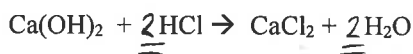


Limiting Reactant and Percent Yield Worksheet

Key

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



- 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?

$$\frac{6.3 \text{ mol HCl}}{2 \text{ mol HCl}} \Bigg| \frac{1 \text{ mol CaCl}_2}{1 \text{ mol Ca(OH)}_2} = 3.2 \text{ mol CaCl}_2$$

$$\frac{2.8 \text{ mol Ca(OH)}_2}{1 \text{ mol Ca(OH)}_2} \Bigg| \frac{1 \text{ mol CaCl}_2}{1 \text{ mol Ca(OH)}_2} = 2.8 \text{ mol CaCl}_2$$

* Ca(OH)₂ is limiting

- b. How many moles of the excess reactant remain?

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

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

2. Aluminum oxidizes according to the following unbalanced equation: $4 \text{Al} + 3 \text{O}_2 \rightarrow 2 \text{Al}_2\text{O}_3$

- a. Powdered Al (0.048 mol) is placed into a container containing 0.030 mol O₂. What is limiting reactant?

$$\frac{0.048 \text{ mol Al}}{4 \text{ mol Al}} \Bigg| \frac{2 \text{ mol Al}_2\text{O}_3}{1 \text{ mol Al}} = 0.024 \text{ mol Al}_2\text{O}_3$$

$$\frac{0.030 \text{ mol O}_2}{3 \text{ mol O}_2} \Bigg| \frac{2 \text{ mol Al}_2\text{O}_3}{1 \text{ mol O}_2} = 0.020 \text{ mol Al}_2\text{O}_3$$

* O₂ is limiting

- b. How many moles of the excess reactant remain?

$$\frac{0.030 \text{ mol O}_2}{3 \text{ mol O}_2} \Bigg| \frac{4 \text{ mol Al}}{1 \text{ mol O}_2} = 0.040 \text{ mol Al used}$$

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

3. Heating zinc sulfide in the presence of oxygen yields the following: $\underline{2}\text{ZnS} + \underline{3}\text{O}_2 \rightarrow \underline{2}\text{ZnO} + \underline{2}\text{SO}_2$

- a. If 1.72 mol of ZnS is heated in the presence of ~~3.94~~^{45.6} g of O₂, which is the limiting reactant? (Balance the equation first.)

$$\frac{1.72 \text{ mol ZnS}}{1 \text{ mol ZnS}} \Bigg| \frac{2 \text{ mol SO}_2}{1 \text{ mol ZnS}} = 3.44 \text{ mol SO}_2$$

$$\frac{45.6 \text{ g O}_2}{32.0 \text{ g O}_2} \Bigg| \frac{1 \text{ mol O}_2}{32.0 \text{ g O}_2} \Bigg| \frac{2 \text{ mol SO}_2}{3 \text{ mol O}_2} = 0.950 \text{ mol SO}_2$$

* O₂ is limiting

- b. How many grams of the excess reactant remain?

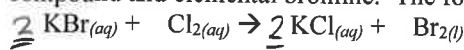
$$\frac{45.6 \text{ g O}_2}{32.0 \text{ g O}_2} \Bigg| \frac{1 \text{ mol O}_2}{32.0 \text{ g O}_2} \Bigg| \frac{2 \text{ mol ZnS}}{3 \text{ mol O}_2} \Bigg| \frac{97.48 \text{ g ZnS}}{1 \text{ mol ZnS}} = 92.6 \text{ g used}$$

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

$$168 \text{ g ZnS} \\ - 92.6 \text{ g ZnS}$$

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:



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

$$\frac{1.855 \text{g Cl}_2}{70.90 \text{g Cl}_2} \times \frac{1 \text{mol Cl}_2}{1 \text{mol Cl}_2} \times \frac{2 \text{mol KCl}}{1 \text{mol Cl}_2} \times \frac{74.55 \text{g KCl}}{1 \text{mol KCl}} = 3.901 \text{g KCl}$$

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

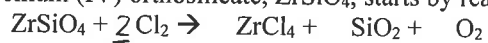
* KBr is limiting

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

$$\frac{3.205 \text{g KBr}}{119.0 \text{g KBr}} \times \frac{1 \text{mol KBr}}{1 \text{mol KBr}} \times \frac{1 \text{mol Br}_2}{2 \text{mol KBr}} \times \frac{159.8 \text{g Br}_2}{1 \text{mol Br}_2} = 2.152 \text{g Br}_2$$

$$2.008 \text{g KCl}$$

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.

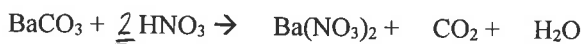


What mass of ZrCl_4 can be produced if 862 g of ZrSiO_4 and 950. g of Cl_2 are available? (You must first determine limiting reactant).

$$\frac{862 \text{g ZrSiO}_4}{183.31 \text{g ZrSiO}_4} \times \frac{1 \text{mol ZrSiO}_4}{1 \text{mol ZrSiO}_4} \times \frac{1 \text{mol ZrCl}_4}{1 \text{mol ZrSiO}_4} \times \frac{233.02 \text{g ZrCl}_4}{1 \text{mol ZrCl}_4} = 1.10 \times 10^3 \text{g ZrCl}_4$$

$$\frac{950. \text{g Cl}_2}{70.90 \text{g Cl}_2} \times \frac{1 \text{mol Cl}_2}{2 \text{mol Cl}_2} \times \frac{1 \text{mol ZrCl}_4}{1 \text{mol Cl}_2} \times \frac{233.02 \text{g ZrCl}_4}{1 \text{mol ZrCl}_4} = 1560 \text{g ZrCl}_4$$

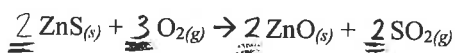
6. In the following (unbalanced) reaction, what mass of $\text{Ba}(\text{NO}_3)_2$ can be formed by combining 55 g BaCO_3 and 26 g HNO_3 ?



$$\frac{55 \text{g BaCO}_3}{197.31 \text{g BaCO}_3} \times \frac{1 \text{mol BaCO}_3}{1 \text{mol BaCO}_3} \times \frac{1 \text{mol Ba}(\text{NO}_3)_2}{1 \text{mol BaCO}_3} \times \frac{261.32 \text{g Ba}(\text{NO}_3)_2}{1 \text{mol Ba}(\text{NO}_3)_2} = 73 \text{g Ba}(\text{NO}_3)_2$$

$$\frac{26 \text{g HNO}_3}{63.02 \text{g HNO}_3} \times \frac{1 \text{mol HNO}_3}{2 \text{mol HNO}_3} \times \frac{1 \text{mol Ba}(\text{NO}_3)_2}{1 \text{mol HNO}_3} \times \frac{261.32 \text{g Ba}(\text{NO}_3)_2}{1 \text{mol Ba}(\text{NO}_3)_2} = 54 \text{g Ba}(\text{NO}_3)_2$$

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



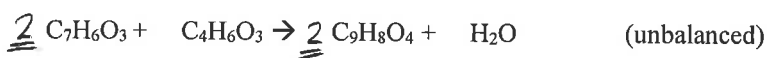
If the typical yield is 86.78%, how much SO_2 should be expected if 4897 g of ZnS are used?

$$\frac{4897 \text{g ZnS}}{97.48 \text{g ZnS}} \times \frac{1 \text{mol ZnS}}{2 \text{mol ZnS}} \times \frac{2 \text{mol SO}_2}{1 \text{mol ZnS}} \times \frac{64.07 \text{g SO}_2}{1 \text{mol SO}_2} = 3219 \text{g SO}_2 \text{ (theoretical)}$$

$$86.78\% = \frac{\text{actual}}{3219 \text{g SO}_2} \times 100\%$$

$$\text{actual} = 2793 \text{g SO}_2$$

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



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

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

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

- b. What mass in grams of aspirin are formed?

$$26.1 \text{ g } C_9H_8O_4 \text{ (aspirin)}$$

* $C_7H_6O_3$ (salicylic acid) is limiting

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:



- a. 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?

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

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

- 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.

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

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

11. Assume that the following hypothetical reaction takes place:
of the following cases:



Calculate the percent yield in each

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

$$\frac{0.0251 \text{ mol A}}{2 \text{ mol A}} \left| \frac{4 \text{ mol C}}{2 \text{ mol A}} \right. = 0.0502 \text{ mol C}$$

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

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

$$\frac{1.19 \text{ mol A}}{2 \text{ mol A}} \left| \frac{3 \text{ mol D}}{2 \text{ mol A}} \right. = 1.79 \text{ mol D}$$

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

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

$$\frac{189 \text{ mol B}}{7 \text{ mol B}} \left| \frac{3 \text{ mol D}}{7 \text{ mol B}} \right. = 81.0 \text{ mol D}$$

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

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

$$\frac{3500 \text{ mol B}}{7 \text{ mol B}} \left| \frac{4 \text{ mol C}}{7 \text{ mol B}} \right. = 2.0 \times 10^3 \text{ mol C}$$

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