Limiting reagent calculations

CH101 Fall 2009
Boston University

Limiting reagent

$3\ A + 2\ B \rightarrow 4\ C$

Balanced chemical equation is the "***recipe***"
Amounts of reactants is ***how much*** can be made
Limiting is which of A or B ***makes the least***

CPS: Limiting reagent

$CoCl_2 \cdot 6H_2O$(*aq*) and Na_3PO_4(*aq*) precipitate $Co_3(PO_4)_2$(*s*)

Net ionic equation:
$3\ Co^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Co_3(PO_4)_2(s)$

Spectator ions:
$Na^+(aq)$ and $Cl^-(aq)$.

Limiting reagent for mixtures, ACS page 103 (ACS 2.9)

$3\ Co^{2+}(aq) + 2\ PO_4^{3+}(aq) \rightarrow Co_3(PO_4)_2(s)$

Mixture 1: 0.15 M $CoCl_2 \cdot 6H_2O$ + 0.15 M Na_3PO_4
Mixture 2: 0.15 M $CoCl_2 \cdot 6H_2O$ + 0.075 M Na_3PO_4
Mixture 3: 0.075 M $CoCl_2 \cdot 6H_2O$ + 0.15 M Na_3PO_4
Mixture 4: 0.075 M $CoCl_2 \cdot 6H_2O$ + 0.075 M Na_3PO_4

colbalt + phosphate → precipitate

Mixture 3 is shown before and after addition of phosphate and after centrifugation.

$Na^+(aq)$ in 50. mL + 50. mL mixture 3, ACS page 103 (ACS 2.9)

$3\ Co^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Co_3(PO_4)_2(s)$
Mixture 3: 0.075 M $CoCl_2 \cdot 6H_2O$ + 0.15 M Na_3PO_4

Na^+ comes from $Na_3PO_4(aq)$ and so …
 3 mol Na^+ per mole of Na_3PO_4

Na^+ is spectator and so …
 $[Na^+]$ = mol Na^+/total volume

What is the molarity of $Na^+(aq)$ after precipitation?

Na^+(*aq*) in 50. mL + 50. mL mixture 3, ACS page 103 (ACS 2.9)

$3\ Co^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Co_3(PO_4)_2(s)$

Mixture 3: 0.075 M $CoCl_2{\cdot}6H_2O$ + 0.15 M Na_3PO_4

mol Na^+
= 0.15 mol Na_3PO_4/L x 0.050 L x 3 mol Na^+/1 mol Na_3PO_4
= 0.0225 mol

[Na^+] = mol Na^+/total volume
= 0.0225 mol/(0.050 L + 0.050 L) = 0.225 M (sf?)

colbalt + more phosphate → ***same amount of precipitate*** → Co^{2+} limiting

Mixtures 3 and 4 are shown after centrifugation.

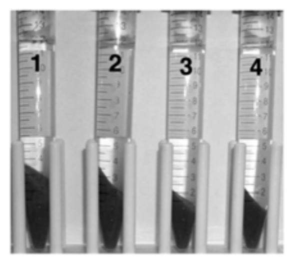
Limiting reagent for mixtures 3 and 4, ACS page 103 (ACS 2.9)

$3\ Co^{2+}(aq) + 2\ PO_4^{3+}(aq) \rightarrow Co_3(PO_4)_2(s)$

Mixture 3: 0.075 M colbalt + 0.15 M phosphate
colbalt → 0.075 M/3 = 0.025 M ppt
phosphate → 0.15 M/2 = 0.075 M ppt

Mixture 4: 0.075 M colbalt + 0.075 M phosphate
colbalt → 0.075 M/3 = 0.025 M ppt
phosphate → 0.075 M/2 = 0.038 M ppt

colbalt + phosphate → precipitate



Why is mixture 2 pink but others are clear?

Limiting reagent for mixtures 1 and 2, ACS page 103 (ACS 2.9)

$3\ Co^{2+}(aq) + 2\ PO_4^{3+}(aq) \rightarrow Co_3(PO_4)_2(s)$

Mixture 1: 0.15 M colbalt + 0.15 M phosphate
colbalt → 0.15 M/3 = 0.050 M ppt
phosphate → 0.15 M/2 = 0.075 M ppt

Mixture 2: 0.15 M colbalt + 0.075 M phosphate
colbalt → 0.15 M/3 = 0.050 M ppt
phosphate → 0.075 M/2 = 0.038 M ppt

Limiting reagent for mixtures 1 and 2, ACS page 103 (ACS 2.9)

$3\ Co^{2+}(aq) + 2\ PO_4^{3+}(aq) \rightarrow Co_3(PO_4)_2(s)$

Mixture 2: 0.15 M colbalt + 0.075 M phosphate
colbalt → 0.15 M/3 = 0.050 M ppt
phosphate → 0.075 M/2 = 0.038 M ppt

What is [Co^{2+}] after pptn?

[Co^{2+}] after pptn for mixture 2, ACS page 103 (ACS 2.9)

$3\ Co^{2+}(aq) + 2\ PO_4^{3+}(aq) \rightarrow Co_3(PO_4)_2(s)$

start Co^{2+} = 0.15 M x 0.050 L = 0.0075 mol
start PO_4^{3+} = 0.075 x 0.050 L = 0.00375 mol

used Co^{2+} = start PO_4^{3+} x (3/2) = 0.005625 mol
unused Co^{2+} = start Co^{2+} – used Co^{2+} = 0.001875 mol

[Co^{2+}] = (0.001875 mol)/(.100 L) = 0.019 M

Limiting reagent example, Dill/3e p. 12

7.39 kg of titanium dioxide reacts with *excess* carbon and chlorine according to the balanced reaction is $TiO_2 + 2\ C + 2Cl_2 \rightarrow TiCl_4 + 2\ CO$.

What is the minimum amount of carbon and chlorine that we need?

The answer is 185 mol for each. Where does this number come from?

g $TiO_2 \rightarrow$ mol $TiO_2 \rightarrow$ mol C, mol Cl_2

Limiting reagent example, Dill/3e p. 12

7.39 kg of titanium dioxide reacts with *excess* carbon and chlorine according to the balanced reaction is $TiO_2 + 2\ C + 2Cl_2 \rightarrow TiCl_4 + 2\ CO$.

g $TiO_2 \rightarrow$ mol TiO_2:
7.39 x 10^3 g x (1 mol/79.88 g) = 92.5 mol TiO_2

mol $TiO_2 \rightarrow$ mol C:
92.5 mol TiO_2 x (2 mol C/1 mol TiO_2) = 185 mol C

mol $TiO_2 \rightarrow$ mol Cl_2:
92.5 mol TiO_2 x (2 mol Cl_2/1 mol TiO_2) = 185 mol Cl_2

Limiting reagent example, Dill/3e p. 15

3 X + 2 Y $\rightarrow$ 4 Z

11.4 mol X and 8.97 mol Y react.
How much Z is formed?
How much, if any, of X and Y remain?

Limiting reagent example, Dill/3e p. 15

3 X + 2 Y $\rightarrow$ 4 Z
11.4 X $\rightarrow$ 11.4 X x 4 Z/(3 X) = 15.2 Z
8.97 Y $\rightarrow$ 8.97 Y x 4 Z/(2 Y) = 17.9 Y

Y used = 11.4 X x 2 Y/(3 X) = 7.60 Y

Y unused = Y initial – Y used
= 8.97 mol – 7.60 mol = 1.37 mol