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

1. Consider the reaction below.

   $Na_3PO_4\,(aq) + Ba(NO_3)_2\,(aq) \rightarrow Ba_3(PO_4)_2\,(ppt) + NaNO_3\,(aq)$

   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

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. Do ALL you significant figure rounding at the END.

The answers are shown in blue. It is important 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 $\left(\frac{1 mol Na_3PO_4}{164 g Na_3PO_4}\right) = \frac{0.0244 mol Na_3PO_4}{2} = 0.0122$
      - 4.00 g $Ba(NO_3)_2$ $\left(\frac{1 mol Ba(NO_3)_2}{262 g Ba(NO_3)_2}\right) = \frac{0.0153 mol Ba(NO_3)_2}{3} = 0.00509$ this number is smaller, thus $Ba(NO_3)_2$ limits
   c. Use the liniting reactant to determine the mass of the excess reactant that must be used (needed) to go with the limit reactant.

      4.00 g $Ba(NO_3)_2$ $\left(\frac{1 mol Ba(NO_3)_2}{262 g Ba(NO_3)_2}\right)\left(\frac{2 Na_3PO_4}{3 Ba(NO_3)_2}\right)\left(\frac{164 g Na_3PO_4}{1 mol Na_3PO_4}\right) = 1.67$ 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 $\left(\frac{1 mol Mg}{24.3 g Mg}\right) = \frac{0.0823 mol Mg}{1} = 0.0823$
      - 5.0 g Cl_2 $\left(\frac{1 mol Cl_2}{71 g Cl_2}\right) = \frac{0.0704 mol Cl_2}{1} = 0.0704$ this number is smaller, thus Cl_2 limits
   c. Use the limiting reactant to determine the mass of the excess reactant that must be used (needed) to go with the limit reactant.

      5.0 g Cl_2 $\left(\frac{1 mol Cl_2}{71 g Cl_2}\right)\left(\frac{1 Mg}{1 Cl_2}\right)\left(\frac{24.3 g Mg}{1 mol Mg}\right) = 1.71$ g of Mg needed

      Thus, 2.0g Mg started with - 1.71 g of Mg needed = 0.29 g Mg left over

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:
      - 26.9 g H_2 $\left(\frac{1 mol H_2}{2.02 g H_2}\right) = \frac{13.3 mol H_2}{2} = 6.7$
      - 28.5 g O_2 $\left(\frac{1 mol O_2}{32 g O_2}\right) = \frac{0.891 mol O_2}{1} = 0.891$ this number is smaller, thus oxygen limits

c. Use the limiting reactant to determine the mass of the excess reactant that must be used (needed) to go with the limit reactant.

28.5 g O_2 $\left(\frac{1 mol O_2}{32 g O_2}\right)\left(\frac{2H_2}{1O_2}\right)\left(\frac{2.02 g H_2}{1 mol H_2}\right)$ = 3.60 g H_2 needed

Thus 26.5 g H_2 given − 3.60 g H_2 needed(used) = 22.9 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 → 2 $AlPO_4$ + 3 H_2

b. First determine which is the limiting reactant:

- 1.82g H_3PO_4 $\left(\frac{1 mol H_3PO_4}{98 g H_3PO_4}\right) = \frac{0.0186 mol H_2}{3} = 0.00619$ this number is smaller, thus H_3PO_4 limits the reaction
- 0.659 g Al $\left(\frac{1 mol Al}{27.0 g Al}\right) = \frac{0.0244 mol Al}{2} = 0.0122$

c. Aluminum is in excess.

d. Use the limiting reactant to determine the mass of the excess reactant that must be used (needed) to go with the limit reactant.

1.82 g H_3PO_4 $\left(\frac{1 mol H_3PO_4}{98 g H_3PO_4}\right)\left(\frac{2Al}{2H_3PO_4}\right)\left(\frac{27.0 g Al}{1 mol Al}\right)$ = 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 → 3 $Mg(OH)_2$ + 2 NH_3

- First determine which is the limiting reactant:
- 58.1g Mg_3N_2 $\left(\frac{1 mol Mg_3N_2}{101 g Mg_3N_2}\right) = \frac{0.575 mol Mg_3N_2}{1} = 0.575$
- 20.4 g H_2O $\left(\frac{1 mol H_2O}{18.0 g H_2O}\right) = \frac{1.13 mol H_2O}{6} = 0.189$ this number is smaller, thus water limits the reaction

b. 20.4 g H_2O $\left(\frac{1 mol H_2O}{18.0 g H_2O}\right)\left(\frac{3Mg(OH)_2}{6H_2O}\right)\left(\frac{58.3 g Mg(OH)_2}{1 mol Mg(OH)_2}\right)$ = 33.0 g $Mg(OH)_2$ formed

20.4 g H_2O $\left(\frac{1 mol H_2O}{18.0 g H_2O}\right)\left(\frac{2NH_3}{6H_2O}\right)\left(\frac{17.0 g NH_3}{1 mol NH_3}\right)$ = 6.42 g NH_3 formed

c. 20.4 g H_2O $\left(\frac{1 mol H_2O}{18.0 g H_2O}\right)\left(\frac{1Mg_3N_2}{6H_2O}\right)\left(\frac{101 g Mg_3N_2}{1 mol Mg_3N_2}\right)$ = 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

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 $Au_2S_3 \left(\frac{1 mol Au_2S_3}{490.15 g Au_2S_3}\right) = \frac{1.02 mol Au_2S_3}{1} = 1.02$
      - 5.67 g $H_2 \left(\frac{1 mol H_2}{2.02 g H_2}\right) = \frac{2.807 mol H_2}{3} = 0.936$ this number is smaller, thus hydrogen gas limits

   c. 5.67 g $H_2 \left(\frac{1 mol H_2}{2.02 g H_2}\right)\left(\frac{1 Au_2S_3}{3 H_2}\right)\left(\frac{490.15 g Au_2S_3}{1 mol Au_2S_3}\right) = 458.6$ 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 $H_2 \left(\frac{1 mol H_2}{2.02 g H_2}\right)\left(\frac{2 Au}{3 H_2}\right)\left(\frac{197 g Au}{1 mol Au}\right) =$ 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 $C_3H_6 \left(\frac{1 mol C_3H_6}{42.1 g C_3H_6}\right) = \frac{0.534 mol C_3H_6}{2} = 0.267$
      - 20.6 g $NH_3 \left(\frac{1 mol NH_3}{17.0 g NH_3}\right) = \frac{1.21 mol NH_3}{2} = 0.606$
      - 18.1 g $O_2 \left(\frac{1 mol O_2}{32 g O_2}\right) = \frac{0.566 mol O_2}{3} = 0.189$ this number is smallest, thus oxygen gas limits

   b. 18.1 g $O_2 \left(\frac{1 mol O_2}{32 g O_2}\right)\left(\frac{6 H_2O}{3 O_2}\right)\left(\frac{18.0 g H_2O}{1 mol H_2O}\right) =$ 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 $\left(\frac{1 mol Al}{27.0 g Al}\right) = \frac{18.5 mol Al}{4} = 4.63$ this number is smallest, thus Aluminum limits the reaction.
      - 500 g $O_2 \left(\frac{1 mol O_2}{32 g O_2}\right) = \frac{15.6 mol O_2}{3} = 5.21$

   c. Oxygen is in excess.
   d. 500 g $O_2 \left(\frac{1 mol O_2}{32 g O_2}\right)\left(\frac{4 Al}{3 O_2}\right)\left(\frac{27.0 g Al}{1 mol Al}\right) = 562.5$g Al needed, thus 62.5 g more of aluminum needed to use up all of the oxygen