Stage 3 - Set 2 Answers: Limiting reagents

1. $NaHCO_3(s) + H^+(aq) \rightarrow Na^+(aq) + H_2O(\ell) + CO_2(g)$

$$n(NaHCO_3) = \frac{0.273}{84.008} = 3.25 \times 10^{-3} \text{ mol} \qquad n(H^+) = 0.0500 \times 2.50 = 0.125 \text{ mol}$$

1 mole of $NaHCO_3$ requires 1 mol of H^+
3.25×10^{-3} $NaHCO_3$ requires 3.25×10^{-3} mol H^+
N(H^+ required) < n(H^+available)
(a) $NaHCO_3$ is LR

(b) N(CO_2) = n($NaHCO_3$)
= 3.25×10^{-3} mol

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

= 8.51×10^{-2} L

2. a) $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

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

= 2.90×10^{-2} mol

2 mol of CO requires 1 mol of O_2
2.90×10^{-2} mol of CO requires ½ (2.90×10^{-2}) = 1.45×10^{-2} mol O_2

N(O_2 required) < n(O_2 available)
CO is LR

b) n(CO_2) = n(CO)

$$V(CO_2) = \frac{(2.90 \times 10^{-2}) \times 8.315 \times (273 + 150)}{102}$$

= 1.00 L

c) n(O_2 remaining) = 1.45×10^{-2}

$$V(O_2) = \frac{(1.45 \times 10^{-2}) \times 8.315 \times (273 + 150)}{102}$$

= 0.500 L

Composition = 1.00 L CO_2, 0.500 L O_2, no CO

3. (a) $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$

$$n(C_2H_4) = \frac{0.02x101.3}{(120+273)x8.315}$$
$$= 6.20 \times 10^{-4} \text{ mol}$$

$$n(O_2) = \frac{0.08x101.3}{(120+273)x8.315}$$
$$= 2.48 \times 10^{-3} \text{ mol}$$

1 mol of C_2H_4 requires 3 mol of O_2
6.20×10^{-4} mol of C_2H_4 requires $3(6.20 \times 10^{-4}) = 1.86 \times 10^{-3}$ mol O_2

n(O_2 required) < n(O_2 available)
C_2H_4 is LR

$n(CO_2) = 2n(C_2H_4)$
$= 1.24 \times 10^{-3}$ mol

$$V(CO_2) = \frac{(1.24x10^{-3})x8.315x(120+273)}{101.3}$$
$$= 4.00 \times 10^{-2} \text{ L (40.0 mL)}$$

$N(H_2O) = 2n(C_2H_4)$
$V(H_2O) = 4.00 \times 10^{-2}$ L (40.0 mL)

(b)Total volume = $V(H_2O) + V(CO_2) + V(O_2 \text{ excess})$
$= 4.00 \times 10^{-2} + 4.00 \times 10^{-2} + 2.00 \times 10^{-2}$
$= 0.100$ L

4. $$n(Cu) = \frac{1.33}{63.55}$$
$$= 2.09 \times 10^{-2} \text{ mol}$$

n(H+)= 0.0250 x 6.00
= 0.150 mol

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

n(H^+ required) < n(H^+ available)
(a) Cu is LR

(b) $n(NO_2)$ = 2n(Cu)
$= 2\ (2.09 \times 10^{-2})$
$= 4.19 \times 10^{-2}$ mol

$$V(NO_2) = \frac{(4.19x10^{-2})x8.315x(33+273)}{104}$$
$$= 1.02 \text{ L}$$

5. $n(MnO_2) = \frac{3.44}{54.94 + 32}$

$= 3.96 \times 10^{-2}$ mol

$n(HC\ell) = 0.0150 \times 6.20$

$= 9.30 \times 10^{-2}$ mol

1 mol of MnO_2 requires 2 mol of $C\ell^-$ (from 2 mole $HC\ell$)
3.96×10^{-2} mol of MnO_2 requires $2(3.96 \times 10^{-2}) = 0.0792$ mol $HC\ell$

n($HC\ell$ required) < n($HC\ell$ available)
MnO_2 is LR
$n(C\ell_2) = n(MnO_2)$
$= 3.96 \times 10^{-2}$ mol

$$P(C\ell_2) = \frac{(3.96 \times 10^{-2}) \times 8.315 \times (35 + 273))}{0.250}$$

$= 4.06 \times 10^2$ kPa

6. $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O$

$n(NH_3) = \frac{16.0 \times 102}{(155 + 273) \times 8.315}$

$= 0.459$ mol

$n(O_2) = \frac{18.0 \times 102}{(155 + 273) \times 8.315}$

$= 0.516$ mol

1 mol NH_3 required 5/4 mol of O_2
0.459 mol NH_3 required 5/4(0.516) = 0.645 mol

n(O_2 required) < n(O_2 available)
NH_3 is LR
$n(NO) = n(NH_3)$
$= 0.459$ mol

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

$= 16.0$ L

Method 2: Using Gay-Lussac's Law of combining volumes
$4NH_3(g) + 5O_2(g) \rightarrow 2NO(g) + 6H_2O$
4 L + 5 L → 2 L + 6 L
1 L NH_3 required 5/4 L of O_2
16 L NH_3 required 5/4(16) L of O_2 = 17.25 L

Vol (O_2 required) < 18 L vol (O_2 available)
NH_3 is LR
$V(NO) = V(NH_3)$
$= 16.0$ L

7. $n(CO) = \frac{6.00x200}{(273+45)x8.315}$

$= 0.454\ mol$

$n(O_2) = \frac{3.00x800}{(273+45)x8.315}$

$= 0.908\ mol$

2 mol CO required 1 mol of O_2
0.454 mol of CO required ½ (0.454) = 0.227 mol of O_2
$n(O_2$ required) < $n(O_2$ available)
CO is LR
$n(CO_2) = n(CO)$
= 0.454 mol

$P(CO_2) = \frac{0.454x8.315x(273+45)}{(6.00+3.00)}$

= 133 kPa

8. $n(Na) = \frac{5.00x10^5}{22.99}$

$= 2.17 \times 10^4$ mol

$n(NH_3) = \frac{(86.9x10^3)x(1.20x10^3)}{(750+273)x8.315}$

$= 1.23 \times 10^4$ mol

1 mol of Na requires 1 mol of NH_3
2.17×10^4 mol of Na requires 2.17×10^4 mol of NH_3
$n(NH_3$ required) > $n(NH_3$ available)
NH_3 is LR
n(NaCN) = n(NH3)
= 1.23×10^4 mol
m(NaCN) = $(1.23 \times 10^4) \times 49.01$
= 6.01×10^5 g

9. $n((NH_4)SO_4) = \frac{30.0}{132.144}$

$= 0.227\ mol$

$n(KNO_3) = \frac{34.0}{101.11}$

$= 0.336\ mol$

1 mol of $(NH_4)_2SO_4$ requires 2 mol of KNO_3
0.227 mol of $(NH_4)_2SO_4$ requires 2(0.227)=0.454 mol KNO_3
n(KNO3 required) > $n(KNO_3$ available)

(a) KNO_3 is LR

(b) $n((NH_4)_2SO_4)$ = 0.227 – ½ (0227)
= 0.114 mol
$m((NH_4)_2SO_4)$ = 0.114 x 132.144
= 15.0 g

(c) $n(N_2)$ = $n(KNO_3)$
= 0.336 mol

$P(N_2) = \frac{0.336x8.315x(273+220)}{0.760}$

$= 1.81 \times 10^3$ kPa