CHEMISTRY

THE LIMITING REAGENT

Recall: *The coefficients in a balanced chemical equation show the molar relationship between the participants.*

Consider the Following … Building A Car

As you know, in order to build a car you need **1** engine and **4** tires.

If you have **unlimited** tires, but only **3** engines, how many cars can be built? What is the ***limiting reagent***?

If you have **unlimited** engines but only **8** tires, how many cars can be built? What is the ***limiting reagent***?

If you have **4** engines and **15** tires, how many cars can be built? What is the ***limiting reagent***?

CHEMISTRY

THE LIMITING REAGENT

Now with chemicals …

$$4\ Fe + 3\ O_2 \longrightarrow 2\ Fe_2O_3$$

The molar relationship 4:3 → 2 dictates that four moles of iron mixed with three moles of oxygen will create exactly two moles of iron(III)oxide.

One cannot create more product by simply adding more of one of the reactants:

Ex: Excess O_2

$$4\ Fe + 4\ O_2 \longrightarrow 2\ Fe_2O_3 + 1\ O_2\ \textit{(Leftover)}$$

Adding more O_2 does not create more product. Since there is only four moles of Iron, and the ratio is 4:3, only 3 moles of O_2 will react.

In this case, with the small amount of iron and the excess oxygen, then iron limits the amount of product produced. This means iron is the ***Limiting Reagent***.

CHEMISTRY

THE LIMITING REAGENT

Determining the Limiting Reagent

The reactant that is completely used up in a chemical reaction is called the ***Limiting Reagent***. This limiting reagent determines how much product is produced.

Note: *The other plentiful reactant is called the* ***Excess Reagent***.
In order to determine which reactant is the limiting reagent:

STEPS:

1.

2.

3.

4.

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Ex: *Lithium nitride reacts with water to form ammonia and lithium hydroxide. If 4.87 g of lithium nitride reacts with 5.80 g of water, find the limiting reagent and how much ammonia is produced.*

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Ex. If you were to react 2.5 g of potassium iodide with 2.5 grams of lead nitrate, how many grams of solid will be produced how many grams of unreacted reactant would still be in solution?

CHEMISTRY

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Ex: 20.0g of sodium chloride are reacted with 5.0g silver chlorate in a double displacement reaction. How much solid precipitate is produced?

CHEMISTRY

THE LIMITING REAGENT

Ex: 6.7g of propane are completely combusted using 20.0g of oxygen gas.

a) How many grams of water will be produced?

b) Is this reaction accurate? Why or why not? What type of reaction would this be?

c) How much water is actually produced?

CHEMISTRY

THE LIMITING REAGENT

Pg. 307 # 31 - 39 Pg. 311 #40 - 50

Practice Problems

31. Hydrogen fluoride, HF(g), is a highly toxic gas. It is produced according to the following balanced chemical equation:

$$CaF_2(s) + H_2SO_4(aq) \rightarrow 2HF(g) + CaSO_4(s)$$

Determine the limiting reactant when 1.00 g of calcium fluoride, $CaF_2(s)$, reacts with 15.5 g of sulfuric acid, $H_2SO_4(aq)$.

32. An ester is an organic compound that forms when a carboxylic acid reacts with an alcohol. Esters often are used as essences or scents. One such ester is methyl salicylate, $C_8H_8O_3(aq)$, which is oil of wintergreen. It is formed by the reaction of salicylic acid, $C_7H_6O_3(aq)$, and methanol, $CH_3OH(aq)$, as shown below:

$$C_7H_6O_3(aq) + CH_3OH(aq) \rightarrow C_8H_8O_3(aq) + H_2O(\ell)$$

If 100.11 g of salicylic acid and 90.4 g of methanol are used to produce oil of wintergreen, which is the limiting reactant?

33. Acetylene, $C_2H_2(g)$, is used in welding. It forms when calcium carbide, $CaC_2(s)$, reacts with water, as shown below:

$$CaC_2(s) + 2H_2O(\ell) \rightarrow Ca(OH)_2(aq) + C_2H_2(g)$$

If 5.50 mol of calcium carbide reacts with 3.75 mol of water, which is the limiting reactant?

34. Nickel(II) chloride, $NiCl_2(aq)$, reacts with sodium phosphate, $Na_3PO_4(aq)$, according to the following balanced chemical equation:

$$3NiCl_2(aq) + 2Na_3PO_4(aq) \rightarrow Ni_3(PO_4)_2(s) + 6NaCl(aq)$$

If 10.0 g of each reactant is used, which is the limiting reactant?

35. Copper metal reacts with nitric acid, $HNO_3(aq)$, as follows:

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(\ell)$$

If 2.5 g of copper reacts with 25.0 g of nitric acid, which reactant is in excess?

36. Lithium reacts with oxygen to form lithium oxide, $Li_2O(s)$.

$$4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$$

When 20.0 g of lithium metal reacts with 30.0 g of oxygen gas, which reactant is limiting and which reactant is in excess?

37. Chlorine gas is used in the textile industry to bleach fabric. Excess chlorine is removed by a reaction with sodium thiosulfate, $Na_2S_2O_3(aq)$, as shown below:

$$Na_2S_2O_3(aq) + 4Cl_2(g) + 5H_2O(\ell) \rightarrow 2NaHSO_4(aq) + 8HCl(aq)$$

If 42.5 g of sodium thiosulfate and 175 g of chlorine gas react with excess water, which is the limiting reactant?

38. Acrylonitrile, $C_3H_3N(g)$, is prepared by the reaction of propylene, $C_3H_6(g)$, with nitric oxide, NO(g).

$$4C_3H_6(g) + 6NO(g) \rightarrow 4C_3H_3N(g) + 6H_2O(g) + N_2(g)$$

If 126 g of propylene reacts with 175 g of nitric oxide, which is the limiting reactant?

39. Insoluble silver carbonate, $Ag_2CO_3(s)$, forms in the following balanced chemical reaction:

$$2AgNO_3(aq) + K_2CO_3(aq) \rightarrow Ag_2CO_3(s) + 2KNO_3(aq)$$

What mass of silver nitrate, $AgNO_3(aq)$, reacts with 25.0 g of potassium carbonate, $K_2CO_3(aq)$, if there is at least 5.5 g of silver nitrate in excess?

CHEMISTRY

THE LIMITING REAGENT

Pg. 311 #40 - 50

Practice Problems

40. The formation of water is represented by the following equation:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

a. What is the limiting reactant if 4 mol of oxygen reacts with 16 mol of hydrogen?

b. What amount (in moles) of water is produced in this reaction?

41. Silver nitrate, $AgNO_3(aq)$, reacts with iron(III) chloride, $FeCl_3(aq)$, to produce silver chloride, $AgCl(s)$, and iron(III) nitrate, $Fe(NO_3)_3(aq)$.

$$3AgNO_3(aq) + FeCl_3(aq) \rightarrow 3AgCl(s) + Fe(NO_3)_3(aq)$$

a. If a solution containing 18.00 g of silver nitrate is mixed with a solution containing 32.4 g of iron(III) chloride, which is the limiting reactant?

b. What amount in moles of iron(III) nitrate is produced in this reaction?

42. Barium sulfate, $BaSO_4(s)$, forms in the following reaction:

$$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$$

If 75.00 g of barium nitrate, $Ba(NO_3)_2(aq)$, reacts with 100.00 g of sodium sulfate, $Na_2SO_4(aq)$, what mass of barium sulfate is produced?

43. Zinc oxide, $ZnO(s)$, is formed by the reaction of zinc sulfide, $ZnS(s)$, with oxygen.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

If 16.7 g of zinc sulfide reacts with 6.70 g of oxygen, what mass of zinc oxide is produced?

44. The following balanced chemical equation represents the reaction of calcium carbonate, $CaCO_3(s)$, with hydrochloric acid:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(\ell)$$

If 155 g of calcium carbonate reacts with 245 g of hydrochloric acid, what mass of calcium chloride, $CaCl_2(s)$, is produced?

45. The reaction of aluminum hydroxide, $Al(OH)_3(aq)$, with hydrochloric acid produces water and aluminum chloride, $AlCl_3(s)$.

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

What mass of aluminum chloride is produced when 8.0 g of hydrochloric acid reacts with an equal mass of aluminum hydroxide?

46. The reaction between solid white phosphorus, $P_4(s)$, and oxygen gas produces solid tetraphosphorus decoxide, $P_4O_{10}(s)$. Determine the mass of tetraphosphorus decoxide that is formed when 25.0 g of solid white phosphorus and 50.0 g of oxygen are combined.

47. A solution containing 14.0 g of silver nitrate, $AgNO_3(aq)$, is added to a solution containing 4.83 g of calcium chloride, $CaCl_2(aq)$. Find the mass of silver chloride, $AgCl(s)$, produced.

48. The reaction between solid sodium and iron(III) oxide, $Fe_2O_3(s)$, is one in a series of reactions that occurs when an automobile air bag inflates.

$$6Na(s) + Fe_2O_3(s) \rightarrow 3Na_2O(s) + 2Fe(s)$$

If 100.0 g of solid sodium and 100.0 g of iron(III) oxide are used in this reaction, what mass of solid iron will be produced?

49. Manganese(III) fluoride, $MnF_3(s)$, is formed by the reaction of manganese(III) iodide, $MnI_2(s)$, with fluorine gas.

$$2MnI_2(s) + 13F_2(g) \rightarrow 2MnF_3(s) + 4IF_5(\ell)$$

a. If 1.23 g of manganese(III) iodide reacts with 25.0 g of fluorine, what mass of manganese(III) fluoride is produced?

b. Which reactant is in excess? How much of this reactant remains at the end of the reaction?

50. Silver nitrate, $AgNO_3(aq)$, reacts with calcium chloride, $CaCl_2(aq)$, in the following reaction:

$$2AgNO_3(aq) + CaCl_2(aq) \rightarrow 2AgCl(s) + Ca(NO_3)_2(aq)$$

There are 7 mol of each reactant present.

a. What is the mass of the excess reactant?

b. What is the mass of the limiting reactant?

c. What are the masses of each product that forms?

CHEMISTRY

THE LIMITING REAGENT

Pg. 307 # 31 - 39 Pg. 311 #40 - 50

Answers

31. $CaF_2(s)$
32. $C_7H_6O_3(aq)$
33. $H_2O(\ell)$
34. $NiCl_2(aq)$
35. $HNO_3(aq)$
36. Li(s) is limiting, $O_2(g)$ is in excess
37. $Na_2S_2O_3(aq)$
38. $C_3H_6(g)$
39. 61 g

40. **a.** oxygen
b. 8
41. **a.** $AgNO_3(aq)$
b. 0.03519 moles
42. 66.98 g
43. 11.4 g
44. 172 g
45. 9.8 g
46. 57.3 g
47. 11.8 g
48. 69.94 g
49. **a.** 0.446 g
b. $F_2(g)$, 24.0 g
50. **a.** 388.4 g of $CaCl_2(aq)$ is excess (the total initial mass of $CaCl_2(aq)$ is 776.9 g)
b. 1189 g of $AgNO_3(aq)$
c. 1003 g of AgCl(s) and 574.3 g of $Ca(NO_3)_2(aq)$