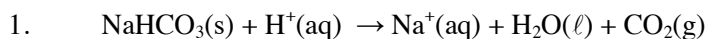




**Stage 3 - Set 2 Answers: Limiting reagents**



$$n(\text{NaHCO}_3) = \frac{0.273}{84.008} \qquad n(\text{H}^+) = 0.0500 \times 2.50$$

$$= 3.25 \times 10^{-3} \text{ mol} \qquad = 0.125 \text{ mol}$$

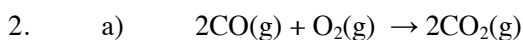
1 mole of  $\text{NaHCO}_3$  requires 1 mol of  $\text{H}^+$   
 $3.25 \times 10^{-3} \text{ NaHCO}_3$  requires  $3.25 \times 10^{-3} \text{ mol H}^+$   
 $n(\text{H}^+ \text{ required}) < n(\text{H}^+ \text{ available})$

(a)  $\text{NaHCO}_3$  is LR

(b)  $n(\text{CO}_2) = n(\text{NaHCO}_3)$   
 $= 3.25 \times 10^{-3} \text{ mol}$

$$V = \frac{(3.25 \times 10^{-3}) \times 8.315 \times (28 + 273)}{95.6}$$

$$= 8.51 \times 10^{-2} \text{ L}$$



$$n(\text{CO}) = \frac{1.00 \times 102}{(156 + 273) \times 8.315}$$

$$= 2.90 \times 10^{-2} \text{ mol}$$

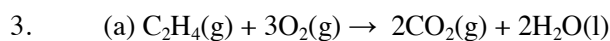
2 mol of CO requires 1 mol of  $\text{O}_2$   
 $2.90 \times 10^{-2} \text{ mol of CO}$  requires  $\frac{1}{2} (2.90 \times 10^{-2}) = 1.45 \times 10^{-2} \text{ mol O}_2$

$n(\text{O}_2 \text{ required}) < n(\text{O}_2 \text{ available})$   
 CO is LR

b)  $n(\text{CO}_2) = n(\text{CO})$   
 $V(\text{CO}_2) = \frac{(2.90 \times 10^{-2}) \times 8.315 \times (273 + 150)}{102}$   
 $= 1.00 \text{ L}$

c)  $n(\text{O}_2 \text{ remaining}) = 1.45 \times 10^{-2}$   
 $V(\text{O}_2) = \frac{(1.45 \times 10^{-2}) \times 8.315 \times (273 + 150)}{102}$   
 $= 0.500 \text{ L}$

Composition = 1.00 L  $\text{CO}_2$ , 0.500 L  $\text{O}_2$ , no CO



$$\begin{aligned} n(\text{C}_2\text{H}_4) &= \frac{0.02 \times 101.3}{(120 + 273) \times 8.315} \\ &= 6.20 \times 10^{-4} \text{ mol} \end{aligned}$$

$$\begin{aligned} n(\text{O}_2) &= \frac{0.08 \times 101.3}{(120 + 273) \times 8.315} \\ &= 2.48 \times 10^{-3} \text{ mol} \end{aligned}$$

1 mol of  $\text{C}_2\text{H}_4$  requires 3 mol of  $\text{O}_2$   
 $6.20 \times 10^{-4}$  mol of  $\text{C}_2\text{H}_4$  requires  $3(6.20 \times 10^{-4}) = 1.86 \times 10^{-3}$  mol  $\text{O}_2$

$n(\text{O}_2 \text{ required}) < n(\text{O}_2 \text{ available})$   
 $\text{C}_2\text{H}_4$  is LR

$$\begin{aligned} n(\text{CO}_2) &= 2n(\text{C}_2\text{H}_4) \\ &= 1.24 \times 10^{-3} \text{ mol} \\ V(\text{CO}_2) &= \frac{(1.24 \times 10^{-3}) \times 8.315 \times (120 + 273)}{101.3} \\ &= 4.00 \times 10^{-2} \text{ L (40.0 mL)} \end{aligned}$$

$$\begin{aligned} N(\text{H}_2\text{O}) &= 2n(\text{C}_2\text{H}_4) \\ V(\text{H}_2\text{O}) &= 4.00 \times 10^{-2} \text{ L (40.0 mL)} \end{aligned}$$

$$\begin{aligned} \text{(b) Total volume} &= V(\text{H}_2\text{O}) + V(\text{CO}_2) + V(\text{O}_2 \text{ excess}) \\ &= 4.00 \times 10^{-2} + 4.00 \times 10^{-2} + 2.00 \times 10^{-2} \\ &= 0.100 \text{ L} \end{aligned}$$

4. 
$$\begin{aligned} n(\text{Cu}) &= \frac{1.33}{63.55} & n(\text{H}^+) &= 0.0250 \times 6.00 \\ &= 2.09 \times 10^{-2} \text{ mol} & &= 0.150 \text{ mol} \end{aligned}$$

1 mol of Cu requires 4 mol of  $\text{H}^+$   
 $2.09 \times 10^{-2}$  of Cu requires  $4(2.09 \times 10^{-2}) = 8.37 \times 10^{-2}$  mol of  $\text{H}^+$

$n(\text{H}^+ \text{ required}) < n(\text{H}^+ \text{ available})$   
(a) Cu is LR

$$\begin{aligned} \text{(b) } n(\text{NO}_2) &= 2n(\text{Cu}) \\ &= 2(2.09 \times 10^{-2}) \\ &= 4.19 \times 10^{-2} \text{ mol} \end{aligned}$$

$$\begin{aligned} V(\text{NO}_2) &= \frac{(4.19 \times 10^{-2}) \times 8.315 \times (33 + 273)}{104} \\ &= 1.02 \text{ L} \end{aligned}$$

$$5. \quad n(\text{MnO}_2) = \frac{3.44}{54.94 + 32} = 3.96 \times 10^{-2} \text{ mol}$$

$$n(\text{HCl}) = 0.0150 \times 6.20 = 9.30 \times 10^{-2} \text{ mol}$$

1 mol of  $\text{MnO}_2$  requires 2 mol of  $\text{Cl}^-$  (from 2 mole  $\text{HCl}$ )  
 $3.96 \times 10^{-2}$  mol of  $\text{MnO}_2$  requires  $2(3.96 \times 10^{-2}) = 0.0792$  mol  $\text{HCl}$

$n(\text{HCl required}) < n(\text{HCl available})$

$\text{MnO}_2$  is LR

$$n(\text{Cl}_2) = n(\text{MnO}_2) = 3.96 \times 10^{-2} \text{ mol}$$

$$P(\text{Cl}_2) = \frac{(3.96 \times 10^{-2}) \times 8.315 \times (35 + 273)}{0.250} = 4.06 \times 10^2 \text{ kPa}$$

$$6. \quad 4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}$$

$$n(\text{NH}_3) = \frac{16.0 \times 102}{(155 + 273) \times 8.315} = 0.459 \text{ mol}$$

$$n(\text{O}_2) = \frac{18.0 \times 102}{(155 + 273) \times 8.315} = 0.516 \text{ mol}$$

1 mol  $\text{NH}_3$  required  $5/4$  mol of  $\text{O}_2$   
 $0.459$  mol  $\text{NH}_3$  required  $5/4(0.516) = 0.645$  mol

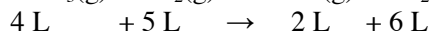
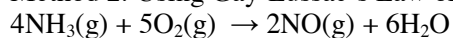
$n(\text{O}_2 \text{ required}) < n(\text{O}_2 \text{ available})$

$\text{NH}_3$  is LR

$$n(\text{NO}) = n(\text{NH}_3) = 0.459 \text{ mol}$$

$$V(\text{NO}) = \frac{0.459 \times 8.315 \times (155 + 273)}{102} = 16.0 \text{ L}$$

Method 2: Using Gay-Lussac's Law of combining volumes



1 L  $\text{NH}_3$  required  $5/4$  L of  $\text{O}_2$

16 L  $\text{NH}_3$  required  $5/4(16)$  L of  $\text{O}_2 = 17.25$  L

$\text{Vol}(\text{O}_2 \text{ required}) < 18 \text{ L vol}(\text{O}_2 \text{ available})$

$\text{NH}_3$  is LR

$$V(\text{NO}) = V(\text{NH}_3) = 16.0 \text{ L}$$

$$7. \quad n(\text{CO}) = \frac{6.00 \times 200}{(273 + 45) \times 8.315}$$

$$= 0.454 \text{ mol}$$

$$n(\text{O}_2) = \frac{3.00 \times 800}{(273 + 45) \times 8.315}$$

$$= 0.908 \text{ mol}$$

2 mol CO required 1 mol of O<sub>2</sub>  
 0.454 mol of CO required  $\frac{1}{2}$  (0.454) = 0.227 mol of O<sub>2</sub>  
 $n(\text{O}_2 \text{ required}) < n(\text{O}_2 \text{ available})$   
 CO is LR  
 $n(\text{CO}_2) = n(\text{CO})$   
 $= 0.454 \text{ mol}$   
 $P(\text{CO}_2) = \frac{0.454 \times 8.315 \times (273 + 45)}{(6.00 + 3.00)}$   
 $= 133 \text{ kPa}$

$$8. \quad n(\text{Na}) = \frac{5.00 \times 10^5}{22.99}$$

$$= 2.17 \times 10^4 \text{ mol}$$

$$n(\text{NH}_3) = \frac{(86.9 \times 10^3) \times (1.20 \times 10^3)}{(750 + 273) \times 8.315}$$

$$= 1.23 \times 10^4 \text{ mol}$$

1 mol of Na requires 1 mol of NH<sub>3</sub>  
 $2.17 \times 10^4 \text{ mol of Na requires } 2.17 \times 10^4 \text{ mol of NH}_3$   
 $n(\text{NH}_3 \text{ required}) > n(\text{NH}_3 \text{ available})$   
 NH<sub>3</sub> is LR  
 $n(\text{NaCN}) = n(\text{NH}_3)$   
 $= 1.23 \times 10^4 \text{ mol}$   
 $m(\text{NaCN}) = (1.23 \times 10^4) \times 49.01$   
 $= 6.01 \times 10^5 \text{ g}$

$$9. \quad n((\text{NH}_4)_2\text{SO}_4) = \frac{30.0}{132.144}$$

$$= 0.227 \text{ mol}$$

$$n(\text{KNO}_3) = \frac{34.0}{101.11}$$

$$= 0.336 \text{ mol}$$

1 mol of (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> requires 2 mol of KNO<sub>3</sub>  
 $0.227 \text{ mol of } (\text{NH}_4)_2\text{SO}_4 \text{ requires } 2(0.227) = 0.454 \text{ mol KNO}_3$   
 $n(\text{KNO}_3 \text{ required}) > n(\text{KNO}_3 \text{ available})$

(a) KNO<sub>3</sub> is LR

(b)  $n((\text{NH}_4)_2\text{SO}_4) = 0.227 - \frac{1}{2}(0.227)$   
 $= 0.114 \text{ mol}$   
 $m((\text{NH}_4)_2\text{SO}_4) = 0.114 \times 132.144$   
 $= 15.0 \text{ g}$

(c)  $n(\text{N}_2) = n(\text{KNO}_3)$   
 $= 0.336 \text{ mol}$

$$P(\text{N}_2) = \frac{0.336 \times 8.315 \times (273 + 220)}{0.760}$$

$$= 1.81 \times 10^3 \text{ kPa}$$