Key

Limiting Reactant and Percent Yield Worksheet

1. Calcium hydroxide, used to neutralize acid spills, reacts with hydrochloric acid according to the following unbalanced equation:

   $Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

   a. If you have spilled 6.3 mol of HCl and put 2.8 mol of $Ca(OH)_2$ on it, which substance is the limiting reactant?

   $\frac{6.3 \text{ mol } HCl \mid 1 \text{ mol } CaCl_2}{\mid 2 \text{ mol } HCl} = 3.2 \text{ mol } CaCl_2$

   $\frac{2.8 \text{ mol } Ca(OH)_2 \mid 1 \text{ mol } CaCl_2}{\mid 1 \text{ mol } Ca(OH)_2} = 2.8 \text{ mol } CaCl_2$

   * $Ca(OH)_2$ is limiting

   b. How many moles of the excess reactant remain?

   $\frac{2.8 \text{ mol } Ca(OH)_2 \mid 2 \text{ mol } HCl}{\mid 1 \text{ mol } Ca(OH)_2} = 5.6 \text{ mol HCl used}$

   $6.3 \text{ mol } HCl - 5.6 \text{ mol } HCl =$ 0.7 mol HCl remain

2. Aluminum oxidizes according to the following unbalanced equation: $4\,Al + 3O_2 \rightarrow 2\,Al_2O_3$

   a. Powdered Al (0.048 mol) is placed into a container containing 0.030 mol O_2. What is limiting reactant?

   $\frac{0.048 \text{ mol } Al \mid 2 \text{ mol } Al_2O_3}{\mid 4 \text{ mol } Al} = 0.024 \text{ mol } Al_2O_3$

   $\frac{0.030 \text{ mol } O_2 \mid 2 \text{ mol } Al_2O_3}{\mid 3 \text{ mol } O_2} = 0.020 \text{ mol } Al_2O_3$

   * O_2 is limiting

   b. How many moles of the excess reactant remain?

   $\frac{0.030 \text{ mol } O_2 \mid 4 \text{ mol } Al}{\mid 3 \text{ mol } O_2} = 0.040 \text{ mol Al used}$

   $0.048 \text{ mol } Al - 0.040 \text{ mol } Al =$ 0.008 mol Al remain

3. Heating zinc sulfide in the presence of oxygen yields the following: $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

   a. If 1.72 mol of ZnS is heated in the presence of ~~3.04~~ 45.6 g of O_2, which is the limiting reactant? (Balance the equation first.)

   $\frac{1.72 \text{ mol } ZnS \mid 2 \text{ mol } SO_2}{\mid 1 \text{ mol } ZnS} = 3.44 \text{ mol } SO_2$

   $\frac{45.6 \text{ g } O_2 \mid 1 \text{ mol } O_2 \mid 2 \text{ mol } SO_2}{\mid 32.0 \text{ g } O_2 \mid 3 \text{ mol } O_2} = 0.950 \text{ mol } SO_2$

   * O_2 is limiting

   b. How many grams of the excess reactant remain?

   $\frac{45.6 \text{ g } O_2 \mid 1 \text{ mol } O_2 \mid 2 \text{ mol } ZnS \mid 97.48 \text{ g } ZnS}{\mid 32.0 \text{ g } O_2 \mid 3 \text{ mol } O_2 \mid 1 \text{ mol } ZnS} = 92.6 \text{ g used}$

   $\frac{1.72 \text{ mol } ZnS \mid 97.48 \text{ g } ZnS}{\mid 1 \text{ mol } ZnS} = 168 \text{ g } ZnS$ (started with)

   $168 \text{ g } ZnS - 92.6 \text{ g } ZnS =$ 75 g ZnS remain

4. Chlorine can replace bromine in bromide compounds forming a chloride compound and elemental bromine. The following unbalanced equation is an example of the reaction: $\underline{2}\ KBr_{(aq)} + Cl_{2(aq)} \rightarrow \underline{2}\ KCl_{(aq)} + Br_{2(l)}$

a. When 1.855g of Cl_2 and 3.205g of KBr are mixed in solution, which is the limiting reactant?

$$\frac{1.855\text{g } Cl_2}{} \times \frac{1 \text{ mol } Cl_2}{70.90\text{g } Cl_2} \times \frac{2 \text{ mol KCl}}{1 \text{ mol } Cl_2} \times \frac{74.55\text{g KCl}}{1 \text{ mol KCl}} = 3.901\text{g KCl}$$

$$\frac{3.205\text{g KBr}}{} \times \frac{1 \text{ mol KBr}}{119.0\text{g KBr}} \times \frac{2 \text{ mol KCl}}{2 \text{ mol KBr}} \times \frac{74.55\text{g KCl}}{1 \text{ mol KCl}} = 2.008\text{g KCl}$$

* KBr is limiting

b. How many grams of *each* product are formed?

$$\frac{3.205\text{g KBr}}{} \times \frac{1 \text{ mol KBr}}{119.0\text{g KBr}} \times \frac{1 \text{ mol } Br_2}{2 \text{ mol KBr}} \times \frac{159.8\text{g } Br_2}{1 \text{ mol } Br_2} = 2.152\text{g } Br_2$$

2.008g KCl

5. A process by which zirconium metal can be produced from the mineral zirconium (IV) orthosilicate, $ZrSiO_4$, starts by reacting it with chlorine gas to form zirconium (IV) chloride. $ZrSiO_4 + \underline{2}\ Cl_2 \rightarrow ZrCl_4 + SiO_2 + O_2$

What mass of $ZrCl_4$ can be produced if 862 g of $ZrSiO_4$ and 950. g of Cl_2 are available? (You must first determine limiting reactant).

$$\frac{862\text{ g } ZrSiO_4}{} \times \frac{1 \text{ mol } ZrSiO_4}{183.31\text{g } ZrSiO_4} \times \frac{1 \text{ mol } ZrCl_4}{1 \text{ mol } ZrSiO_4} \times \frac{233.02\text{g } ZrCl_4}{1 \text{ mol } ZrCl_4} = 1.10 \times 10^3\text{g } ZrCl_4$$

$$\frac{950.\text{g } Cl_2}{} \times \frac{1 \text{ mol } Cl_2}{70.90\text{g } Cl_2} \times \frac{1 \text{ mol } ZrCl_4}{2 \text{ mol } Cl_2} \times \frac{233.02\text{g } ZrCl_4}{1 \text{ mol } ZrCl_4} = 1560\text{g } ZrCl_4$$

6. In the following (unbalanced) reaction, what mass of $Ba(NO_3)_2$ can be formed by combining 55 g $BaCO_3$ and 26 g HNO_3?

$BaCO_3 + \underline{2}\ HNO_3 \rightarrow Ba(NO_3)_2 + CO_2 + H_2O$

$$\frac{55\text{g } BaCO_3}{} \times \frac{1 \text{ mol } BaCO_3}{197.31\text{g } BaCO_3} \times \frac{1 \text{ mol } Ba(NO_3)_2}{1 \text{ mol } BaCO_3} \times \frac{261.32\text{g } Ba(NO_3)_2}{1 \text{ mol } Ba(NO_3)_2} = 73\text{g } Ba(NO_3)_2$$

$$\frac{26\text{g } HNO_3}{} \times \frac{1 \text{ mol } HNO_3}{63.02\text{g } HNO_3} \times \frac{1 \text{ mol } Ba(NO_3)_2}{2 \text{ mol } HNO_3} \times \frac{261.32\text{g } Ba(NO_3)_2}{1 \text{ mol } Ba(NO_3)_2} = 54\text{g } Ba(NO_3)_2$$

7. Huge quantities of sulfur dioxide are produced from zinc sulfide by means of the following unbalanced reaction:

$\underline{2}\ ZnS_{(s)} + \underline{3}\ O_{2(g)} \rightarrow \underline{2}\ ZnO_{(s)} + \underline{2}\ SO_{2(g)}$

If the typical yield is 86.78%, how much SO_2 should be expected if 4897 g of ZnS are used?

$$\frac{4897\text{g ZnS}}{} \times \frac{1 \text{ mol ZnS}}{97.48\text{g ZnS}} \times \frac{2 \text{ mol } SO_2}{2 \text{ mol ZnS}} \times \frac{64.07\text{g } SO_2}{1 \text{ mol } SO_2} = 3219\text{g } SO_2 \text{ (theoretical)}$$

$$86.78\% = \frac{\text{actual}}{3219\text{g } SO_2} \times 100\%$$

actual = 2793g SO_2

8. Aspirin, $C_9H_8O_4$, is synthesized by the reaction of salicylic acid, $C_7H_6O_3$, with acetic anhydride, $C_4H_6O_3$.

$$\underline{2}\ C_7H_6O_3 + C_4H_6O_3 \rightarrow \underline{2}\ C_9H_8O_4 + H_2O \qquad \text{(unbalanced)}$$

a. When 20.0 g of $C_7H_6O_3$ and 20.0g of $C_4H_6O_3$ react, which is the limiting reagent?

$$\frac{20.0\text{ g } C_7H_6O_3}{} \times \frac{1\text{ mol } C_7H_6O_3}{138.12\text{ g } C_7H_6O_3} \times \frac{2\text{ mol } C_9H_8O_4}{2\text{ mol } C_7H_6O_3} \times \frac{180.15\text{ g } C_9H_8O_4}{1\text{ mol } C_9H_8O_4} = 26.1\text{ g } C_9H_8O_4$$

$$\frac{20.0\text{ g } C_4H_6O_3}{} \times \frac{1\text{ mol } C_4H_6O_3}{102.09\text{ g } C_4H_6O_3} \times \frac{2\text{ mol } C_9H_8O_4}{1\text{ mol } C_4H_6O_3} \times \frac{180.15\text{ g } C_9H_8O_4}{1\text{ mol } C_9H_8O_4} = 70.6\text{ g } C_9H_8O_4$$

* $C_7H_6O_3$ (salicylic acid) is limiting

b. What mass in grams of aspirin are formed?

26.1 g $C_9H_8O_4$ (aspirin)

9. Dichlorine monoxide, Cl_2O is sometimes used as a powerful chlorinating agent in research. It can be produced by passing chlorine gas over heated mercury (II) oxide according to the following unbalanced equation:

$$HgO + \underline{2}\ Cl_2 \rightarrow HgCl_2 + Cl_2O$$

What is the percent yield, if the quantity of the reactants is sufficient to produce 0.86 g of Cl_2O but only 0.71 g is obtained?

$$\%\text{ Yield} = \frac{0.71\text{ g } Cl_2O}{0.86\text{ g } Cl_2O} \times 100 = 83\%$$

4 pts total:
- 1 pt = work
- 1 pt = units in work
- 1 pt = correct answer
- 1 pt = correct sig figs

10. In the commercial production of the element arsenic, arsenic(III) oxide is heated with carbon, which reduces the oxide to the metal according to the following unbalanced equation: $\underline{2}\ As_2O_3 + \underline{3}\ C \rightarrow \underline{3}\ CO_2 + \underline{4}\ As$

a. If 8.87 g of As_2O_3 is used in the reaction and 5.33 g of As is produced, what is the percent yield?

$$\frac{8.87\text{ g } As_2O_3}{} \times \frac{1\text{ mol } As_2O_3}{197.84\text{ g } As_2O_3} \times \frac{4\text{ mol As}}{2\text{ mol } As_2O_3} \times \frac{74.92\text{ g As}}{1\text{ mol As}} = 6.72\text{ g As (theoretical)}$$

$$\%\text{ Yield} = \frac{5.33\text{ g As}}{6.72\text{ g As}} \times 100 = 79.3\%$$

b. If 67 g of carbon is used up in a different reaction and 425 g of As is produced, calculate the percent yield of this reaction.

$$\frac{67\text{ g C}}{} \times \frac{1\text{ mol C}}{12.011\text{ g C}} \times \frac{4\text{ mol As}}{3\text{ mol C}} \times \frac{74.92\text{ g As}}{1\text{ mol As}} = 560\text{ g As (theoretical)}$$

$$\%\text{ Yield} = \frac{425\text{ g As}}{560\text{ g As}} \times 100 = 76\%$$

11. Assume that the following hypothetical reaction takes place: $2A + 7B \rightarrow 4C + 3D$ Calculate the percent yield in each of the following cases:

a. The reaction of 0.0251 mol of A produces 0.0349 mol of C.

$$\frac{0.0251 \text{ mol A} \mid 4 \text{ mol C}}{\mid 2 \text{ mol A}} = 0.0502 \text{ mol C}$$

$$\% \text{ Yield} = \frac{0.0349 \text{ mol C}}{0.0502 \text{ mol C}} \times 100 = \boxed{69.5\%}$$

b. The reaction of 1.19 mol of A produces 1.41 mol of D.

$$\frac{1.19 \text{ mol A} \mid 3 \text{ mol D}}{\mid 2 \text{ mol A}} = 1.79 \text{ mol D}$$

$$\% \text{ Yield} = \frac{1.41 \text{ mol D}}{1.79 \text{ mol D}} \times 100 = \boxed{78.8\%}$$

c. The reaction of 189 mol of B produces 39 mol of D.

$$\frac{189 \text{ mol B} \mid 3 \text{ mol D}}{\mid 7 \text{ mol B}} = 81.0 \text{ mol D}$$

$$\% \text{ Yield} = \frac{39 \text{ mol D}}{81.0 \text{ mol D}} = \boxed{48\%}$$

d. The reaction of 3500 mol of B produces 1700 mol of C.

$$\frac{3500 \text{ mol B} \mid 4 \text{ mol C}}{\mid 7 \text{ mol B}} = 2.0 \times 10^3 \text{ mol C}$$

$$\% \text{ Yield} = \frac{1700 \text{ mol C}}{2.0 \times 10^3 \text{ mol C}} = \boxed{85\%}$$