Chemistry 20 – Lesson 35
Limiting reactants – stoichiometry

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Practice problem

1. $K_2Cr_2O_{7(aq)} + Pb(NO_3)_{2(aq)} \longrightarrow 2\,KNO_{3\,(aq)} + PbCr_2O_{7(s)}$

$v_{K_2Cr_2O_7} = 0.0400\,L$ $v_{Pb(NO_3)_2} = 0.0300\,L$

$c_{K_2Cr_2O_7} = 0.35\,{}^{mol}\!/\!{}_{L}$ $c_{Pb(NO_3)_2} = 0.50\,{}^{mol}\!/\!{}_{L}$

$m_{yield} = 5.75\,g$

$m_{PbCr_2O_7} = ?$

$M_{PbCr_2O_7} = 423.19\,{}^{g}\!/\!{}_{mol}$

A. Find the limiting reactant.

I. calculate moles

$n_{K_2Cr_2O_7} = 0.35\,{}^{mol}\!/\!{}_{L} \times 0.0400\,L$

$n_{K_2Cr_2O_7} = 0.014\,mol$

$n_{Pb(NO_3)_2} = 0.50\,{}^{mol}\!/\!{}_{L} \times 0.0300\,L$

$n_{Pb(NO_3)_2} = 0.015\,mol$

II. mole ratios

$\dfrac{n_{PbCr_2O_7}}{1} = \dfrac{n_{K_2Cr_2O_7}}{1}$

$n_{PbCr_2O_7} = 0.14\,mol\ (\textbf{LR}) \longrightarrow \boxed{m_{PbCr_2O_7} = 5.92\,g}$

The limiting reactant is potassium dichromate.

$\dfrac{n_{PbCr_2O_7}}{1} = \dfrac{n_{Pb(NO_3)_2}}{1}$

$n_{PbCr_2O_7} = \cancel{0.15\,mol}$

III. calculate mass

$m_{PbCr_2O_7} = 0.14\,mol \times 423.19\,{}^{g}\!/\!{}_{mol}$

B. Calculate % error.

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}} \times 100$$

$$\%error = \frac{5.75 - 5.92}{5.92} \times 100$$

$$\boxed{\%error = -2.9\%}$$

C. To determine the remaining ions in solution, begin with the total ionic equation and then calculate the moles of each species that <u>remains</u> in solution.

$$2K^+_{(aq)} + Cr_2O^{2-}_{7(aq)} + Pb^{2+}_{(aq)} + 2NO^-_{3(aq)} \longrightarrow 2K^+_{(aq)} + 2NO^-_{3(aq)} + PbCr_2O_{7(s)}$$

limiting reactant

$n_{Cr_2O_7^{2-}} = 0$

excess reactant

$n_{Pb^{2+}} = 0.015 - 0.014$

$n_{Pb^{2+}} = 0.001\,mol$

$n_{K^+} = 2 \times 0.014$

$n_{K^+} = 0.028\,mol$

$n_{NO_3^-} = 2 \times 0.015$

$n_{NO_3^-} = 0.030\,mol$

D. Calculate the concentration of each ion. Since 40.0 mL was added to 30.0 mL, the final volume is 70.0 mL.

$$\left[K^+_{(aq)}\right] = \frac{0.028\,mol}{0.070\,L} = 0.40\,{}^{mol}\!/\!{}_{L}$$

$$\left[NO^-_{3\,(aq)}\right] = \frac{0.030\,mol}{0.070\,L} = 0.43\,{}^{mol}\!/\!{}_{L}$$

$$\left[Pb^{2+}_{(aq)}\right] = \frac{0.001\,mol}{0.070\,L} = 0.0143\,{}^{mol}\!/\!{}_{L}$$

Assignment

1. $2H_{2(g)} \quad + \quad O_{2(g)} \longrightarrow 2H_2O_{(g)}$

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$m_{H_2} = 9.09\,g$ $m_{O_2} = 88.0\,g$ $m_{yield} = 73.0\,g$

$M_{H_2} = 2.02\,{}^{g}\!/\!_{mol}$ $M_{O_2} = 32.00\,{}^{g}\!/\!_{mol}$ $m_{H_2O} = ?$

$M_{H_2O} = 18.02\,{}^{g}\!/\!_{mol}$

A. Find the limiting reactant.

I. calculate moles   II. mole ratios   III. calculate mass

$$n_{O_2} = \frac{88.0\,g}{32.00\,{}^{g}\!/\!_{mol}} \qquad \frac{n_{H_2O}}{2} = \frac{n_{O_2}}{1}$$

$$n_{O_2} = 2.75\,mol \qquad \frac{n_{H_2O}}{2} = \frac{2.75\,mol}{1}$$

$$n_{H_2O} = \xcancel{5.50\,mol}$$

$$n_{H_2} = \frac{9.09\,g}{2.02\,{}^{g}\!/\!_{mol}} \qquad \frac{n_{H_2O}}{2} = \frac{n_{H_2}}{2} \qquad m_{H_2O} = 4.50\,mol \times 18.02\,{}^{g}\!/\!_{mol}$$

$$n_{H_2} = 4.50\,mol \qquad n_{H_2O} = 4.50\,mol(\mathbf{LR}) \longrightarrow \boxed{m_{H_2O} = 81.1g}$$

The limiting reactant is the hydrogen gas.

B. Calculate % error.

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}} \times 100$$

$$\%error = \frac{73.0 - 81.1}{81.1} \times 100$$

$$\boxed{\%error = -10\%}$$

2. $2\,RbBr_{(aq)} + Pb(NO_3)_{2(aq)} \longrightarrow 2\,RbNO_{3\,(aq)} + PbBr_{2(s)}$

$v_{RbBr} = 0.0300\,L$ $m_{Pb(NO_3)_2} = 8.00\,g$

$c_{RbBr} = 1.50\,{}^{mol}\!/\!_{L}$ $M_{Pb(NO_3)_2} = 331.22\,{}^{g}\!/\!_{mol}$

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$m_{yield} = 6.83\,g - 1.21\,g = 5.62\,g$

$m_{PbBr_2} = ?$

$M_{PbBr_2} = 367.0\,{}^{g}\!/\!_{mol}$

A. Find the limiting reactant.

I. calculate moles

$n_{RbBr} = 1.50\,{}^{mol}\!/\!_{L} \times 0.0300\,L$

$n_{RbBr} = 0.0450\,mol$

$n_{Pb(NO_3)_2} = \dfrac{8.00\,g}{331.22\,{}^{g}\!/\!_{mol}}$

$n_{Pb(NO_3)_2} = 0.02415\,mol$

II. mole ratios

$\dfrac{n_{PbBr_2}}{1} = \dfrac{n_{RbBr}}{2}$

$\dfrac{n_{PbBr_2}}{1} = \dfrac{0.0450\,mol}{2}$

$n_{PbBr_2} = 0.0225\,mol$ (**LR**) $\longrightarrow \boxed{m_{PbBr_2} = 8.26\,g}$

The limiting reactant is rubidium bromide.

$\dfrac{n_{PbBr_2}}{1} = \dfrac{n_{Pb(NO_3)_2}}{1}$

$n_{PbBr_2} = \cancel{0.02415\,mol}$

III. calculate mass

$m_{PbBr_2} = 0.0225\,mol \times 367.0\,{}^{g}\!/\!_{mol}$

B. Calculate % error.

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}} \times 100$$

$$\%error = \frac{5.62 - 8.26}{8.26} \times 100$$

$$\boxed{\%error = -32\%}$$

3. $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)}$

$m_{H_2} = 20.20\,g$ $\quad m_{O_2} = 150.5\,g$ $\quad m_{yield} = 72.05\,g$

$M_{H_2} = 2.02\,{}^{g}\!/_{mol}$ $\quad M_{O_2} = 32.00\,{}^{g}\!/_{mol}$ $\quad m_{H_2O} = ?$

/10 $\quad M_{H_2O} = 18.02\,{}^{g}\!/_{mol}$

A. Find the limiting reactant.

I. calculate moles | II. mole ratios | III. calculate mass

$$n_{O_2} = \frac{150.5\,g}{32.00\,{}^{g}\!/_{mol}} \qquad \frac{n_{H_2O}}{2} = \frac{n_{O_2}}{1}$$

$$n_{O_2} = 4.703\,mol \qquad \frac{n_{H_2O}}{2} = \frac{4.703\,mol}{1} \qquad m_{H_2O} = 9.406\,mol \times 18.02\,{}^{g}\!/_{mol}$$

$$n_{H_2O} = 9.406\,mol\ (\mathbf{LR}) \longrightarrow \boxed{m_{H_2O} = 169.5\,g}$$

The limiting reactant is oxygen.

$$n_{H_2} = \frac{20.20\,g}{2.02\,{}^{g}\!/_{mol}} \qquad \frac{n_{H_2O}}{2} = \frac{n_{H_2}}{2}$$

$$n_{H_2} = 10.00\,mol \qquad n_{H_2O} = \xcancel{10.00\,mol}$$

B. Calculate % error.

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}} \times 100$$

$$\%error = \frac{73.0 - 169.5}{169.5} \times 100$$

$$\boxed{\%error = -57\%}$$

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4. $Zn_{(s)} + 2\,HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$

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$m_{Zn} = 100\,g$ $\quad v_{HCl} = 0.750\,L$ $\quad m_{yield} = 184\,g$

$M_{Zn} = 65.41\,g/mol$ $\quad c_{HCl} = 4.00\,mol/L$ $\quad m_{ZnCl_2} = ?$

$M_{ZnCl_2} = 136.30\,g/mol$

A. Find the limiting reactant.

I. calculate moles

$$n_{Zn} = \frac{100\,g}{65.41\,g/mol}$$

$$n_{Zn} = 1.53\,mol$$

$$n_{HCl} = 4.00\,mol/L \times 0.750\,L$$

$$n_{HCl} = 3.00\,mol$$

II. mole ratios

$$\frac{n_{ZnCl_2}}{1} = \frac{n_{Zn}}{1}$$

$$n_{ZnCl_2} = \cancel{1.53\,mol}$$

$$\frac{n_{ZnCl_2}}{1} = \frac{n_{HCl}}{2}$$

$$\frac{n_{ZnCl_2}}{1} = \frac{3.00\,mol}{2}$$

$$n_{ZnCl_2} = 1.50\,mol(\mathbf{LR}) \longrightarrow$$

The limiting reactant is hydrochloric acid.

III. calculate mass

$$m_{ZnCl_2} = 1.50\,mol \times 136.30\,g/mol$$

$$\boxed{m_{ZnCl_2} = 204\,g}$$

B. Calculate % error.

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}} \times 100$$

$$\%error = \frac{184 - 204}{204} \times 100$$

$$\boxed{\%error = -9.8\%}$$

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5. $2\,Na_3PO_{4\,(aq)} \quad + \quad 3\,Ba(NO_3)_{2(aq)} \longrightarrow 6\,NaNO_{3\,(aq)} \quad + \quad Ba_3(PO_4)_{2(s)}$

$v_{Na_3PO_4} = 0.200\,L \qquad v_{Ba(NO_3)_2} = 0.400\,L$

/10 $c_{Na_3PO_4} = 0.500\,{}^{mol}\!/\!_{L} \qquad c_{Ba(NO_3)_2} = 0.500\,{}^{mol}\!/\!_{L}$

$m_{yield} = 25.6\,g$

$m_{Ba_3(PO_4)_2} = ?$

$M_{Ba_3(PO_4)_2} = 601.93\,{}^{g}\!/\!_{mol}$

A. Find the limiting reactant.

I. calculate moles   II. mole ratios   III. calculate mass

$n_{Na_3PO_4} = 0.500\,{}^{mol}\!/\!_{L} \times 0.200\,L \qquad \frac{n_{Ba_3(PO_4)_2}}{1} = \frac{n_{Na_3PO_4}}{2}$

$n_{Na_3PO_4} = 0.100\,mol \qquad \frac{n_{Ba_3(PO_4)_2}}{1} = \frac{0.100\,mol}{2} \qquad m_{Ba_3(PO_4)_2} = 0.0500\,mol \times 601.93\,{}^{g}\!/\!_{mol}$

$n_{Ba_3(PO_4)_2} = 0.0500\,mol\ (\mathbf{LR}) \longrightarrow \boxed{m_{Ba_3(PO_4)_2} = 30.1\,g}$

The limiting reactant is sodium phosphate.

$n_{Ba(NO_3)_2} = 0.500\,{}^{mol}\!/\!_{L} \times 0.400\,L \qquad \frac{n_{Ba_3(PO_4)_2}}{1} = \frac{n_{Ba(NO_3)_2}}{3}$

$n_{Ba(NO_3)_2} = 0.200\,mol \qquad \frac{n_{Ba_3(PO_4)_2}}{1} = \frac{0.200\,mol}{3}$

$n_{Ba_3(PO_4)_2} = \xcancel{0.0667\,mol}$

B. Calculate % error.

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}} \times 100$$

$$\%error = \frac{25.6 - 30.1}{30.1} \times 100$$

$$\boxed{\%error = -15\%}$$

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6. $2C_2H_{6(g)} + 7O_{2(g)} \longrightarrow 6H_2O_{(g)} + 4CO_{2(g)}$

$m_{C_2H_6} = 1.30\,g$ $m_{O_2} = 2.362\,g$ $m_{H_2O} = ?$

/10 $M_{C_2H_6} = 30.08\,^{g}/_{mol}$ $M_{O_2} = 32.00\,^{g}/_{mol}$ $M_{H_2O} = 18.02\,^{g}/_{mol}$

A. Find the limiting reactant.

I. calculate moles | II. mole ratios | III. calculate mass

$n_{O_2} = \dfrac{2.362\,g}{32.00\,^{g}/_{mol}}$ $\dfrac{n_{H_2O}}{6} = \dfrac{n_{O_2}}{7}$

$n_{O_2} = 0.07381 mol$ $\dfrac{n_{H_2O}}{6} = \dfrac{0.07381\,mol}{7}$ $m_{H_2O} = 0.06327\,mol \times 18.02\,^{g}/_{mol}$

$n_{H_2O} = 0.06327\,mol(\mathbf{LR}) \longrightarrow$ $\boxed{m_{H_2O} = 1.14\,g}$

The limiting reactant is the oxygen gas.

$n_{C_2H_6} = \dfrac{1.30\,g}{30.08\,^{g}/_{mol}}$ $\dfrac{n_{H_2O}}{6} = \dfrac{n_{C_2H_6}}{2}$

$n_{C_2H_6} = 0.0432\,mol$ $\dfrac{n_{H_2O}}{6} = \dfrac{0.0432\,mol}{2}$

$n_{H_2O} = \cancel{0.130\,mol}$

7. $2\,NaCl_{(aq)} \;+\; Pb(NO_3)_{2(aq)} \longrightarrow 2\,NaNO_{3\,(aq)} \;+\; PbCl_{2(s)}$

$v_{NaCl} = 0.250\,L$ $\quad m_{Pb(NO_3)_2} = 5.0\,g$ $\qquad m_{PbCl_2} = ?$

/10 $\quad c_{NaCl} = 0.85\,{}^{mol}\!/\!_{L}$ $\quad M_{Pb(NO_3)_2} = 331.22\,{}^{g}\!/\!_{mol}$ $\qquad M_{PbCl_2} = 278.1\,{}^{g}\!/\!_{mol}$

A. Find the limiting reactant.

I. calculate moles

$$n_{NaCl} = 0.85\,{}^{mol}\!/\!_{L} \times 0.250\,L$$

$$n_{NaCl} = 0.21\,mol$$

II. mole ratios

$$\frac{n_{PbCl_2}}{1} = \frac{n_{NaCl}}{2}$$

$$\frac{n_{PbCl_2}}{1} = \frac{0.21\,mol}{2}$$

$$n_{PbCl_2} = \xcancel{0.106\,mol}$$

III. calculate mass

I. calculate moles

$$n_{Pb(NO_3)_2} = \frac{5.00\,g}{331.22\,{}^{g}\!/\!_{mol}}$$

$$n_{Pb(NO_3)_2} = 0.015\,mol$$

II. mole ratios

$$\frac{n_{PbCl_2}}{1} = \frac{n_{Pb(NO_3)_2}}{1}$$

$$n_{PbCl_2} = 0.015\,mol(\mathbf{LR}) \longrightarrow \boxed{m_{PbCl_2} = 4.2\,g}$$

III. calculate mass

$$m_{PbCl_2} = 0.015\,mol \times 278.1\,{}^{g}\!/\!_{mol}$$

The limiting reactant is lead (II) nitrate.

B. Since $Pb(NO_3)_2$ is the limiting reactant, all of it would have reacted with the NaCl. Therefore, **sodium chloride remains**. To determine the amount of remaining NaCl we must first calculate the amount of NaCl that reacted with the lead (II) nitrate.

$$\frac{n_{NaCl}}{2} = \frac{n_{Pb(NO_3)_2}}{1}$$

$$\frac{n_{NaCl}}{2} = \frac{0.015\,mol}{1}$$

$$n_{NaCl} = 0.030\,mol$$

Subtracting the amount reacted from what was initially present we get the amount of NaCl remaining.

$n_{NaCl\ remaining}$ = 0.21 mol – 0.030 mol = 0.18 mol

Now calculate mass

$$m_{NaCl\,remaining} = 0.018\,mol \times 58.44\,{}^{g}\!/\!_{mol}$$

$$\boxed{m_{NaCl\,remaining} = 10.7\,g}$$

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8. $BaCl_{2\,(aq)} + 2\,AgNO_{3\,(aq)} \longrightarrow Ba(NO_3)_{2\,(aq)} + 2\,AgCl_{(s)}$

$v_{BaCl_2} = 0.0500\,L \qquad v_{AgNO_3} = 0.100\,L$

/10 $c_{BaCl_2} = 0.00100\,{}^{mol}\!/\!_{L} \qquad c_{AgNO_3} = 0.000500\,{}^{mol}\!/\!_{L}$

$m_{yield} = 6.50\,mg$

$m_{AgCl} = ?$

$M_{AgCl} = 143.32\,{}^{g}\!/\!_{mol}$

A. Find the limiting reactant.

I. calculate moles II. mole ratios III. calculate mass

$n_{BaCl_2} = 0.00100\,{}^{mol}\!/\!_{L}(0.0500\,L) \qquad \frac{n_{AgCl}}{2} = \frac{n_{BaCl_2}}{1}$

$n_{BaCl_2} = 5.00\times10^{-5}\,mol \qquad \frac{n_{AgCl}}{2} = \frac{5.00\times10^{-5}\,mol}{1}$

$n_{AgCl} = \cancel{1.00\times10^{-4}\,mol}$

$n_{AgNO_3} = 0.000500\,{}^{mol}\!/\!_{L}(0.100L) \qquad \frac{n_{AgCl}}{2} = \frac{n_{AgNO_3}}{2} \qquad m_{AgCl} = 5.00\times10^{-5}\,mol \times 143.32\,{}^{g}\!/\!_{mol}$

$n_{AgNO_3} = 5.00\times10^{-4}\,mol \qquad n_{AgCl} = 5.00\times10^{-5}\,mol(\mathbf{LR}) \longrightarrow \boxed{m_{AgCl} = 7.17\times10^{-3}\,g \text{ or } 7.17\,mg}$

The limiting reactant is silver nitrate.

B. Calculate % error.

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}}\times100$$

$$\%error = \frac{6.5 - 7.17}{7.17}\times100$$

$$\boxed{\%error = -9.3\%}$$

9. $2Sc^{3+}_{(aq)} + 3S^{2-}_{(aq)} \longrightarrow Sc_2S_{3(s)}$

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$v_{Sc^{3+}_{(aq)}} = 0.100\,L \quad v_{S^{2-}_{(aq)}} = 0.100\,L$

$c_{Sc^{3+}_{(aq)}} = 0.150\,{}^{mol}\!/\!_{L} \quad c_{S^{2-}_{(aq)}} = 0.250\,{}^{mol}\!/\!_{L}$

$m_{yield} = 1.30\,g$

$m_{Sc_2S_3} = ?$

$M_{Sc_2S_3} = 186.13\,{}^{g}\!/\!_{mol}$

A. Find the limiting reactant.

I. calculate moles — II. mole ratios — III. calculate mass

$$n_{Sc^{3+}_{(aq)}} = 0.150\,{}^{mol}\!/\!_{L}(0.100\,L) \qquad \frac{n_{Sc_2S_3}}{1} = \frac{n_{Sc^{3+}_{(aq)}}}{2}$$

$$n_{Sc^{3+}_{(aq)}} = 0.0150\,mol \qquad \frac{n_{Sc_2S_3}}{1} = \frac{0.0150\,mol}{2} \qquad m_{Sc_2S_3} = 0.0075\,mol \times 186.13\,{}^{g}\!/\!_{mol}$$

$$n_{Sc_2S_3} = 0.0075\,mol(\mathbf{LR}) \longrightarrow \boxed{m_{Sc_2S_3} = 1.40\,g}$$

The limiting reactant is the scandium ions.

$$n_{S^{2-}_{(aq)}} = 0.250\,{}^{mol}\!/\!_{L}(0.100L) \qquad \frac{n_{Sc_2S_3}}{1} = \frac{n_{S^{2-}_{(aq)}}}{3}$$

$$n_{S^{2-}_{(aq)}} = 0.0250\,mol \qquad \frac{n_{Sc_2S_3}}{1} = \frac{0.0250\,mol}{3}$$

$$n_{Sc_2S_3} = \xcancel{0.0083\,mol}$$

B. Calculate % error.

$$\%error = \frac{\text{exp. yield} - \text{theo. yield}}{\text{theo. yield}} \times 100$$

$$\%error = \frac{1.30 - 1.40}{1.40} \times 100$$

$$\boxed{\%error = -6.9\%}$$

C. Since Sc^{3+} is the limiting reactant, all of it would have reacted with the S^{2-}. Therefore, **S^{2-} remains**. To determine the concentration of the remaining S^{2-} we must first calculate the amount of S^{2-} that reacted with the Sc^{3+}.

$$\frac{n_{S^{2-}_{(aq)}}}{3} = \frac{n_{Sc^{3+}_{(aq)}}}{2}$$

$$\frac{n_{S^{2-}_{(aq)}}}{3} = \frac{0.0075\,mol}{2}$$

$$n_{S^{2-}_{(aq)}} = 0.01125\,mol$$

Subtracting the amount reacted from what was initially present we get:

$$n_{S^{2-}_{(aq)}\text{remaining}} = 0.0250\,mol - 0.01125\,mol = 0.01375\,mol$$

Now calculate concentration

$$\left[S^{2-}_{(aq)}\right] = \frac{0.01375\,mol}{0.100\,L + 0.100\,L}$$

$$\boxed{\left[S^{2-}_{(aq)}\right] = 0.0688\,{}^{mol}\!/\!_{L}}$$

10. $Ga_2(SO_4)_{3\,(aq)} \quad + \quad 3Ba(NO_3)_{2\,(aq)} \longrightarrow 2Ga(NO_3)_{3\,(aq)} \quad + \quad 3BaSO_{4\,(s)}$

$v_{Ga_2(SO_4)_3} = 0.0150\,L \qquad v_{Ba(NO_3)_2} = 0.0250\,L \qquad m_{BaSO_4} = ?$

/10 $\quad c_{Ga_2(SO_4)_3} = 0.250\,{}^{mol}\!/\!_{L} \qquad c_{Ba(NO_3)_2} = 0.140\,{}^{mol}\!/\!_{L} \qquad M_{BaSO_4} = 233.40\,{}^{g}\!/\!_{mol}$

A. Find the limiting reactant and the mass of the precipitate.

I. calculate moles

$n_{Ga_2(SO_4)_3} = 0.250\,{}^{mol}\!/\!_{L}(0.0150\,L)$

$n_{Ga_2(SO_4)_3} = 0.00375\,mol$

$n_{Ba(NO_3)_2} = 0.140\,{}^{mol}\!/\!_{L}(0.0250L)$

$n_{Ba(NO_3)_2} = 0.00350mol$

II. mole ratios

$$\frac{n_{BaSO_4}}{3} = \frac{n_{Ga_2(SO_4)_3}}{1}$$

$$\frac{n_{BaSO_4}}{3} = \frac{0.00375\,mol}{1}$$

$$n_{BaSO_4} = \cancel{0.01125\,mol}$$

$$\frac{n_{BaSO_4}}{3} = \frac{n_{Ba(NO_3)_2}}{3}$$

$$n_{BaSO_4} = 0.00350mol(\mathbf{LR}) \longrightarrow \boxed{m_{BaSO_4} = 0.817\,g}$$

The limiting reactant is barium nitrate.

III. calculate mass

$$m_{BaSO_4} = 0.00350mol \times 233.40\,{}^{g}\!/\!_{mol}$$

B. Since the gallium ions are spectator ions:

$$Ga_2(SO_4)_{3\,(aq)} \longrightarrow 2Ga^{3+}{}_{(aq)} \quad + \quad 3SO^{2-}_{4(aq)}$$

$$\frac{n_{Ga^{3+}_{(aq)}}}{2} = \frac{n_{Ga_2(SO_4)_3}}{1}$$

$$n_{Ga^{3+}_{(aq)}} = 2 \times 0.00375\,mol$$

$$n_{Ga^{3+}_{(aq)}} = 0.00750\,mol$$

$$\left[Ga^{3+}_{(aq)}\right] = \frac{n_{Ga^{3+}_{(aq)}}}{v} = \frac{0.00750\,mol}{0.0150L + 0.0250L}$$

$$\boxed{\left[Ga^{3+}_{(aq)}\right] = 0.188\,{}^{mol}\!/\!_{L}}$$

C. Since all the barium ions reacted to form the precipitate, the remaining concentration of barium ions in solution is zero.

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11. $CaI_{2\,(aq)} \quad + \quad Pb(ClO_3)_{2\,(aq)} \longrightarrow Ca(ClO_3)_{2\,(aq)} \quad + \quad PbI_{2\,(s)}$

$v_{CaI_2} = 0.0183\,L \quad v_{Pb(ClO_3)_2} = 0.0241\,L \quad m_{PbI_2} = ?$

$c_{CaI_2} = 0.250\,\text{mol}/\text{L} \quad c_{Pb(ClO_3)_2} = 0.313\,\text{mol}/\text{L} \quad M_{PbI_2} = 461.0\,\text{g}/\text{mol}$

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A. Find the limiting reactant and the mass of the precipitate.

I. calculate moles | II. mole ratios | III. calculate mass

$n_{Pb(ClO_3)_2} = 0.313\,\text{mol}/\text{L}\,(0.0241\,L)$

$n_{Pb(ClO_3)_2} = 0.0075433\,\text{mol}$

$\frac{n_{PbI_2}}{1} = \frac{n_{Pb(ClO_3)_2}}{1}$

$n_{PbI_2} = \cancel{0.0075433\,\text{mol}}$

$n_{CaI_2} = 0.250\,\text{mol}/\text{L}\,(0.0183\,L)$

$n_{CaI_2} = 0.004575\,\text{mol}$

$\frac{n_{PbI_2}}{1} = \frac{n_{CaI_2}}{1}$

$n_{PbI_2} = 0.004575\,\text{mol}(\mathbf{LR}) \longrightarrow \boxed{m_{PbI_2} = 2.11\,g}$

$m_{PbI_2} = 0.004575\,\text{mol} \times 461.0\,\text{g}/\text{mol}$

The limiting reactant is calcium iodide.

B. To determine the concentration of the remaining Pb^{2+} we must first calculate the amount of $Pb(ClO_3)_2$ that reacted with the CaI_2.

$\frac{n_{Pb(ClO_3)_2\,\text{reacted}}}{1} = \frac{n_{CaI_2}}{1}$

$n_{Pb(ClO_3)_2\,\text{reacted}} = 0.004575\,\text{mol}$

Subtracting the amount reacted from what was initially present we get:

$$n_{Pb(ClO_3)_2\,\text{remaining}} = 0.0075433\,\text{mol} - 0.04575\,\text{mol} = 0.00297\,\text{mol}$$

Now calculate concentration

$$\left[Pb^{2+}_{(aq)}\right] = \frac{0.00297\,\text{mol}}{0.0183\,L + 0.0241\,L}$$

$$\boxed{\left[Pb^{2+}_{(aq)}\right] = 0.0700\,\text{mol}/\text{L}}$$

C. Since the calcium ions are spectator ions:

$$CaI_{2\,(aq)} \longrightarrow Ca^{2+}_{(aq)} \quad + \quad 2\,I^-_{(aq)}$$

$$\frac{n_{Ca^{2+}_{(aq)}}}{1} = \frac{n_{CaI_2}}{1}$$

$$n_{Ca^{2+}_{(aq)}} = 0.004575\,\text{mol}$$

$$\left[Ca^{2+}_{(aq)}\right] = \frac{n_{Ca^{2+}_{(aq)}}}{v} = \frac{0.004575\,\text{mol}}{0.0183\,L + 0.0241\,L}$$

$$\boxed{\left[Ca^{2+}_{(aq)}\right] = 0.108\,\text{mol}/\text{L}}$$