

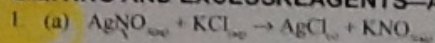
18. 1
19. solvent
20. stoichiometry
21. balanced
22. amounts

## 2.10

## EXTENSION EXERCISE

(Page 101)

### LIMITING AND EXCESS REAGENTS—ADDITIONAL PRACTICE



$$n_{\text{AgNO}_3} = 5.10 \text{ g AgNO}_3 \times \frac{1 \text{ mol AgNO}_3}{169.88 \text{ g AgNO}_3}$$

$$n_{\text{AgNO}_3} = 0.0300 \text{ mol}$$

$$n_{\text{KCl}} = 4.48 \text{ g KCl} \times \frac{1 \text{ mol KCl}}{74.55 \text{ g KCl}}$$

$$n_{\text{KCl}} = 0.0601 \text{ mol}$$

Therefore,  $\text{AgNO}_{3(aq)}$  is the limiting reagent.

$$(b) m_{\text{AgCl}} = 0.0300 \text{ mol AgNO}_3 \times \frac{1 \text{ mol AgCl}}{1 \text{ mol AgNO}_3} \times \frac{143.32 \text{ g AgCl}}{1 \text{ mol AgCl}}$$

$$m_{\text{AgCl}} = 4.3 \text{ g AgCl}$$

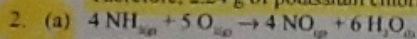
The mass of silver chloride formed is 4.3 g.

Before the reaction, there is 0.0601 mol potassium chloride. During the reaction, 0.0300 mol potassium chloride is consumed. The mole ratio is 1:1. Therefore, 0.0301 mol potassium chloride remain after the reaction.

$$m_{\text{KCl}} = 0.0301 \text{ mol KCl} \times \frac{74.55 \text{ g KCl}}{1 \text{ mol KCl}}$$

$$m_{\text{KCl}} = 2.24 \text{ g KCl}$$

Therefore, 2.24 g of potassium chloride remains unreacted.



(b)

Balanced equation	4 NH <sub>3(g)</sub>	+	5 O <sub>2(g)</sub>	→	4 NO <sub>(g)</sub>	+	6 H <sub>2</sub> O <sub>(l)</sub>
Before reaction	4.00 mol		7.00 mol				
Reaction according to balanced equation	4.00 mol		5.00 mol				
After reaction	0 mol		2.00 mol				

Ammonia is the limiting reagent.

$$n_{\text{NH}_3} = 4.00 \text{ mol NH}_3$$

$$M_{\text{NO}} = 30.01 \text{ g/mol NO}$$

$$1 \text{ mol NO} = 30.01 \text{ g NO}$$

$$4 \text{ mol NO} = 4 \text{ mol NH}_3$$

$$m_{\text{NO}} = 4.00 \text{ mol NH}_3 \times \frac{4 \text{ mol NO}}{4 \text{ mol NH}_3} \times \frac{30.01 \text{ g NO}}{1 \text{ mol NO}}$$

$$m_{\text{NO}} = 120 \text{ g NO}$$

The mass of nitrogen monoxide formed is 120 g.

(c) According to the reaction chart, 2.00 mol oxygen remains after the reaction.

$$m_{\text{O}_2} = 2.00 \text{ mol O}_2 \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2}$$

$$m_{\text{O}_2} = 64.0 \text{ g O}_2$$

Therefore, 64.0 g of oxygen remains unreacted.

3. According to the balanced equation, 3 mol iodine is required to react with 2 mol aluminum. Before the reaction, there is 2.00 mol aluminum, but only 0.500 mol iodine. Therefore, iodine is the limiting reagent.

$$m_{\text{AlI}_3} = 0.500 \text{ mol I}_2 \times \frac{2 \text{ mol AlI}_3}{3 \text{ mol I}_2} \times \frac{407.68 \text{ g AlI}_3}{1 \text{ mol AlI}_3}$$

$$m_{\text{AlI}_3} = 136 \text{ g AlI}_3$$

$$\frac{\text{I}}{\text{Al}} = \frac{3}{2} = 1.5 \times$$

$2.00 \times 1.5 = 3.00$

The theoretical yield of aluminum iodide is 136 g.

4. (a)  $\text{N}_{2(g)} + 2 \text{O}_{2(g)} + 2 \text{NO}_{2(g)}$   
 (b) According to the balanced equation, 1 mol nitrogen is required to react with 2 mol oxygen. Before the reaction, there is 0.200 mol nitrogen and 0.200 mol oxygen. Therefore, oxygen is the limiting reagent.

$$m_{\text{NO}_2} = 0.200 \text{ mol O}_2 \times \frac{2 \text{ mol NO}_2}{2 \text{ mol O}_2} \times \frac{46.01 \text{ g NO}_2}{1 \text{ mol NO}_2}$$

$$m_{\text{NO}_2} = 9.20 \text{ g NO}_2$$

The theoretical yield of nitrogen dioxide is 9.20 g.

(c) Nitrogen is the limiting reagent.

$$n_{\text{NO}_2} = 2.00 \text{ mol N}_2 \times \frac{2 \text{ mol NO}_2}{1 \text{ mol N}_2}$$

$$n_{\text{NO}_2} = 4.00 \text{ mol NO}_2$$

The amount of nitrogen dioxide produced is 4.00 mol.

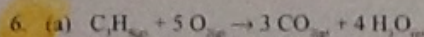
5. (a)  $2 \text{SO}_{2(g)} + \text{O}_{2(g)} + 2 \text{H}_2\text{O}_{(l)} \rightarrow 2 \text{H}_2\text{SO}_{4(l)}$   
 (b) According to the balanced equation, 2 mol sulfur dioxide reacts with 1 mol oxygen and 2 mol water. Before the reaction, there is 1.50 mol sulfur dioxide, 1.00 mol oxygen, and 2.00 mol water. Therefore, sulfur dioxide is the limiting reagent.

$$m_{\text{H}_2\text{SO}_4} = 1.50 \text{ mol SO}_2 \times \frac{2 \text{ mol H}_2\text{SO}_4}{2 \text{ mol SO}_2} \times \frac{98.08 \text{ g H}_2\text{SO}_4}{1 \text{ mol H}_2\text{SO}_4}$$

$$m_{\text{H}_2\text{SO}_4} = 147 \text{ g H}_2\text{SO}_4$$

The theoretical yield of hydrogen sulfate is 147 g.



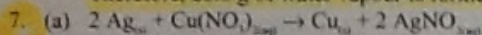


(b) According to the balanced equation, 1 mol propane reacts with 5 mol oxygen. Before the reaction, there is 16.0 mol propane and 2.00 mol oxygen. Therefore, oxygen is the limiting reagent.

$$m_{\text{H}_2\text{O}} = 2.00 \text{ mol O}_2 \times \frac{4 \text{ mol H}_2\text{O}}{5 \text{ mol O}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}}$$

$$m_{\text{H}_2\text{O}} = 28.8 \text{ g H}_2\text{O}$$

Therefore, 28.8 g of water vapour is formed.



(b) According to the balanced equation, 2 mol silver reacts with 1 mol copper(II) nitrate. Before the reaction, there is 2.000 mol silver and 2.000 mol copper(II) nitrate. Therefore, silver is the limiting reagent.

$$m_{\text{Cu}} = 2.000 \text{ mol Ag} \times \frac{1 \text{ mol Cu}}{2 \text{ mol Ag}} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}}$$

$$m_{\text{Cu}} = 63.55 \text{ g Cu}$$

Therefore, 63.55 g of copper is formed.

## 2.11

## ALTERNATIVE EXERCISE

(Pages 104–105)

### ACTIVITY: THE LIMITING REAGENT AND PERCENTAGE COMPOSITION OF A MIXTURE

#### Observations

##### Part A

	Precipitate forms with $\text{Ba}(\text{NO}_3)_2$ (Yes/No)	Precipitate forms with $\text{CuSO}_4$ (Yes/No)
Test 1	yes	—
Test 2	—	no

##### Part B

Mass of filter paper + precipitate (step 12)	2.35 g
Mass of filter paper (step 5)	1.38 g
(a) Mass of precipitate	0.97 g

#### Analysis

(b) Since a precipitate formed when barium nitrate was added to the filtrate in test tube 1, but not when copper sulfate was added to the filtrate in test tube 2, barium nitrate is the limiting reagent.

(c) Since barium nitrate is the limiting reagent in this reaction, its amount (and mass) in the  $\text{Ba}(\text{NO}_3)_2/\text{CuSO}_4$  mixture may be calculated using the mass of the barium sulfate precipitate formed in the reaction.

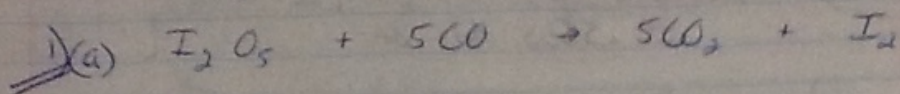
$$m_{\text{Ba}(\text{NO}_3)_2} = 0.97 \text{ g BaSO}_4 \times \frac{1 \text{ mol BaSO}_4}{233.39 \text{ g BaSO}_4} \times \frac{1 \text{ mol Ba}(\text{NO}_3)_2}{1 \text{ mol BaSO}_4} \times \frac{261.35 \text{ g Ba}(\text{NO}_3)_2}{1 \text{ mol Ba}(\text{NO}_3)_2}$$

$$m_{\text{Ba}(\text{NO}_3)_2} = 1.1 \text{ g Ba}(\text{NO}_3)_2$$

$$\% \text{ Ba}(\text{NO}_3)_2 \text{ in } \text{Ba}(\text{NO}_3)_2/\text{CuSO}_4 \text{ mixture} = \frac{1.1 \text{ g}}{2.01 \text{ g}} \times 100\%$$

$$\% \text{ Ba}(\text{NO}_3)_2 \text{ in } \text{Ba}(\text{NO}_3)_2/\text{CuSO}_4 \text{ mixture} = 55\%$$

# Limiting Reagents + Percent Yield Worksheet



	80g	28g
M	333.8 g/mol	28.01 g/mol
mol	0.2397	0.9996

**LR**  $\frac{I_2O_5}{CO} = \frac{1}{5} = \frac{0.2397}{x} \quad x = 1.1985 \quad \therefore CO$

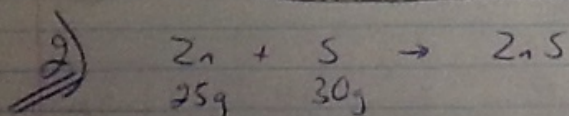
**Product**  $\frac{CO}{I_2} = \frac{5}{1} = \frac{0.9996}{x} \quad x = 0.19992 \text{ mol } I_2$

**Mass**  $m = n \times M$   
 $= 0.19992 \times (126.9 \times 2)$   
 $= 50.7397 \text{ g}$

(b)  $mass = n \times M$   
 $= 0.160 \times (126.9 \times 2)$   
 $= 40.608$

% yield =  $\frac{40.608}{50.7397} \times 100$

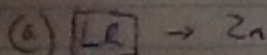
$= 80.032 \%$



mol      0.3824      0.9357

$mass_{ZnS} = 0.3824 \times 97.44$

(b)  $ZnS = 37.26 \text{ grams}$



**Product**  $Zn/ZnS = \frac{1}{1} \quad ZnS \text{ mol} = 0.3824 \quad (C) \text{ on back}$



$$\text{2c)} \quad \begin{array}{c} \text{S} \\ 0.9357 \text{ mol} - 0.3824 \text{ mol} \\ = 0.5533 \text{ left over} \end{array}$$
  

$$\text{mass} = 32.06 \text{ g/mol} \times 0.5533 \text{ mol}$$

$$= 17.74 \text{ grams}$$

$\frac{\text{S}}{\text{Zn}} = \frac{1}{1} = 0.3824$  (used)

$$\text{3.) } 2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$$
  

$$\begin{array}{ccc} 3\text{g} & 2.2\text{g} & \\ \text{mol} & 0.1234 & 0.06875 \end{array}$$
  

$$\boxed{\text{LR}} \quad \frac{m_{\text{Mg}}}{m_{\text{O}_2}} = \frac{2}{1} = \frac{0.1234}{x} \quad x = 0.0617 \quad \therefore \text{Mg is LR}$$
  

$$\boxed{\text{O}_2 \text{ is in excess}} \quad 0.06875 - 0.0617 = \underline{\quad} \times 32 \text{ g/mol}$$
  

$$\boxed{\text{Product}} \quad \frac{m_{\text{Mg}}}{m_{\text{MgO}}} = \frac{2}{2} = \frac{0.1234}{x} \quad x = 0.1234 \text{ mol}$$
  

$$\text{mass} = 0.1234 \times 40.31$$

$$= \boxed{4.97 \text{ grams of MgO}}$$

$$\text{4.) } 2\text{Al} + 3\text{S} \rightarrow \text{Al}_2\text{S}_3$$
  

$$\begin{array}{ccc} 5\text{g} & 10\text{g} & \\ \text{mol} & 0.1853 & 0.3119 \end{array}$$
  

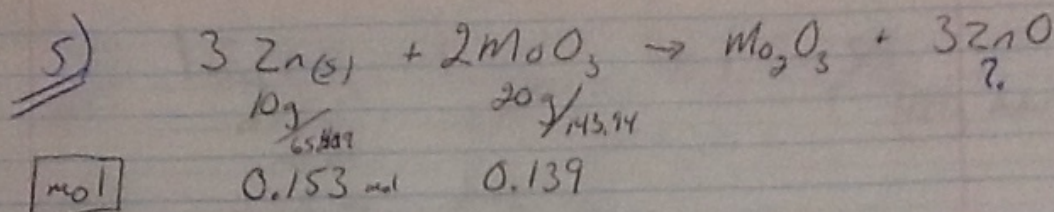
$$\boxed{\text{LR}} \quad \frac{\text{Al}}{\text{S}} = \frac{2}{3} = \frac{0.1853}{x} \quad x = 0.27795 \text{ S needed}$$
  

$$\therefore \text{Al is LR}$$
  

$$\boxed{\text{Product}} \quad \frac{\text{Al}}{\text{Al}_2\text{S}_3} = \frac{2}{1} = \frac{0.1853}{x} \quad x = 0.09265 \text{ mol}$$
  

$$\text{mass} = 0.09265 \times 150.05$$

$$\boxed{\text{Al}_2\text{S}_3 = 13.9 \text{ g}}$$



mol

LR.

$$\frac{\text{Zn}}{\text{MnO}_3} = \frac{3}{2} = \frac{0.153}{x}$$

$$x = 0.102 \text{ MnO}_3 \text{ needed}$$

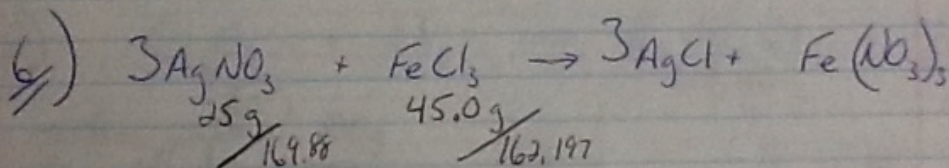
∴ Zn is LR

Product

$$\frac{\text{Zn}}{\text{ZnO}} = \frac{3}{3} =$$

$$\text{ZnO} = 0.153 \text{ mol}$$

$$\begin{aligned} \text{mass} &= 0.153 \times 81.409 \\ &= 12.4 \text{ g} \end{aligned}$$



mol

$$0.147 \quad 0.27744$$

LR

$$\frac{\text{AgNO}_3}{\text{FeCl}_3} = \frac{3}{1} = \frac{0.147}{x}$$

$$x = 0.049 \text{ mol}$$

∴ AgNO<sub>3</sub> is LR

Product

$$\frac{\text{AgCl}}{\text{AgNO}_3} = \frac{3}{3} = \frac{x}{0.147}$$

$$x = 0.147$$

Mass

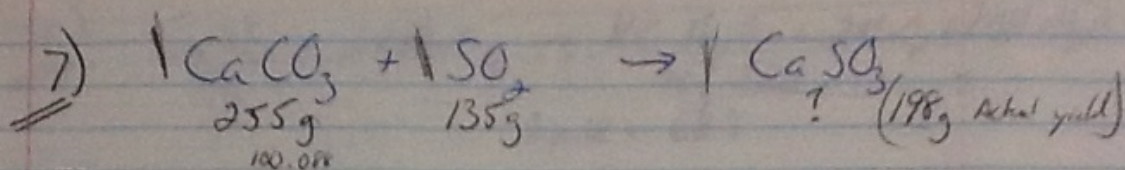
$$\begin{aligned} \text{AgCl} &= 0.147 \text{ mol} \times 143.32 \text{ g/mol} \\ &= 21.07 \text{ g} \end{aligned}$$

Excess

$$0.27744 - 0.049 = 0.22844 \text{ mol}$$

$$0.22844 \text{ mol} \times 162.197 = 37.05 \text{ g}$$





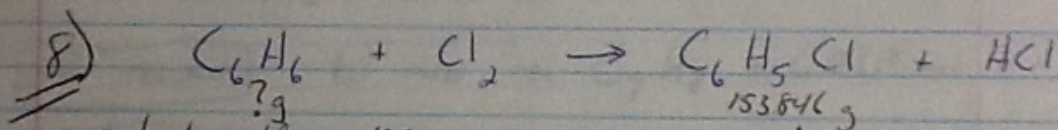
**mol**  $\frac{255\text{g}}{100.08\text{g/mol}} = 2.55\text{ mol}$   $\frac{135\text{g}}{64.06\text{g/mol}} = 2.107\text{ mol}$

**LR** 1:1  $\therefore \text{SO}_2$  is LR.

**Product** 1:1  $\therefore \text{CaSO}_3 = 2.107\text{ mol}$

**Mass**  $\text{CaSO}_3 = 2.107 \times 120.16 = 253.13\text{g}$

$\% \text{ yield} = \frac{198}{253.13} \times 100 = 78.22\%$



actual yield = 100g

$\% \text{ yield} = 65\% \rightarrow .65$

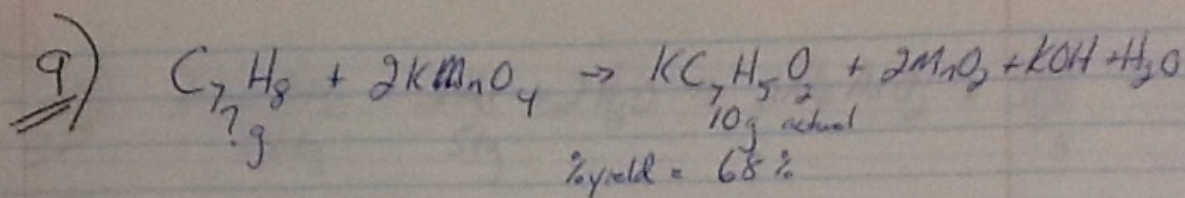
$\% \text{ yield} = \frac{\text{act}}{\text{theo}} \times 100$

$\therefore \text{theoretical yield} = \frac{\text{Actual}}{\text{yield}\%} = \frac{100\text{g}}{.65} = 153.846\text{g}$

**Mole**  $\text{C}_6\text{H}_5\text{Cl} = \frac{153.846\text{mol}}{112.56\text{g/mol}} = 1.3668\text{ mol}$

**Reagent** 1:1  $\therefore \text{mole of C}_6\text{H}_6 = 1.3668\text{ mol}$

**mass of reagent**  $\text{C}_6\text{H}_6 = 1.3668 \times 78.12 = 106.77\text{g}$



Theo yield

$$\% \text{ yield} = \frac{\text{actual}}{\text{theo}} \times 100$$

$$68\% = \frac{10g}{\text{theo}} \times 100$$

$$0.68 = \frac{10g}{\text{theo}}$$

$$\text{theo} = \frac{10g}{0.68} = 14.706 g$$

Mole product

$$\frac{14.706 g}{160.2183} = 0.0918 \text{ mol}$$

Mol reactant

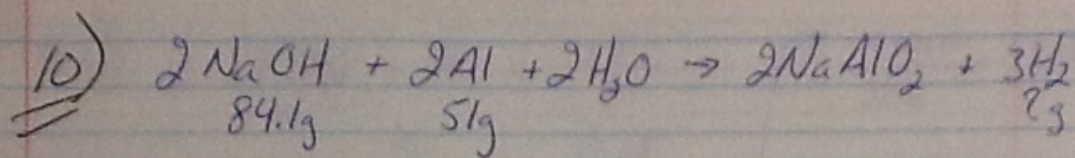
$$1:1 \text{ ratio } \therefore C_7H_8 = 0.0918 \text{ mol}$$

Mass reactant

$$C_7H_8 = 0.0918 \text{ mol} \times 92.15 g/mol$$

$$= 8.46 \text{ grams}$$





mole                  2.103                  1.89

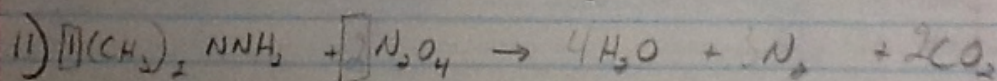
LR  $\frac{\text{NaOH}}{\text{Al}} = \frac{1}{1} = \therefore \text{Al is L.R.}$

Product  $\text{H}_2$   $\frac{\text{Al}}{\text{H}_2} = \frac{2}{3} = \frac{1.89}{x} \quad x = 2.835 \text{ mol}$

Mass  $\text{H}_2$  mass =  $2.835 \times 2.016 = 5.71536 \text{ g}$

Excess Reagent  $\begin{array}{ccc} \text{Avail} & \text{Used} & 1:1 \text{ ratio} \\ \text{NaOH} = 2.103 & - 1.89 & \\ & = 0.213 \text{ mol} & \end{array}$

$\text{NaOH} = 39.908 \times 0.213$   
 $= 8.50 \text{ g}$



150kg	460kg	210.15 kg
60	92	26.02
2.5	5	7.5

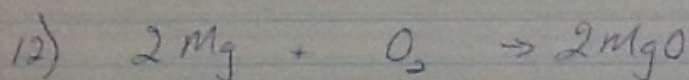
$$11.iii) \quad \frac{30 \text{ kg}}{x} \times 100 = 68\% \quad \leftarrow \frac{44.11765}{200} = 1.575 \text{ kmol}$$

$$\frac{30}{x} = 0.68$$

$$x = 44.11765 \text{ kg theoretical yield}$$

$$\frac{N_2}{N_2O_4} = \frac{3}{2} = \frac{1.575 \text{ kmol}}{x} \quad x = 1.05 \text{ kmol of } N_2O_4$$

$$\text{mass of } N_2O_4 = 1.05 \text{ kmol} \times 92 \frac{\text{g}}{\text{mol}} = \boxed{96.57 \text{ kg of } N_2O_4}$$



$$\frac{5 \text{ g}}{24.31 \frac{\text{g}}{\text{mol}}} \quad \frac{5 \text{ g}}{32 \frac{\text{g}}{\text{mol}}} \quad ? \text{ g}$$

$$0.20568 \quad 0.15625$$

$$\frac{\text{Mg}}{\text{O}_2} = \frac{2}{1} = \frac{0.20568}{x} \quad x = 0.10284 \text{ needed}$$

O<sub>2</sub> is excess

$$\frac{\text{Mg}}{\text{MgO}} = \frac{2}{2} \Rightarrow \text{MgO} = 0.20568 \text{ mol formed}$$

$$\text{mass MgO} = 0.20568 \times (16 + 24.31) = 8.29 \text{ g}$$

$$\text{O}_2 \quad 0.15625 - 0.10284 = 0.05341$$

$$\text{mass O}_2 \rightarrow 0.05341 \times 32 \frac{\text{g}}{\text{mol}} = 1.71 \text{ g}$$