P 9.5 (pg 1 of 4) Stoichiometry - Limiting Reactant – mass

Who causes the reaction to stop?

1. Consider the reaction below.

   Na_3PO_4 (aq) + $Ba(NO_3)_2$ (aq) ----> $Ba_3(PO_4)_2$ (ppt) + $NaNO_3$ (aq)

   Suppose you react 4.00 g Na_3PO_4 with 4.00 g of $Ba(NO_3)_2$

   a. Balance the equation above.
   b. Which is the limiting reactant?
   c. Which substance is left over? What mass?

MM g/mole	
sodium phosphate	164
barium nitrate	261
barium phosphate	602
sodium nitrate	87.0

2. Consider the reaction between magnesium and chlorine gas.
   Given 2.0 g of magnesium, and 5.0 g of chlorine gas:

   a. Write a balanced equation.
   b. Determine which substance limits the reaction.
   c. Is there anything left over? Which substance? What mass?

MM g/mole	
magnesium	24.3
chlorine gas	70.9
magnesium chloride	95.2

3. Consider the reaction for the synthesis of H_2O from hydrogen gas and oxygen gas.
   If you have been given 28.5 grams of O_2 and 26.9 grams of H_2

   a. Write a balanced equation
   b. Which gas is the limiting reactant?
   c. Which gas is left over? How many grams of it?

MM g/mole	
hydrogen	2.02
oxygen gas	32.0
water	18.0

4. Consider the reaction of phosphoric acid reacting with aluminum to produce aluminum phosphate and hydrogen gas.
   Suppose you used 1.82 g of phosphoric acid and 0.659 g of aluminum.

   a. Write the balanced equation for the reaction described above.
   b. Which reactant limits the reaction?
   c. Which reactant is in excess?
   d. How many grams of the excess reactant are left over?

MM g/mole	
aluminum	27.0
phosphoric acid	98.0
aluminum phosphate	122
hydrogen gas	2.02

5. Consider the reaction of magnesium nitride with water to form magnesium hydroxide and ammonia gas (aka nitrogen trihydride)
   If you did this reaction with 58.1 g of magnesium nitride and 20.4 g of water,

   a. Write a balanced equation that describes the reaction
   b. What mass of each product could you make?
   c. How much of which reactant is left over.

MM g/mole	
magnesium nitride	100.9
water	18.0
magnesium hydroxide	58.3
ammonia	17.0

6. Consider the reaction between gold(III) sulfide and hydrogen gas to produce dihydrogen sulfide gas and gold.
   If 500.00 g of gold(III) sulfide is reacted with 5.67 g of hydrogen gas,

   a. Write a balanced equation that represents the reaction above.
   b. Which reactant is limits the reaction?
   c. Which reactant is in excess? What mass of the excess is left over?
   d. What mass of each gold could be formed?

MM g/mole	
gold(III) sulfide	490.15
hydrogen gas	2.02
dihydrogen sulfide	34.0
gold	197

7. Consider the reaction of ammonia (NH_3) with propene (C_3H_6) and oxygen gas to produce C_3H_3N and water.
   If you start with 22.5 g of propene and 20.6 g of ammonia and 18.1 g of oxygen gas,

   a. Write a balanced equation for the reaction
   b. How much water can be produced?

MM g/mole	
C_3H_6	42.1
ammonia	17.0
oxygen	32.0
C_3H_3N	53.0
water	18.0

8. Write the balanced equation that describes the reaction of aluminum burning in oxygen gas to produce aluminum oxide.
   If you used 500.0 g of oxygen gas and 500.0 g of aluminum,

   a. Write the balanced equation that describes the reaction above.
   b. Which reactant limits the reaction?
   c. Which reactant is in excess?
   d. If you wanted to use up all of the excess reactant, how many more grams of the limiting reactant must be added.

MM g/mole	
aluminum	27.0
oxygen gas	32.0
aluminum oxide	102

 Stoichiometry - Limiting Reactant – mass Who causes the reaction to stop? **ANSWERS**

As in the P 9.4, you must recognize the fundamental difference in this problem type is that you have been give two reactant quantities, however this time it is in mass, not moles. This is distinctly different from the first three Practice Sheets in which you were given one quantity and an unlimited amount of the other reactant. As the title indicates, this problem is a limiting reactant problem. This means that one of the two quantities given will "run out" and limit the amount of product that can be made.

When starting one of these problems, you first must determine which reactant is the "limiting reactant." There is more than one way to determine this, but one of the easiest is to convert your quantities to moles ("When in doubt, change to moles.) and divide each reactant's mole amount by its own coefficient in the balanced equation. The resulting smallest number will indicate the limiting reactant. Then do not use these numbers for any further calculations. Start with the original mass or mole amount of the limiting reactant to answer any further questions.

Consistent with the rest of the Practices in this unit, the ratio that is from the coefficients in the balanced equation highlighted in red. The answers are in blue. Intermediate numbers that you will calculate as you go along, are in green. Ideally you should hold these numbers in your computer and NOT round them off as I have in the table. Do ALL you rounding at the END.

The answers are shown in blue. Each problem is solved showing the "table logic," and using dimensional analysis. Either method is fine - the most important issue is to put your work on paper and label your numbers with **units** (moles, grams, etc), **identifiers** (O_2, H_2O, etc,) and **descriptors** (needed, produced, etc).

1. Suppose you react 4.00 g Na_3PO_4 with 4.00 g of $Ba(NO_3)_2$
   a. $2\ Na_3PO_{4\ (aq)} + 3\ Ba(NO_3)_{2\ (aq)} \rightarrow Ba_3(PO_4)_{2\ (ppt)} + 6\ NaNO_{3\ (aq)}$
   b. First determine which is the limiting reactant:
      - 4.00 g Na_3PO_4 * 1mol Na_3PO_4/164g Na_3PO_4 = 0.0244 mole Na_3PO_4/2 = 0.0122
      - 4.00 g of $Ba(NO_3)_2$ * 1mol $Ba(NO_3)_2$/262g $Ba(NO_3)_2$ = 0.0153 mole $Ba(NO_3)_2$/ 3 = 0.00509, this number is smaller, thus barium nitrate limits

Equation	$2\ Na_3PO_{4\ (aq)}$ +	$3\ Ba(NO_3)_{2\ (aq)}$ →	$Ba_3(PO_4)_{2\ (ppt)}$ +	$6\ NaNO_{3\ (aq)}$
ratio	2	3	1	6
moles	0.0102 needed	0.0153 used		
conversion	164g/mol	261g/mol	602	87.0
mass	1.67 needed	4.00 given		

   c. 4.00 g of $Ba(NO_3)_2$ * 1mol$Ba(NO_3)_2$/262g$Ba(NO_3)_2$ * 2molNa_3PO_4/3mol$Ba(NO_3)_2$ * 164gNa_3PO_4/1molNa_3PO_4 = 1.67 g of Na_3PO_4 needed
      Thus, 4.00 g Na_3PO_4 started with - 1.67 g of Na_3PO_4 needed = 2.33 g sodium phosphate left over

2. Given 2.0 g of magnesium, and 5.0 g of chlorine gas:
   a. $Mg + Cl_2 \rightarrow MgCl_2$
   b. First determine which is the limiting reactant:
      - 2.0 g Mg * 1mol Mg/24.3 Mg = 0.0823mole Mg/1 = 0.0823
      - 5.0 g Cl_2 * 1molCl_2/71g Cl_2 = 0.0704mole Cl_2/ 1 = 0.0704, this number is smaller, thus Cl_2 limits

Equation	Mg +	Cl_2 →	$MgCl_2$
ratio	1	1	1
moles	0.0704 needed	0.0704 used	
conversion	24.3 g/mol	71 g/mol	95.2
mass	1.71 needed	5.0 given	

   c. 5.0 g Cl_2 * 1molCl_2/71g Cl_2 * 1molMg/1molCl_2 * 24.3gMg/1molMg= 1.71 g of Mg needed
      Thus, 2.0g Mg started with - 1.71 g of Mg needed = 0.29 g Mg left over

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3. If you have been given 20.0 grams of O_2 and 40.0 grams of H_2
   a. $2\ H_2 + O_2 \rightarrow 2\ H_2O$
   b. First determine which is the limiting reactant:
      - 40.0 g H_2 * 1mol H_2/2.02g H_2 = 19.8 mole H_2/2 = 9.90
      - 20.0 g O_2 * 1molO_2/32.0g O_2 = 0.625 mole O_2/ 1 = 0.625 this number is smaller, thus oxygen limits

Equation	$2\ H_2 + O_2 \rightarrow 2\ H_2O$		
ratio	2	1	2
moles	1.25 needed	0.625 used	
conversion	2.02 g/mol	32.0 g/mol	18.0
mass	2.52 needed	20 given	

   c. 20.0 g O_2 * 1molO_2/32.0g O_2 * 2mol H_2 /1mol O_2 * 2.02g H_2/1mol H_2 = 2.52 g H_2 needed
      Thus 40.0 g H_2 given - 2.52 g H_2 needed(used) = 37.5 g hydrogen(H_2) gas left over

4. Suppose you used 1.82 g of phosphoric acid and 0.659 g of aluminum
   a. $2\ H_3PO_4 + 2\ Al \rightarrow 2\ AlPO_4 + 3\ H_2$
   b. First determine which is the limiting reactant:
      - 1.82g H_3PO_4 * 1molH_3PO_4/98.0g H_3PO_4 = 0.0186/3 = 0.00619 this number is smaller, thus phosphoric acid limits the reaction
      - 0.659 g Al * 1molAl/27.0g Al = 0.0244 mol Al/ 2 = 0.122
   c. Aluminum is in excess.

Equation	$2\ Al + 2\ H_3PO_4 \rightarrow 2\ AlPO_4 + 3\ H_2$			
ratio	2	2	2	3
moles	0.0186 used	0.0186 used		
conversion	27.0 g/mol	98.0 g/mol	122	2.02
mass	0.501 needed	1.82 given		

   d. 1.82 g H_3PO_4 * 1mol H_3PO_4/98.0g H_3PO_4 * 2molAl/2molH_3PO_4 * 27.0g Al/1mol Al = 0.501 g Al needed
      Thus 0.659 g Al given - 0.501 g Al needed(used) = 0.158 g of aluminum is left over.

5. If you did this reaction with 58.1 g of magnesium nitride and 20.4 g of water,
   a. $Mg_3N_2 + 6\ H_2O \rightarrow 3\ Mg(OH)_2 + 2\ NH_3$
      - First determine which is the limiting reactant:
      - 58.1g Mg_3N_2 * 1mol Mg_3N_2/101g Mg_3N_2 = 0.575 mole Mg_3N_2/1 = 0.575
      - 20.4 g H_2O * 1mol H_2O/18.0g H_2O =1.13/6 = 0.189 this number is smaller, thus water limits the reaction

Equation	$Mg_3N_2 + 6\ H_2O \rightarrow 3\ Mg(OH)_2 + 2\ NH_3$			
ratio	1	6	3	2
moles	0.189 needed	1.13 used		
conversion	101 g/mol	18.0 g/mol	58.3	17.0
mass	19.1 needed	20.4 given		

   b. 20.4 g H_2O * 1mol H_2O/18.0g H_2O * 2molAl/1molH_3PO_4 * 33.0 g $Mg(OH)_2$ formed and 6.42 g NH_3 formed
   c. 20.4 g H_2O * 1mol H_2O/18.0g H_2O * 1molMg_3N_2/6molH_2O * 101g Mg_3N_2/1mol Mg_3N_2 = 19.1 g Mg_3N_2 needed
      Thus 58.1 g Mg_3N_2 given - 19.1 g Mg_3N_2 needed(used) = 39.0 g Mg_3N_2 left over

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6. If 500.00 g of gold(III) sulfide is reacted with 5.67 g of hydrogen gas,
   a. $Au_2S_3 + 3\ H_2 \rightarrow 3\ H_2S + 2\ Au$
   b. First determine which is the limiting reactant:
      - 500.0 g Au_2S_3 * 1mol H_2/490.15g Au_2S_3 = 1.02 mole Au_2S_3/ 1 = 1.02
      - 5.67 g H_2 * 1mol H_2/2.02g H_2 = 2.807 mole H_2/3 = 0.936, this number is smaller, thus hydrogen gas limits

Equation	Au_2S_3 +	$3\ H_2$ →	$3\ H_2S$ +	$2\ Au$
ratio	1	3	3	2
moles	0.936 needed	2.807 used		1.871 produced
conversion	490.15 g/mol	2.02 g/mol	34.0	197
mass	458.6 needed	5.67 given		369 produced

   c. 5.67 g H_2 * 1mol H_2/2.02g H_2 * 1molAu_2S_3/3molH_2 * 490.15gAu_2S_3/1molAu_2S_3 = 458.6 g Au_2S_3 needed
      Thus 500.0 g Au_2S_3 given - 458.6 g Au_2S_3 needed(used) = 41.4 g gold(III) sulfide is left over
   d. 5.67 g H_2 * 1mol H_2/2.02g H_2 * 2molAu/3molH_2 * 197gAu/1molAu = 369 g of gold can be produced

7. If you start with 22.5 g of propene and 20.6 g of ammonia and 18.1 g of oxygen gas.
   a. $2\ C_2H_4 + 2\ NH_3 + 3\ O_2 \rightarrow 2\ C_3H_3N + 6\ H_2O$

      Even though the question does not ask, you must first determine the limiting reactant.
      - 22.5 g C_3H_6 * 1mol C_3H_6/42.1g C_3H_6 = 0.534 mole C_3H_6/ 2 = 0.267
      - 20.6 g NH_3 * 1mol NH_3/17.0g NH_3 = 1.21 mole NH_3/2 = 0.606
      - 18.1 g O_2 * 1mol O_2/32.0g O_2 = 0.566 mole O_2/3 = 0.189 this number is smallest, thus oxygen gas limits

	$2\ C_3H_6$ +	$2\ NH_3$ +	$3\ O_2$ →	$2\ C_3H_3N$ +	$6\ H_2O$
ratio	2	2	3	2	6
moles			0.566 used		
conversion	42.1 g/mol	17.0 g/mol	32.0	53.0	18.0
mass			18.1 given		

   b. 18.1 g O_2 * 1mol O_2/32.0g O_2 * 6molH_2O/3moleO_2 * 18.0g H_2O/1molH_2O = 20.4 g H_2O formed

8. If you used 500.0 g of oxygen gas and 500.0 g of aluminum,
   a. $4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$
   b. First determine which reactant limits
      - 500.0g Al * 1molAl/27.0g Al = 18.5 molAl/4 = 4.63 this number is smallest, thus Aluminum limits the reaction.
      - 500 g O_2 * 1mol O_2/32.0g O_2 = 15.6 mole O_2/3 = 5.21
   c. Oxygen is in excess.

Equation	$4\ Al$ +	$3\ O_2$ →	$2\ Al_2O_3$
ratio	4	3	2
moles	20.83 needed	15.625 used	
conversion	27.0g/mol	32.0 g/mol	102 g/mol
mass	562.5 needed	500.0 given	

   d. 500 g O_2 * 1mol O_2/32.0g O_2 * 4molAl/3moleO_2 * 27.0gAl/1molAl = 562.5g Al needed, thus 62.5 g more of aluminum needed to use up all of the oxygen