrate + copper

$Zn_{(s)} + Cu(NO_3)_{2(aq)} \rightarrow Zn(NO_3)_{2(aq)} + Cu_{(s)}$

316 g ? g

$316\ g\ Zn \times \frac{1\ mol\ Zn}{65.38\ g\ Zn} \times \frac{1\ mol\ Cu}{1\ mol\ Zn} \times \frac{63.55\ g\ Cu}{1\ mol\ Cu} = 307\ g\ Cu$

2. 347 g of hydrochloric acid are added to a beaker containing a solution of calcium hydroxide. How many grams of calcium chloride (110.98 g/mol) are produced?

hydrochloric acid + calcium hydroxide → calcium chloride + water

$2\ HCl_{(aq)} + Ca(OH)_{2(aq)} \rightarrow CaCl_{2(aq)} + 2H_2O_{(l)}$

2.02 g ? g

$2.02\ g\ \cancel{HCl} \times \frac{1\ \cancel{mol\ HCl}}{36.46\ \cancel{g\ HCl}} \times \frac{1\ mol\ \cancel{CaCl_2}}{2\ mol\ \cancel{HCl}} \times \frac{110.98\ g\ CaCl_2}{1\ mol\ \cancel{CaCl_2}} = 3.07\ g\ CaCl_2$

3. What mass, in grams, of hydrogen gas (~~2.1~~ 2.016 g/mol) is produced if 170.9 g of zinc metal (65.39 g/mol) are added to an excess hydrochloric acid (36.46 g/mol)?

Zinc + hydrochloric acid → zinc chloride + hydrogen

$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$

996 g ? g

$996\ g\ \cancel{Zn} \times \frac{1\ \cancel{mol\ Zn}}{65.39\ \cancel{g\ Zn}} \times \frac{1\ \cancel{mol\ H_2}}{1\ mol\ \cancel{Zn}} \times \frac{2.016\ g\ H_2}{1\ \cancel{mol\ H_2}} = 30.7\ g\ H_2$

4. Calculate the mass of nitrogen gas produced from ~~37.7~~ 47.6 g ammonium dichromate in the volcano reaction.

$$(NH_4)_2Cr_2O_7 \rightarrow Cr_2O_3 + N_2 + 4H_2O$$

27.6 g ? g

ammonium dichromate → chromium(III) oxide + nitrogen + water

$$27.6\ g\ (NH_4)_2Cr_2O_7 \times \frac{1\ mol\ (NH_4)_2Cr_2O_7}{252.1\ g\ (NH_4)_2Cr_2O_7} \times \frac{1\ mol\ N_2}{1\ mol\ (NH_4)_2Cr_2O_7} \times \frac{28.02\ g\ N_2}{1\ mol\ N_2}\ 3.07\ g\ N$$

5. If 1.16×10^{35} g of carbon dioxide are produced from the combustion of propane, C_3H_8, how many molecules of propane were burned?

propane + oxygen → carbon dioxide + water

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

? molecules 6.73×10^{34} g

$$6.73\times10^{34}\ g\ CO_2 \times \frac{1\ mol\ CO_2}{44.01\ g\ CO_2} \times \frac{1\ mol\ C_3H_8}{3\ mol\ CO_2} \times \frac{6.02\times10^{23}\ molecules\ C_3H_8}{1\ mol\ C_3H_8} = 3.07\times10^{56}\ molecules\ C_3H_8$$

6. If 1.07×10^{50} g of hydrochloric acid (36.46 g/mol) and 9.45×10^{49} g of aluminum hydroxide (78.01 g/mol) react to form aluminum chloride (133.33 g/mol) and water (18.02 g/mol), how many grams of water will be produced? What is the limiting reactant?

hydrochloric acid + aluminum hydroxide → aluminum chloride + water

$$3HCl(aq) + Al(OH)_3(s) \rightarrow AlCl_3(aq) + 3H_2O(l)$$

8.23×10^{50} g 4.43×10^{49} g ? g

$$8.23\times10^{50}\ g\ HCl \times \frac{1\ mol\ HCl}{36.46\ g\ HCl} \times \frac{3\ mol\ H_2O}{3\ mol\ HCl} \times \frac{18.02\ g\ H_2O}{1\ mol\ H_2O} = \cancel{4.07\times10^{50}\ g\ H_2O}$$

$$4.43\times10^{49}\ g\ Al(OH)_3 \times \frac{1\ mol\ Al(OH)_3}{78.01\ g\ Al(OH)_3} \times \frac{3\ mol\ H_2O}{1\ mol\ Al(OH)_3} \times \frac{18.02\ g\ H_2O}{1\ mol\ H_2O} = 3.07\times10^{49}\ g\ H_2O$$

L.R.

7. How many grams of ethylene oxide, C_2H_4O, (44.05 g/mol) will be produced from 6.73×10^7 g of KOH (56.11 g/mol) reacting with 9.75×10^7g ethylene chlorohydrin, C_2H_5ClO, (80.51 g/mol) as shown in the equation below? What is the limiting reactant?

$$KOH + C_2H_5ClO \rightarrow C_2H_4O + KCl + H_2O$$

3.91×10^7 g $\quad 9.75 \times 10^7$ g $\quad$? g

potassium hydroxide + ethylene chlorohydrin → ethylene oxide + potassium chloride + H_2

3.91×10^7 g KOH × $\frac{1 \text{ mol KOH}}{56.11 \text{ g KOH}}$ × $\frac{1 \text{ mol } C_2H_4O}{1 \text{ mol KOH}}$ × $\frac{44.05 \text{ g } C_2H_4O}{1 \text{ mol } C_2H_4O}$ = 3.07×10^7 g C_2H_4O

LR

KOH is L.R.

9.75×10^7 g C_2H_5ClO × $\frac{1 \text{ mol } C_2H_5ClO}{80.51 \text{ g } C_2H_5ClO}$ × $\frac{1 \text{ mol } C_2H_4O}{1 \text{ mol } C_2H_5ClO}$ × $\frac{44.05 \text{ g } C_2H_4O}{1 \text{ mol } C_2H_4O}$ = ~~5.33×10^7 g C_2H_4O~~

8. Carbon monoxide(28.01 g/mol) can be combined with hydrogen to produce methanol, CH_3OH. Methanol is used as an industrial solvent, as a reactant in synthesis, and as a clean-burning fuel for some racing cars. If you had 4.71 mg CO and .664 mg H_2, how many grams of CH_3OH (32.04 g/mol) would be produced?

carbon monoxide + hydrogen → methanol

$$CO(g) + 2 H_2(g) \rightarrow CH_3OH(l)$$

17.5 mg $\quad$ .386 mg $\quad$? g

17.5 mg CO × $\frac{1 \text{ g CO}}{1000 \text{ mg CO}}$ × $\frac{1 \text{ mol CO}}{28.01 \text{ g CO}}$ × $\frac{1 \text{ mol } CH_3OH}{1 \text{ mol CO}}$ × $\frac{32.04 \text{ g } CH_3OH}{1 \text{ mol } CH_3OH}$ = ~~.0200~~ g CH_3OH

.386 mg H_2 × $\frac{1 \text{ g } H_2}{1000 \text{ mg } H_2}$ × $\frac{1 \text{ mol } H_2}{2.016 \text{ g } H_2}$ × $\frac{1 \text{ mol } CH_3OH}{2 \text{ mol } H_2}$ × $\frac{32.04 \text{ g } CH_3OH}{1 \text{ mol } CH_3OH}$ = .00307 g CH_3OH

LR

9. When 57.0 g of magnesium metal are burned in excess oxygen (32.00 g/mol), 49.9 g of magnesium oxide (40.31 g/mol) are produced. What is the percent for this reaction?

magnesium + oxygen → magnesium oxide

$Mg(s) + \frac{1}{2} O_2(g) \rightarrow MgO(s)$

76.0 g $\quad\quad$ 38.8 g act $\quad$? g theo

$\% Y = \frac{act}{theo} \times 100$

$= \frac{38.8}{126}$ 100

76.0 g Mg × $\frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}}$ × $\frac{1 \text{ mol MgO}}{1 \text{ mol Mg}}$ × $\frac{40.31 \text{ g MgO}}{1 \text{ mol MgO}}$ = 126 g MgO

30.8 %

75.1

10. When aluminum metal is placed into a solution of copper (II) sulfate the aluminum replaces the copper to form an aluminum sulfate solution and copper metal. If 40.19 g of aluminum is placed into the solution and only 75.0 g of copper were formed, what is the percent yield for this reaction?

aluminum + copper (II) sulfate → aluminum sulfate + copper

$2\,Al_{(s)} + 3\,CuSO_{4\,(aq)} \rightarrow Al_2(SO_4)_{3\,(aq)} + 3\,Cu_{(s)}$

54.1 g — 58.5 act, ? g theo

$$54.1\ Al \times \frac{1\ mol\ Al}{26.98\ g\ Al} \times \frac{3\ mol\ Cu}{2\ mol\ Al} \times \frac{63.55\ g\ Cu}{1\ mol\ Cu} = 191\ g\ Cu$$

$$\%\,Y = \frac{act}{theo} \times 100 = \frac{58.5}{191} \times 100 = 30.6\ \%$$

11. Burning 114.7 g of iron(II) sulfide (87.92 g/mol) produces 5.502 g of solid product. What is the percent yield for this reaction? (Fe_2O_3 - 159.7 g/mol)

iron(II) sulfide + oxygen → iron(III) oxide + sulfur dioxide

$$4\,FeS(s) + 7\,O_2(g) \rightarrow 2\,Fe_2O_3(s) + 4\,SO_2(g)$$

153.6 g — 4.283 g act, ? g theo

$$153.6\ FeS \times \frac{1\ mol\ FeS}{87.92\ g\ FeS} \times \frac{2\ mol\ Fe_2O_3}{4\ mol\ FeS} \times \frac{159.7\ g\ Fe_2O_3}{1\ mol\ Fe_2O_3} = 139.5\ g\ Fe_2O_3$$

~~506.7~~

$$\%\,Y = \frac{act}{theo} \times 100 = \frac{4.283}{139.5} \times 100 = 3.070\ \%$$

10.76 L

12. A chemist is studying reactions that evolve carbon dioxide gas. One reaction is calcium carbonate (100.09 g/mol) decomposing into calcium oxide (56.08 g/mol) and carbon dioxide (44.01 g/mol). How many grams of calcium carbonate are needed to produce enough carbon dioxide to fill the dual air bags on my truck with a total volume of .1076 L? The density of carbon dioxide is 1.961 g/L.

Calcium carbonate → calcium oxide + carbon dioxide

$CaCO_{3\,(s)} \rightarrow CaO_{(s)} + CO_{2\,(g)}$

? g — 68.8 L (~~.1076~~)

$$68.8\ L\ CO_2 \times \frac{1.961\ g\ CO_2}{1\ L\ CO_2} \times \frac{1\ mol\ CO_2}{44.01\ g\ CO_2} \times \frac{1\ mol\ CaCO_3}{1\ mol\ CO_2} \times \frac{100.09\ g\ CaCO_3}{1\ mol\ CaCO_3} = 307\ g\ CaCO_3$$

13. 8.79×10^{-11} g of carbon react with excess water. How many grams of methane (16.04 g/mol) can be expected if the percent yield for this reaction is 90.0%?

Carbon + water → methane + carbon dioxide

$$2\,C(s) + 2\,H_2O(l) \rightarrow CH_4(g) + CO_2(g)$$

5.11×10^{-11} g   90.0%

? g theo

? g act

$$5.11\times10^{-11}\,g\,C \times \frac{1\,mol\,C}{12.01\,g\,C} \times \frac{1\,mol\,CH_4}{2\,mol\,C} \times \frac{16.04\,g\,CH_4}{1\,mol\,CH_4} = 3.41\times10^{-11}\,g\,CH_4$$

theo × % = act

$$(3.41\times10^{-11})(.900) = \cancel{4.11\times10^{-11}}\ 3.07\times10^{-11}\,g\,CH_4$$

14. The air bag in a car needs 7.72 L of nitrogen to inflate properly. How many grams of sodium will also be produced from this reaction if there is enough nitrogen gas to fill this air bag? Nitrogen gas has a density of 1.251 g/L at this temperature.

sodium azide → sodium + nitrogen

$$2\,NaN_3(s) \rightarrow 2\,Na(s) + 3\,N_2(g)$$

? g   44.9 L

$$44.9\,L\,N_2 \times \frac{1.251\,g\,N_2}{1\,L\,N_2} \times \frac{1\,mol\,N_2}{28.02\,g\,N_2} \times \frac{2\,mol\,Na}{3\,mol\,N_2} \times \frac{22.99\,g\,Na}{1\,mol\,Na} = 30.7\,g\,Na$$

15. Calcium oxide, which is used in cement, can be derived by decomposing the calcium carbonate that occurs naturally in limestone. How many milliliters of CO_2 (44.01 g/mol) will be liberated when .014 g of CaO (56.08 g/mol) have been produced? The density of CO_2 is 1.997 g/L.

calcium carbonate → calcium oxide + carbon dioxide

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

.00781 g   ? mL

$$.00781\,g\,CaO \times \frac{1\,mol\,CaO}{56.08\,g\,CaO} \times \frac{1\,mol\,CO_2}{1\,mol\,CaO} \times \frac{44.01\,g\,CO_2}{1\,mol\,CO_2} \times \frac{1\,L\,CO_2}{1.997\,g\,CO_2} \times \frac{1000\,mL\,CO_2}{1\,L\,CO_2} = 3.07\,mL\,CO_2$$

16. How many liters of oxygen will evolve from the decomposition of 1.93×10^4 grams potassium chlorate (122.55 g/mol)? The density of oxygen is 1.429 g/L. The other product is potassium chloride.

potassium chlorate → potassium chloride + oxygen

$$\underset{1.12\times10^4\,g}{2KClO_{3(s)}} \rightarrow 2KCl_{(s)} + \underset{?\,L}{3O_{2(g)}}$$

$$1.12\times10^4\ KClO_3 \times \frac{1\,mol\ KClO_3}{122.55\,g\ KClO_3} \times \frac{3\,mol\ O_2}{2\,mol\ KClO_3} \times \frac{32.00\,g\ O_2}{1\,mol\ O_2} \times \frac{1\,L\ O_2}{1.429\,g\ O_2} = 3070\ L\ O_2$$

17. How many liters of air must react 5.44×10^6 mL of benzene (78.11 g/mol) in order for combustion to occur completely? The percentage of oxygen in air is 20.9%. The density of benzene is 0.8787 g/mL and oxygen's density is 1.331 g/L.

Benzene + oxygen → carbon dioxide + water

$$\underset{3.16\times10^6\,mL}{C_6H_6} + \underset{?\,L}{\tfrac{15}{2}O_2} \rightarrow 6CO_2 + 3H_2O$$

$$3.16\times10^6\ mL\ C_6H_6 \times \frac{0.8787\,g\ C_6H_6}{1\,mL\ C_6H_6} \times \frac{1\,mol\ C_6H_6}{78.11\,g\ C_6H_6} \times \frac{15/2\,mol\ O_2}{1\,mol\ C_6H_6} \times \frac{32.00\,g\ O_2}{1\,mol\ O_2} \times \frac{1\,L\ O_2}{1.331\,g\ O_2} \times \frac{100\,L\ air}{20.9\,L\ O_2} = 3.07\times10^7\,L\ air$$

18. A truck emits NO_2 (46.1 g/mol) at a rate of 50.6 g/km. From the equations below, determine how much ozone (48.00 g/mol) can be produced per kilometer of travel by this vehicle.

$$\underset{29.5\,g/km}{NO_2\,(g)} \rightarrow NO\,(g) + O\,(g)$$

$$O_2\,(g) + O\,(g) \rightarrow \underset{?\,g/km}{O_3\,(g)}$$

$$\frac{29.5\,g\ NO_2}{km} \times \frac{1\,mol\ NO_2}{46.1\,g\ NO_2} \times \frac{1\,mol\ O}{1\,mol\ NO_2} \times \frac{1\,mol\ O_3}{1\,mol\ O} \times \frac{48.0\,g\ O_3}{1\,mol\ O_3} = \frac{30.7\,g\ O_3}{km}$$