Limiting Reagents and Percentage Yield Worksheet

1. Consider the reaction

iodine pentoxide

$$I_2O_5(g) + 5\ CO(g) \text{ -------> } 5\ CO_2(g) + I_2(g)$$

a) 80.0 grams of iodine(V) oxide, I_2O_5, reacts with 28.0 grams of carbon monoxide, CO.

Determine the mass of iodine I_2, which could be produced?

b) If, in the above situation, only 0.160 moles, of iodine, I_2 was produced.

i) what mass of iodine was produced?

ii) what percentage yield of iodine was produced.

2. Zinc and sulphur react to form zinc sulphide according to the equation.

$$Zn \ + \ S \text{ --------> } ZnS$$

If 25.0 g of zinc and 30.0 g of sulphur are mixed,

a) Which chemical is the limiting reactant?

b) How many grams of ZnS will be formed?

c) How many grams of the excess reactant will remain after the reaction is over?

3. Which element is in excess when 3.00 grams of Mg is ignited in 2.20 grams of pure oxygen?
What mass is in excess? What mass of MgO is formed?

4. How many grams of Al_2S_3 are formed when 5.00 grams of Al is heated with 10.0 grams S?

5. When MoO_3 and Zn are heated together they react

$$3\ Zn(s) + 2\ MoO_3(s) \text{ ----------> } Mo_2O_3(s) + 3\ ZnO(s)$$

What mass of ZnO is formed when 20.0 grams of MoO_3 is reacted with 10.0 grams of Zn?

iron (III)

6. Silver nitrate, $AgNO_3$, reacts with ferric chloride, $FeCl_3$, to give silver chloride, AgCl, and ferric nitrate, $Fe(NO_3)_3$. In a particular experiment, it was plannned to mix a solution containing 25.0 g of $AgNO_3$ with another solution containing 45.0 grams of $FeCl_3$.

a) Write the chemical equation for the reaction.

b) Which reactant is the limiting reactant?

c) What is the maximum number of moles of AgCl that could be obtained from this mixture?

d) What is the maximum number of grams of AgCl that could be obtained?

e) How many grams of the reactant in excess will remain after the reaction is over?

7. Solid calcium carbonate, $CaCO_3$, is able to remove sulphur dioxide from waste gases by the reaction:

$$CaCO_3 + SO_2 + \text{other reactants} \text{------>} CaSO_3 + \text{other products}$$

In a particular experiment, 255 g of $CaCO_3$ was exposed to 135 g of SO_2 in the presence of an excess amount of the other chemicals required for the reaction.

a) What is the theoretical yield of $CaSO_3$?

b) If only 198 g of $CaSO_3$ was isolated from the products, what was the precentage yield of $CaSO_3$ in this experiment?

8. A research supervisor told a chemist to make 100.g of chlorobenzene from the reaction of benzene with chlorine and to expect a yield no higher that 65%. What is the minimum quantity of benzene that can give 100 g of chlorobenzene if the yield is 65%? The equation for the reaction is:

$$\underset{\text{benzene}}{C_6H_6} + Cl_2 \text{----------->} \underset{\text{chlorobenzene}}{C_6H_5Cl} + HCl$$

9. Certain salts of benzoic acid have been used as food additives for decades. The potassium salt of benzoic acid, potassium benzoate, can be made by the action of potassium permanganate on toluene.

toluene

$$\underset{\text{toluene}}{C_7H_8} + 2\,KMnO_4 \text{------->} \underset{\text{potassium benzoate}}{KC_7H_5O_2} + 2\,MnO_2 + KOH + H_2O$$

If the yield of potassium benzoate cannot realistically be expected to be more than 68%, what is the minimum number of grams of toluene needed to achieve this yield while producing 10.0 g of $KC_7H_5O_2$?

reacte

10. Aluminum dissolves in an aqueous solution of NaOH according to the following reaction:

$$2\,NaOH + 2\,Al + 2\,H_2O \text{----->} 2\,NaAlO_2 + 3\,H_2$$

If 84.1 g of NaOH and 51.0 g of Al react:

i) Which is the limiting reagent?

ii) How much of the other reagent remains?

iii) What mass of hydrogen is produced?

11. Dimethylhydrazine, $(CH_3)_2NNH_2$, was used as a fuel for the Apollo Lunar Descent Module, with N_2O_4 being used as the oxidant. The products of the reaction are H_2O, N_2, and CO_2.

i) Write a balanced chemical equation for the combustion reaction.

ii) If 150 kg of $(CH_3)_2NNH_2$ react with 460 kg of N_2O_4, what is the theoretical yield of N_2?

iii) If a 30 kg yield of N_2 gas represents a 68% yield, what mass of N_2O_4 would have been used up in the reaction?

12. Magnesium metal reacts quantitatively with oxygen to give magnesium oxide, MgO. If 5.00 g of Mg and 5.00 g of O_2 are allowed to react, what weight of MgO is formed, and what of which reactant is left in excess?

mass

13. Adipic acid, $C_6H_{10}O_4$, is a raw material for the making of nylon and it can be prepared in the laboratory by the following reaction between cyclohexene, C_6H_{10}, and sodium dichromate, $Na_2Cr_2O_7$ in sulphuric acid.

$$3\ C_6H_{10}(l) + 4\ Na_2Cr_2O_7(aq) + 16\ H_2SO_4(aq) \text{ --------->} \; 3\ C_6H_{10}O_4(aq) + 4\ Cr_2(SO_4)_3(aq) + 4\ Na_2SO_4(aq) + 16\ H_2O$$

There are side reactions. These plus losses of product during its purification reduce the overall yield. A typical yield of purified adipic acid is 68.6%.

(a) To prepare 12.5 grams of adipic acid in 68.6% yield requires how many grams of cyclohexene?

(b) The only available supply of sodium dichromate is its dihydrate, $Na_2Cr_2O_7 \cdot 2H_2O$. (Since the reaction occurs in an aqueous medium, the water in the dihydrate causes no problems, but it does contribute to the mass of what is taken of this reactant). How many grams of this dihydrate are also required in the preparation of 12.5 grams of adipic acid in a yield of 68.6%?

Answer Key Limiting Reagents + Percentage Yield Worksheet

1\. a)

$$80.0\,g\ \overset{INXS}{\boxed{I_2O_5}} \times \frac{1\,mol}{333.8\,g} \times \frac{1\,mol\ I_2}{1\,mol\ I_2O_5} \times \frac{253.81\,g}{1\,mol\ I_2} = \overset{fake}{\cancel{60.8\,g}}\ I_2$$

$$28.0\,g\ \underset{LR}{\boxed{CO}} \times \frac{1\,mol\ CO}{28.01\,g} \times \frac{1\,mol\ I_2}{5\,mol\ CO} \times \frac{253.81\,g}{1\,mol\ I_2} \boxed{= \overset{max}{\underset{TY}{50.7\,g\ I_2}}}$$

b) i) $0.160\,mol\ I_2 \times \frac{253.81\,g}{1\,mol\ I_2} = \boxed{40.6\,g\ I_2} = AY$

ii) $\%\ yield = \frac{AY}{TY} \times 100 = \frac{40.6\,g}{50.7\,g} \times 100 = \boxed{80.1\%}$

2\. S should be S_8! but ignore this time

$$25.0\,g\ \overset{LR}{\cancel{Zn}} \times \frac{1\,mol\ \cancel{Zn}}{65.38\,\cancel{g}} \times \frac{1\,mol\ ZnS}{1\,mol\ \cancel{Zn}} \times \frac{97.474\,g}{1\,mol\ \cancel{ZnS}} \boxed{= 37.3\,g\ ZnS}$$

$$30.0\,g\ \underset{INXS}{S} \times \frac{1\,mol\ S}{32.065\,g} \times \frac{1\,mol\ ZnS}{1\,mol\ S} \times \frac{97.474\,g}{1\,mol\ ZnS} = \underset{fake}{\cancel{91.2\,g\ ZnS}}$$

a) Zn = LR

b) 37.3 g ZnS

$$\begin{array}{r} 30.0\,g\ S \\ -\ 12.3\,g \\ \hline 17.7\,g\ S \end{array}\ \text{LEFT OVER}$$

c) $25.0\,g\ Zn \times \frac{1\,mol\ Zn}{65.38\,g} \times \frac{1\,mol\ S}{1\,mol\ Zn} \times \frac{32.065\,g}{1\,mol\ S} = \boxed{12.3\,g\ S\ \text{USED}}$

3. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

$\underset{LR}{3.00g}$ $\quad$ $2.20g$

formed max

$$3.00g\ Mg \times \frac{1mol\ Mg}{24.31g} \times \frac{2mol\ MgO}{2mol\ Mg} \times \frac{40.31g}{1mol\ MgO} = \boxed{4.97g\ MgO}$$

$$\underset{INXS}{2.20g\ O_2} \times \frac{1mol\ O_2}{32.00g} \times \frac{2mol\ MgO}{1mol\ O_2} \times \frac{40.31g}{1mol\ MgO} = \cancel{5.54g\ MgO}$$

fake

$$3.00g\ Mg \times \frac{1mol\ Mg}{24.31g} \times \frac{1mol\ O_2}{2mol\ Mg} \times \frac{32.00g}{1mol\ O_2} = 1.97g\ O_2\ USED$$

$2.20g\ O_2$ HAD

$-1.97g\ O_2$ USED

$0.23g\ O_2$ LEFT OVER

4. $2Al(s) + 3S(s) \rightarrow Al_2S_3(s)$ ionic

$5.00g$ $\quad$ $10.0g$

$$5.00g\ Al \times \frac{1mol\ Al}{26.98g} \times \frac{1mol\ Al_2S_3}{2mol\ Al} \times \frac{150.16g}{1mol\ Al_2S_3} = \boxed{13.9g\ Al_2S_3}$$

$$10.0g\ S \times \frac{1mol\ S}{32.065g} \times \frac{1mol\ Al_2S_3}{3mol\ S} \times \frac{150.16g}{1mol\ Al_2S_3} = \cancel{15.6g\ Al_2S_3}$$

fake

5. $$20.0g\ MoO_3 \times \frac{1mol}{143.94g} \times \frac{3mol\ ZnO}{2mol\ MoO_3} \times \frac{81.38g}{1mol\ ZnO} = \cancel{17.0g\ ZnO}$$

fake

$$10.0g\ Zn \times \frac{1mol\ Zn}{65.38g} \times \frac{3mol\ ZnO}{3mol\ Zn} \times \frac{81.38g}{1mol\ ZnO} = \boxed{12.4g\ ZnO}$$

~~a)~~

$$6.\ 3AgNO_3 + FeCl_3 \longrightarrow 3AgCl + Fe(NO_3)_3$$

d)

$$25.0g\ \overset{LR}{\boxed{AgNO_3}} \times \frac{1mol\ AgNO_3}{169.87g} \times \frac{3mol\ AgCl}{3mol\ AgNO_3} \times \frac{143.32g}{1mol\ AgCl} = \boxed{21.1g\ AgCl}$$

$$\underset{INXS}{45.0g\ FeCl_3} \times \frac{1mol\ FeCl_3}{162.2g} \times \frac{3mol\ AgCl}{1mol\ FeCl_3} \times \frac{142.32g}{1mol\ AgCl} = \underset{fake}{\cancel{118g}}$$

c)

$$21.1g\ AgCl \times \frac{1mol}{143.32g} = 0.147\ mol\ AgCl$$

$$25.0g\ AgNO_3 \times \frac{1mol}{169.87g} \times \frac{1mol\ FeCl_3}{3mol\ AgNO_3} \times \frac{162.2g}{1mol\ FeCl_3} = 7.96g\ FeCl_3\ \underline{\underline{USED}}$$

$45.0g\ FeCl_3$ you had

$-\ 7.96g\ FeCl_3$ used

$37.0g\ FeCl_3$ LEFT OVER

7.

$$\underset{INXS}{255g\ CaCO_3} \times \frac{1mol\ CaCO_3}{100.0869g} \times \frac{1mol\ CaSO_3}{1mol\ CaCO_3} \times \frac{120.17g}{1mol\ CaSO_3} = \overset{fake}{\cancel{306g\ CaSO_3}}$$

$$\underset{LR}{135\ SO_2} \times \frac{1mol\ SO_2}{64.066g} \times \frac{1mol\ CaSO_3}{1mol\ SO_2} \times \frac{120.17g}{1mol\ CaSO_3} = \underset{TY}{\boxed{253g\ CaSO_3}}$$

$$\%\ yield = \frac{AY}{TY} \times 100 = \frac{198g\ CaSO_3}{253g\ CaSO_3} \times 100 = \boxed{78.3\%}$$

8. $AY = 100.g$ $\quad \% \text{ yield} = 65\%$

$$\frac{TY \cdot \% \cancel{\text{yield}}}{\% \cancel{\text{yield}}} = \frac{AY}{\cancel{TY}} \times 100 \cdot \frac{\cancel{TY}}{\% \text{ yield}}$$

$$= \frac{100.g \times 100}{65\%} = 154g = TY$$

154g

$$154g\ C_6H_5Cl \times \frac{1mol}{112.56g} \times \frac{1mol\ C_6H_6}{1mol\ C_6H_5Cl} \times \frac{78.11g}{1mol\ C_6H_6} = \boxed{107g\ C_6H_6}$$

9. $\% \text{ yield} = 68\%$

$$14.7g\ PB \times \frac{1mol\ PB}{160.21g} \times \frac{1mol\ C_7H_8}{1mol\ PB} \times \frac{92.14g}{1mol\ C_7H_8} = \boxed{8.45\ g\ C_7H_8}$$

$$\% \text{ yield} = \frac{AY}{TY} \times 100 \qquad 10.0g\ PB = AY$$

to start

$$TY = \frac{AY \times 100}{\% \text{ yield}} = \frac{10.0g \times 100}{68\%} = \underset{TY}{14.7g\ PB}$$

fake

10. $$\underset{INXS}{84.1g\ NaOH} \times \frac{1mol}{40.0g} \times \frac{3mol\ H_2}{2mol\ H_2} \times \frac{2.02g}{1mol\ H_2} = \cancel{63.7g\ H_2}$$

$$\underset{LR}{51.0g\ Al} \times \frac{1mol\ Al}{26.98g} \times \frac{3mol\ H_2}{2mol\ Al} \times \frac{2.02g}{1mol\ H_2} = \boxed{5.73g\ H_2}$$

produced

$$51.0g\ Al \times \frac{1mol\ Al}{26.98g} \times \frac{2mol\ NaOH}{2mol\ Al} \times \frac{40.0g}{1mol\ NaOH} = 75.6g \text{ USED}$$

$$\underset{HAD}{84.1g} - 75.6g = \boxed{8.5g\ LO}$$

i) DMH DNTO

11. $(CH_3)_2N_2H_{2(l)} + 2N_2O_{4(l)} \rightarrow 3N_{2(g)} + 4H_2O_{(g)} + 2CO_{2(g)}$

150kg 460.kg ?

ii) DMH $150.kg \times \frac{1000g}{1kg} \times \frac{1mol}{60.1g} \times \frac{3mol\ N_2}{1mol\ DMH} \times \frac{28g\ N_2}{1mol\ N_2} = 21\bar{0}\ kg\ N_2$

DNTO $460.kg \times \frac{1000g}{1kg} \times \frac{1mol\ DN}{92.01g} \times \frac{3mol\ N_2}{2mol\ DN} \times \frac{28g\ N_2}{1mol\ N_2} = 21\bar{0}\ kg\ N_2$

$\boxed{so\ 21\bar{0}\ kg\ N_2}$

30. kg = AY of N_2

iii) $\%\ yield = \frac{AY}{TY} \times 100$ $TY = \frac{AY \times 100}{\%\ yield}$

$= \frac{(30.kg)(100)}{(68\%)} = 44\ kg\ N_2$

$44\ \cancel{kg}\ N_2 \times \frac{1000\cancel{g}}{1\cancel{kg}} \times \frac{1mol\ N_2}{28\cancel{g}} \times \frac{2mol\ N_2O_4}{3mol\ N_2} \times \frac{92.01g}{1mol\ DNTO} = \boxed{96kg\ N_2O_4}$

12. $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$

5.00g 5.00g

$5.00g\ \underset{LR}{\boxed{Mg}} \times \frac{1mol\ Mg}{24.31g} \times \frac{2mol\ MgO}{2mol\ Mg} \times \frac{40.31g}{1mol\ MgO} = \boxed{8.29g\ MgO}$

$\underset{INXS}{5.00g\ O_2} \times \frac{1mol\ O_2}{32g} \times \frac{2mol\ MgO}{1mol\ O_2} \times \frac{40.31g}{1mol\ MgO} = \cancel{12.6g}\ MgO$ fake

$8.29\,g\,MgO \times \frac{1\,mol}{40.31\,g} \times \frac{1\,mol\,O_2}{2\,mol\,MgO} \times \frac{32\,g}{1\,mol\,O_2} = 3.29\,g\,O_2$

USED!

$$\begin{array}{ll} \text{Had} & 5.00\,g\,O_2 \\ \text{USED} - & 3.29\,g\,O_2 \\ \hline & 1.71\,g\,O_2 \end{array}$$

LEFT OVER

Use English to explain the math!

13. $\%\ yield = \frac{AY}{TY} \times 100$

$TY = \frac{AY \times 100}{\%\ yield}$

$= \frac{12.5\,g \times 100}{68.6\%}$

$= 18.2\,g\ AA$

a) $18.2\,g\,AA \times \frac{1\,mol\,AA}{146.14\,g} \times \frac{3\,mol\,CH}{3\,mol\,AA} \times \frac{82.14\,g}{1\,mol\,CH}$

$= 10.2\,g\ CH$

b) $18.2\,g\,AA \times \frac{1\,mol\,AA}{146.14\,g} \times \frac{4\,mol\,SCDH}{3\,mol\,AA} \times \frac{298\,g}{1\,mol} = 49.5\,g$ $Na_2Cr_2O_7 \cdot 2H_2O$