

Chapter 9 Problem Set

Hudecek, 2009.

Directions: As always, you must show all calculations with proper units in order to earn credit for your assignment. Problems asking for a limiting reactant must be accompanied by a calculation of proof.

A. Basic Stoichiometry

- Sodium chloride is produced from its elements through a synthesis reaction.
 - Write the balanced chemical equation for this reaction.
 - How many moles of chlorine gas are needed to produce 12.50 grams of sodium chloride?
 - What mass of sodium metal would be needed to produce 45.0 grams of sodium chloride?
 - What mass of sodium chloride would be produced from 12.0 moles of chlorine gas?
- Iron metal reacts with an aqueous solution of copper(II) sulfate by single replacement to produce iron(III) sulfate.
 - Write the balanced chemical equation for this reaction.
 - What mass of copper is produced from 4.50 moles of iron?
 - How many moles of iron(III) sulfate could be produced from 3.75 grams of iron?
 - How many grams of copper could be produced from a solution that contains 5.00 grams of copper(II) sulfate?
- Sulfuric acid reacts with sodium hydrogen carbonate to produce carbon dioxide, water, and a salt.
 - Write the balanced chemical equation for this reaction.
 - How many moles of water are produced from 0.750 moles of sulfuric acid?
 - What mass of sodium sulfate is produced from 3.50 moles of sulfuric acid?
 - What mass of sodium hydrogen carbonate is needed to produce 45.20 grams of the salt?
- Write the chemical equation for the combustion of ethane (C_2H_6).
 - How many moles of oxygen would be needed to react with 3.50 kilograms of ethane?
 - How many grams of oxygen would be needed to produce 55.0 milligrams of carbon dioxide gas?
 - What volume of carbon dioxide gas, in liters at STP, would be produced from the complete combustion of 85.0 grams of ethane? (density of CO_2 at STP = 1.997 g/L)
- Copper metal reacts with a nitric acid solution to produce copper(II) nitrate, nitrogen dioxide, and water.
 - Write the balanced chemical reaction for this reaction.
 - How many moles of nitric acid would be necessary to produce 35.50 grams of copper(II) nitrate?
 - How many grams of copper metal would be necessary to produce 5.00 moles of nitrogen dioxide gas?
 - What volume of liquid water could be produced from a solution that contains 25.0 centigrams of aqueous hydrogen nitrate? Assume the density of water = 0.998 g/mL.

6. Iron is generally produced from iron ore through a reaction in a blast furnace where iron(III) oxide reacts with carbon monoxide to produce iron metal and carbon dioxide.
- Write out the balanced chemical equation for this reaction.
 - What mass of carbon monoxide is needed to completely react with 5.875 kilograms of iron(III) oxide?
 - What mass of iron can be produced from 78.85 grams of iron(III) oxide? How many moles of carbon dioxide are also produced?
 - How many moles of carbon dioxide are produced from the reaction of 8.75 moles of iron(III) oxide?
7. Aqueous solutions of aluminum chloride and ammonium carbonate react by double replacement to produce a precipitate of aluminum carbonate.
- Write out the balanced chemical equation for this reaction.
 - How many moles of aluminum chloride are needed to react with 6.50 moles of ammonium carbonate?
 - How many moles of ammonium chloride are produced from the reaction of a solution containing 73.25 grams of ammonium carbonate?
 - What mass of precipitate is produced from a solution that contains 23.55 grams of aluminum chloride?
8. a. Write the balanced equation for the combustion of propane (C_3H_8).
- How many moles of oxygen would be necessary to react completely with 8.50 moles of propane?
 - How many moles of each product would be produced from the reaction in part a.
 - How many grams of propane would react to produce 950.0 milliliters of carbon dioxide at STP? (Density of carbon dioxide at STP = 1.997 g/L)
9. Phosphorus burns in air, reacting with oxygen gas to produce tetraphosphorus decoxide.
- What mass of phosphorus will be needed to produce 3.25 moles of the oxide?
 - What volume of oxygen gas at STP is consumed by reacting with 4579 kilograms of phosphorus? Density of oxygen at STP = 1.429 g/L.
10. When hot steam(H_2O) is passed over iron metal, it oxidizes to produce hydrogen gas and Fe_3O_4 . If 625 grams of Fe_3O_4 is produced, how many moles of hydrogen gas are also produced?
11. A reaction between hydrazine, N_2H_4 , and dinitrogen tetroxide, has been used to launch rockets into space. The reaction produces nitrogen gas and water vapor. How many grams of water are made when 450. kg of N_2O_4 are consumed?
12. The intense heat of a welding torch is produced from the combustion of acetylene (C_2H_2). The densities of these gases at STP are: acetylene = 1.165 g/L, oxygen = 1.429 g/L, carbon dioxide = 1.997 g/L.
- How many liters of oxygen are needed to burn 245.0 mL acetylene?
 - How many grams of acetylene are needed to produce 5.00 kL of carbon dioxide?
 - How many liters of dry air are consumed by completely reacting 85.0 kL of acetylene gas? The density of dry air is 1.293 g/L and is 21.0% oxygen by mass.

B. Limiting Reactants

13. 45.0 grams of hexane (C_6H_{14}) react by combustion in the presence of 115.0 grams of oxygen gas.
 - a. Determine the limiting reactant showing a calculation of proof.
 - b. Calculate the mass of excess reactant.
 - c. How many moles of carbon dioxide are theoretically produced?
 - d. How many grams of water vapor are theoretically produced?

14. 4.5 moles of sulfuric acid reacts with 4.0 moles of sodium hydroxide.
 - a. Identify the limiting reactant showing a calculation of proof.
 - b. How many moles of excess reactant will remain?
 - c. How many moles of the salt should form?

15. 120.0 grams of aluminum carbonate reacts with 3.50 moles of nitric acid.
 - a. Identify the limiting reactant showing a calculation of proof.
 - b. How many moles of excess reactant will remain?
 - c. How many moles of the salt should form?

16. 165.0 grams of sulfuric acid react with 48.5 grams of aluminum hydroxide by double replacement.
 - a. Identify the limiting reactant showing a calculation of proof.
 - b. Calculate the mass of excess reactant.
 - c. Calculate the mass of the salt that forms (assume 100% yield).

17. 125.0 grams of aluminum nitrate react with 125.0 grams of sodium sulfate.
 - a. Identify the limiting reactant.
 - b. Calculate the mass of excess reactant.
 - c. Calculate the theoretical mass of aluminum sulfate precipitate formed.
 - d. Calculate the percent yield for an experiment that collected 88.70 grams of precipitate from this reaction.

18. How many grams of aluminum oxide would be produced by the reaction of 15.0 grams of aluminum metal with 10.0 grams of oxygen gas(theoretically)?

19. 50.0 grams of copper and 270.0 grams of silver nitrate are available to react by single replacement. What mass of silver metal can theoretically be produced?

20. Ammonia (NH_3) reacts with oxygen gas to produce nitrogen monoxide and water.
 - a. If 2.90 moles of ammonia and 3.75 moles of oxygen are available, how many moles of each product are formed?
 - b. Which reactant is limiting if 4.20×10^4 grams of ammonia and 7.40×10^4 grams of oxygen are available?
 - c. What mass of NO is formed in the reaction of 869.0 kg of ammonia and 2480.0 kg oxygen?
 - d. What volume of water (density 0.997 g/mL) is formed when 4.58 L NH_3 (density 0.761 g/L) reacts with 5.10 L oxygen (density 0.714 g/L)?

C. Percent Yield

21. Calculate the percent yield for each of the following:
 - a. theoretical yield = 20.0 g, actual yield = 15.0 g, percent yield = ?
 - b. theoretical yield = 2.531 g, percent yield = 90.0%, actual yield = ?
 - c. theoretical yield = 5.205 g, actual yield = 4.75 g, percent yield = ?
 - d. theoretical yield = 3.451 g, percent yield = 89.2%, actual yield = ?

22. 34.5 grams of iron are recovered from the reaction 50.0 grams of hot magnetic iron oxide (Fe_3O_4) with an excess of hydrogen gas (steam is the other product of the reaction). What is the percent yield for the reaction?

23. Phosphorus(V) oxide reacts with water to produce phosphoric acid.
 - a. Write the balanced chemical equation for this reaction.
 - b. If the percent yield for this reaction is 85.2%, what mass of phosphoric acid is expected from the reaction of 73.7 grams phosphorus(V) oxide with excess water?

24. Aluminum oxide is decomposed into its elements by heating. What is the percent yield for this reaction if 175.0 milligrams of aluminum are recovered from 35.0 centigrams of the oxide?

25. In the commercial production of the element arsenic, arsenic(III) oxide is heated with carbon, producing carbon dioxide and arsenic.
 - a. What is the percent yield if 5.33 grams of arsenic are produced from 8.87 grams of arsenic(III) oxide?
 - b. What mass of arsenic is recovered from 125.0 kilograms of arsenic(III) oxide if the percent yield is 92.50%?

26. Solutions of ammonium sulfate and chromium(III) nitrite react to produce a precipitate of chromium(III) sulfate.
 - a. Solutions containing 35.00 grams of ammonium sulfate and 10.00 grams of chromium nitrite are mixed. What is the limiting reactant?
 - b. How many grams of excess reactant remain in solution?
 - c. If a student has a percent yield of 89.5%, how much precipitate did they collect?

27. During the summer months, Mr. Hudecek regularly purifies himself by working out stoichiometry problems in his hyperbaric chamber for one-week intervals. While in the chamber, he sustains himself on a minimal diet of pure cane sugar ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$). Excited for his first session of the summer, Mr. Hudecek accidentally locked himself in the chamber without checking his supplies. Checking his gauges, he found 37.38 grams of sugar and 42.79 liters of pure oxygen were available (assume oxygen density = 1.429 g/L). Strangely, Mr. Hudecek knows that to survive a week in the chamber, his body must produce a minimum of 1.30 moles of carbon dioxide from the combustion of his dietary sugar. Immediately, he began calculations to determine whether there was any chance of survival. Is his teaching career over? Does he survive this ordeal? Please, help Mr. Hudecek calculate his fate.

Chapter 9 Problem Set Key

Hudecek, 2009

A. Basic Stoichiometry

- $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$
 - 0.1069 mol Cl_2
 - 17.7 g Na
 - 1.40×10^3 g NaCl
- $2\text{Fe} + 3\text{CuSO}_4 \rightarrow \text{Fe}_2(\text{SO}_4)_3 + 3\text{Cu}$
 - 429 g Cu
 - 0.0336 mol $\text{Fe}_2(\text{SO}_4)_3$
 - 1.99 g Cu
- $\text{H}_2\text{SO}_4 + 2\text{NaHCO}_3 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O} + \text{Na}_2\text{SO}_4$
 - 1.50 mol H_2O
 - 497 g Na_2SO_4
 - 53.46 g NaHCO_3
- $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$
 - 407 mol O_2
 - 0.0700 g O_2
 - 125 L CO_2
- $\text{Cu} + 4\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{NO}_2 + 2\text{H}_2\text{O}$
 - 0.7571 mol HNO_3
 - 159 g Cu
 - 0.0358 mL H_2O
- $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
 - 3091 g CO
 - 55.15 g Fe, 1.481 mol CO_2
 - 26.2 mol CO_2
- $2\text{AlCl}_3 + 3(\text{NH}_4)_2\text{CO}_3 \rightarrow \text{Al}_2(\text{CO}_3)_3 + 6\text{NH}_4\text{Cl}$
 - 4.33 mol AlCl_3
 - 1.524 mol NH_4Cl
 - 20.66 g $\text{Al}_2(\text{CO}_3)_3$
- $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$
 - 42.5 mol O_2
 - 25.5 mol CO_2 , 34.0 mol H_2O
 - 0.6338 g C_3H_8

9. $4\text{P} + 5\text{O}_2 \rightarrow \text{P}_4\text{O}_{10}$
 a. 403 g P
 b. 4.139×10^6 L O_2
10. $3\text{Fe} + 4\text{H}_2\text{O} \rightarrow 4\text{H}_2 + \text{Fe}_3\text{O}_4$
 10.8 mol H_2
11. $2\text{N}_2\text{H}_4 + \text{N}_2\text{O}_4 \rightarrow 3\text{N}_2 + 4\text{H}_2\text{O}$
 3.52×10^5 g H_2O
12. $2\text{C}_2\text{H}_2 + 5\text{O}_2 \rightarrow 4\text{CO}_2 + 2\text{H}_2\text{O}$
 a. 0.6136 L O_2
 b. 2950 g C_2H_2
 c. 1.12×10^6 L air

B. Limiting Reactants

13. $2\text{C}_6\text{H}_{14} + 19\text{O}_2 \rightarrow 12\text{CO}_2 + 14\text{H}_2\text{O}$
 a. O_2 is limiting
 b. 12.4 g C_6H_{14} excess
 c. 2.270 mol CO_2 produced
 d. 47.72 g H_2O produced
14. a. NaOH is limiting
 b. 2.5 mol H_2SO_4 excess
 c. 2.0 mol Na_2SO_4 produced
15. a. $\text{Al}_2(\text{CO}_3)_3 + 6\text{HNO}_3 \rightarrow 3\text{CO}_2 + 3\text{H}_2\text{O} + 2\text{Al}(\text{NO}_3)_3$
 b. $\text{Al}_2(\text{CO}_3)_3$ is limiting
 c. 0.42 mol HNO_3 excess
 d. 1.026 mol $\text{Al}(\text{NO}_3)_3$ produced
16. a. $\text{Al}(\text{OH})_3$ is limiting
 b. 73.5 g H_2SO_4 excess
 c. 106 g $\text{Al}_2(\text{SO}_4)_3$ produced
17. a. Both can be considered limiting!!!
 b. No excess reactants!!! Nothing left!!!
 c. 100.4 g $\text{Al}_2(\text{SO}_4)_3$ produced
 d. 88.35 % yield
18. $4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3$
 O_2 is limiting
 21.2 g Al_2O_3 produced
19. $\text{Cu} + 2\text{AgNO}_3 \rightarrow 2\text{Ag} + \text{Cu}(\text{NO}_3)_2$

Cu is limiting
170. g Ag produced

20. a. NH_3 is limiting
2.90 mol NO, 4.35 mol H_2O
b. O_2 is limiting
c. NH_3 is limiting
 1.530×10^6 g NO produced
d. O_2 is limiting
2.47 mL H_2O produced

C. Percent Yield

21. a. 75.0 % yield
b. 2.28 g actual yield
c. 91.3% yield
d. 3.08 g actual yield
22. $\text{Fe}_2\text{O}_4 + 4\text{H}_2 \rightarrow 3\text{Fe} + 4\text{H}_2\text{O}$
95.3% yield
23. a. $\text{P}_2\text{O}_5 + 3\text{H}_2\text{O} \rightarrow 2\text{H}_3\text{PO}_4$
b. 86.7 g H_3PO_4
24. $2\text{Al}_2\text{O}_3 \rightarrow 4\text{Al} + 3\text{O}_2$
94.48% yield
25. $\text{As}_2\text{O}_3 + 3\text{C} \rightarrow 3\text{CO}_2 + 4\text{As}$
a. 79.3%
b. 87570 g As (87.57 kg As)
26. a. $\text{Cr}(\text{NO}_2)_3$
b. 24.57 g $(\text{NH}_4)_2\text{SO}_4$
c. 9.23 g $\text{Cr}_2(\text{SO}_4)_3$
27. By the skin of his teeth!!!

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 - 25.5 mol CO_2 , 34.0 mol H_2O
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- $2\text{C}_2\text{H}_2 + 5\text{O}_2 \rightarrow 4\text{CO}_2 + 2\text{H}_2\text{O}$
 - 0.6136 L O_2
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B. Limiting Reactants

- $2\text{C}_6\text{H}_{14} + 19\text{O}_2 \rightarrow 12\text{CO}_2 + 14\text{H}_2\text{O}$
 - O_2 is limiting
 - 12.4 g C_6H_{14} excess
 - 2.270 mol CO_2 produced
 - 47.72 g H_2O produced

14. a. NaOH is limiting
b. 2.5 mol H₂SO₄ excess
c. 2.0 mol Na₂SO₄ produced
15. a. $\text{Al}_2(\text{CO}_3)_3 + 6\text{HNO}_3 \rightarrow 3\text{CO}_2 + 3\text{H}_2\text{O} + 2\text{Al}(\text{NO}_3)_3$
b. $\text{Al}_2(\text{CO}_3)_3$ is limiting
c. 0.42 mol HNO₃ excess
d. 1.026 mol Al(NO₃)₃ produced
16. a. Al(OH)₃ is limiting
b. 73.5 g H₂SO₄ excess
c. 106 g Al₂(SO₄)₃ produced
17. a. Both can be considered limiting!!!
b. No excess reactants!!! Nothing left!!!
c. 100.4 g Al₂(SO₄)₃ produced
d. 88.35 % yield
18. $4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3$
O₂ is limiting
21.2 g Al₂O₃ produced
19. $\text{Cu} + 2\text{AgNO}_3 \rightarrow 2\text{Ag} + \text{Cu}(\text{NO}_3)_2$
Cu is limiting
170. g Ag produced
20. a. NH₃ is limiting
2.90 mol NO, 4.35 mol H₂O
b. O₂ is limiting
c. NH₃ is limiting
1.530 × 10⁶ g NO produced
d. O₂ is limiting
2.47 mL H₂O produced

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21. a. 75.0 % yield
b. 2.28 g actual yield
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94.48% yield
25. $\text{As}_2\text{O}_3 + 3\text{C} \rightarrow 3\text{CO}_2 + 4\text{As}$
a. 79.3%
b. 87570 g As (87.57 kg As)
26. a. Cr(NO₂)₃
b. 24.57 g (NH₄)₂SO₄
c. 9.23 g Cr₂(SO₄)₃
27. By the skin of his teeth!!!

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3.52×10^5 g H₂O

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26. a. Cr(NO₂)₃

- b. 24.57 g $(\text{NH}_4)_2\text{SO}_4$
- c. 9.23 g $\text{Cr}_2(\text{SO}_4)_3$

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