Act on Your Strategy

Amount in moles, n, of $Ca(CH_3COO)_2(aq)$:

$$n_{Ca(CH_3COO)_2} = c \times V$$
$$= 0.40 \text{ mol/}\cancel{L} \times 0.250 \ \cancel{L}$$
$$= 0.10 \text{ mol}$$

Molar mass, M, of $Ca(CH_3COO)_2(s)$:

$$M_{Ca(CH_3COO)_2} = 1M_{Ca} + 4M_C + 6M_H + 4M_O$$
$$= 1(40.08 \text{ g/mol}) + 4(12.01 \text{ g/mol}) + 6(1.01 \text{ g/mol}) + 4(16.00 \text{ g/mol})$$
$$= 158.18 \text{ g/mol}$$

Mass, m, of $Ca(CH_3COO)_2(s)$:

$$m_{Ca(CH_3COO)_2} = n \times M$$
$$= 0.10 \ \cancel{mol} \times 158.18 \text{ g/}\cancel{mol}$$
$$= 15.818 \text{ g}$$
$$= 16 \text{ g}$$

The mass of calcium acetate is 16 g.

Check Your Solution

The units for amount and concentration are correct. The answer has two significant digits and seems reasonable.

Section 9.2 Solution Stoichiometry

Solutions for Practice Problems

Student Edition page 420

21. Practice Problem (page 420)

Lead(II) sulfide, PbS(s), is a black, insoluble substance. Calculate the maximum mass of lead(II) sulfide that will precipitate when 6.75 g of sodium sulfide, $Na_2S(s)$, is added to 250 mL of 0.200 mol/L lead(II) nitrate, $Pb(NO_3)_2(aq)$.

What Is Required?

You need to find the mass of lead(II) sulfide that will precipitate.

What Is Given?
You know the mass of the sodium sulfide solution: 6.75 g
You know the volume of the lead(II) nitrate solution: 250 mL
You know the concentration of the lead(II) nitrate solution: 0.200 mol/L

Plan Your Strategy
Write the balanced chemical equation for the reaction.
Determine the molar mass of $Na_2S(s)$.
Calculate the amount in moles of each reactant.
To allow for the mole ratio of the reactants, divide the amount of each reactant by its coefficient in the chemical equation. The smaller result identifies the limiting reactant.
Use the mole ratio in the balanced equation and the amount in moles of the limiting reactant to find the amount in moles of the precipitate.
Determine the molar mass of PbS(s).
Calculate the mass of PbS(s) using the relationship $m = n \times M$.

Act on Your Strategy
Balanced chemical equation: $Na_2S(s) + Pb(NO_3)_2(aq) \rightarrow 2NaNO_3(aq) + PbS(s)$

Amount in moles, n, of $Na_2S(s)$:

$$\begin{aligned} n_{Na_2S} &= \frac{n}{M} \\ &= \frac{6.75\ \cancel{g}}{78.05\ \cancel{g}/\text{mol}} \\ &= 8.6483 \times 10^{-2}\ \text{mol} \end{aligned}$$

Molar mass, M, of $Na_2S(s)$:

$$\begin{aligned} M_{Na_2S} &= 2M_{Na} + 1M_S \\ &= 2(22.99\ \text{g/mol}) + 1(32.07\ \text{g/mol}) \\ &= 78.05\ \text{g/mol} \end{aligned}$$

Amount in moles, n, of $Pb(NO_3)_2(aq)$:

$$\begin{aligned} n_{Pb(NO_3)_2} &= c \times V \\ &= 0.200\ \text{mol}/\cancel{L} \times 0.250\ \cancel{L} \\ &= 5.00 \times 10^{-2}\ \text{mol} \end{aligned}$$

Identification of the limiting reactant:

$$\frac{\text{amount of } Na_2S}{\text{coefficient}} = \frac{8.6483 \times 10^{-2}\ \text{mol}}{1}$$
$$= 8.6483 \times 10^{-2}\ \text{mol}$$

$$\frac{\text{amount of } Pb(NO_3)_2}{\text{coefficient}} = \frac{5.00 \times 10^{-2}\ \text{mol}}{1}$$
$$= 5.00 \times 10^{-2}\ \text{mol}$$

$Pb(NO_3)_2(aq)$ is the limiting reactant because it is the smaller amount.

Amount in moles, n, of the precipitate, PbS(s):

$$\frac{1\ \text{mol}\ Pb(NO_3)_2}{1\ \text{mol PbS}} = \frac{5.00 \times 10^{-2}\ \text{mol}\ Pb(NO_3)_2}{n_{PbS}}$$
$$n_{PbS} = \frac{1\ \text{mol PbS} \times 5.00 \times 10^{-2}\ \cancel{\text{mol}\ Pb(NO_3)_2}}{1\ \cancel{\text{mol}\ Pb(NO_3)_2}}$$
$$= 5.00 \times 10^{-2}\ \text{mol}$$

Molar mass, M, of PbS(s):

$$M_{PbS} = 1M_{Pb} + 1M_S$$
$$= 1(207.2\ \text{g/mol}) + 1(32.07\ \text{g/mol})$$
$$= 239.27\ \text{g/mol}$$

Mass, m, of PbS(s):

$$m_{PbS} = n \times M$$
$$= 5.00 \times 10^{-2}\ \cancel{\text{mol}} \times 239.27\ \text{g}/\cancel{\text{mol}}$$
$$= 11.963\ \text{g}$$
$$= 12\ \text{g}$$

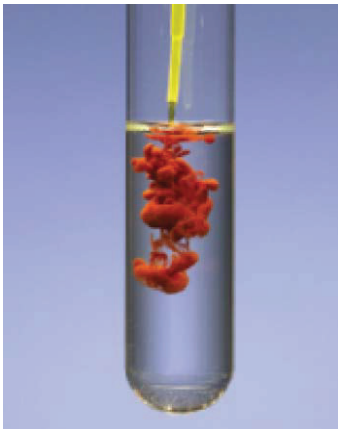
The mass of lead(II) sulfide that precipitates is 12 g.

Check Your Solution

The mass of precipitate seems reasonable compared with the number of moles of reactant used in this reaction. The answer correctly shows two significant digits.

22. Practice Problem (page 420)

Silver chromate, $Ag_2CrO_4(s)$, is a brick-red insoluble substance that is used to stain neurons so that they can be viewed under a microscope. Silver chromate can be formed by the reaction between silver nitrate, $AgNO_3(aq)$, and potassium chromate, $K_2CrO_4(aq)$, as shown in the photograph below. Calculate the mass of silver chromate that forms when 25.0 mL of 0.125 mol/L silver nitrate reacts with 20.0 mL of 0.150 mol/L potassium chromate.



What Is Required?

You need to find the mass of silver chromate that will precipitate.

What Is Given?

You know the volume of the silver nitrate solution: 25.0 mL
You know the concentration of the silver nitrate solution: 0.125 mol/L
You know the volume of the potassium chromate solution: 20.0 mL
You know the concentration of the potassium chromate solution: 0.150 mol/L

Plan Your Strategy

Write the balanced chemical equation for the reaction.
Calculate the amount in moles of each reactant using the relationship $n = c \times V$.
To allow for the mole ratio of the reactants, divide the amount of each reactant by its coefficient in the chemical equation. The smaller result identifies the limiting reactant.
Use the mole ratios to find the amount in moles, n, of the precipitate.
Determine the molar mass of $Ag_2CrO_4(s)$.
Calculate the mass of $Ag_2CrO_4(s)$ using the relationship $m = n \times M$.

Amount in moles, n, of $Na_2CO_3(aq)$:

$$\frac{1\ \text{mol}\ Ba^{2+}}{1\ \text{mol}\ Na_2CO_3} = \frac{6.250 \times 10^{-3}\ \text{mol}\ Ba^{2+}}{n_{Na_2CO_3}}$$

$$n_{Na_2CO_3} = \frac{1\ \text{mol}\ Na_2CO_3 \times 6.250 \times 10^{-3}\ \cancel{\text{mol}\ Ba^{2+}}}{1\ \cancel{\text{mol}\ Ba^{2+}}}$$

$$= 6.250 \times 10^{-3}\ \text{mol}$$

Molar mass, M, of $Na_2CO_3(s)$:

$$M_{Na_2CO_3} = 2M_{Na} + 1M_C + 3M_O$$

$$= 2(22.99\ \text{g/mol}) + 1(12.01\ \text{g/mol}) + 3(16.00\ \text{g/mol})$$

$$= 105.99\ \text{g/mol}$$

Mass, m, of $Na_2CO_3(s)$:

$$m_{Na_2CO_3} = n \times M$$

$$= 6.25 \times 10^{-3}\ \cancel{\text{mol}} \times 105.99\ \text{g}/\cancel{\text{mol}}$$

$$= 6.6254 \times 10^{-1}\ \text{g}$$

$$= 6.62 \times 10^{-1}\ \text{g}$$

The mass of sodium carbonate required is 6.62×10^{-1} g.

Check Your Solution

The mass is correctly expressed in grams and shows three significant digits. This answer seems reasonable based upon the mole ratio in the balanced equation and the quantity of reactant that has been given.

25. Practice Problem (page 420)

What is the maximum mass of lead(II) iodide, $PbI_2(s)$, that can precipitate when 40.0 mL of a 0.345 mol/L solution of lead(II) nitrate, $Pb(NO_3)_2(aq)$, is mixed with 85.0 mL of a 0.210 mol/L solution of potassium iodide, KI(aq)? Why might the actual mass precipitated be less?

What Is Required?

You need to the find the maximum mass of lead iodide that will precipitate when solutions of lead(II) nitrate and potassium iodide are mixed.

What Is Given?
You know the volume of the potassium iodide solution: 85.0 mL
You know the concentration of the potassium iodide solution: 0.210 mol/L
You know the volume of the lead(II) nitrate solution: 40.0 mL
You know the concentration of the lead(II) nitrate solution: 0.345 mol/L

Plan Your Strategy
Write the balanced chemical equation for the reaction.
Calculate the amount in moles of each reactant using the relationship the relationship $n = c \times V$.
To allow for the mole ratio of the reactants, divide the amount of each reactant by its coefficient in the chemical equation. The smaller result identifies the limiting reactant.
Use the mole ratio in the balanced equation and the amount in moles of the limiting reactant to find the amount in moles of the precipitate, $PbI_2(s)$.
Determine the molar mass of $PbI_2(s)$.
Calculate the mass of $PbI_2(s)$ using the relationship $m = n \times M$.

Act on Your Strategy
Balanced chemical equation:
$2KI(aq) + Pb(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + PbI_2(s)$

Amount in moles, n, of KI(aq):

$$\begin{aligned} n_{KI} &= c \times V \\ &= 0.210\ \text{mol/}\cancel{\text{L}} \times 0.0850\ \cancel{\text{L}} \\ &= 1.785 \times 10^{-2}\ \text{mol} \end{aligned}$$

Amount in moles, n, of $Pb(NO_3)_2(aq)$:

$$\begin{aligned} n_{Pb(NO_3)_2} &= c \times V \\ &= 0.345\ \text{mol/}\cancel{\text{L}} \times 0.0400\ \cancel{\text{L}} \\ &= 1.380 \times 10^{-2}\ \text{mol} \end{aligned}$$

Identification of limiting reactant:

$$\begin{aligned} \frac{\text{amount of KI}}{\text{coefficient}} &= \frac{1.785 \times 10^{-2}\ \text{mol}}{2} \\ &= 8.925 \times 10^{-3}\ \text{mol} \end{aligned}$$

$$\begin{aligned} \frac{\text{amount of } Pb(NO_3)_2}{\text{coefficient}} &= \frac{1.380 \times 10^{-2}\ \text{mol}}{1} \\ &= 1.380 \times 10^{-2}\ \text{mol} \end{aligned}$$

KI(aq) is the limiting reactant because it is the smaller amount.

Amount in moles, n, of the precipitate, $PbI_2(s)$:

$$\frac{2\ \text{mol KI}}{1\ \text{mol PbI}_2} = \frac{1.785\times10^{-2}\ \text{mol KI}}{n_{PbI_2}}$$

$$n_{PbI_2} = \frac{1\ \text{mol PbI}_2 \times 1.785 \times 10^{-2}\ \cancel{\text{mol KI}}}{2\ \cancel{\text{mol KI}}}$$

$$= 8.925 \times 10^{-3}\ \text{mol}$$

Molar mass, M, of $PbI_2(s)$:

$$M_{PbI_2} = 1M_{Pb} + 2M_I$$

$$= 1(207.2\ \text{g/mol}) + 2(126.90\ \text{g/mol})$$

$$= 461.00\ \text{g/mol}$$

Mass, m, of $PbI_2(s)$:

$$m_{PbI_2} = n \times M$$

$$= 8.925 \times 10^{-3}\ \cancel{\text{mol}} \times 461.00\ \text{g}/\cancel{\text{mol}}$$

$$= 4.1144\ \text{g}$$

$$= 4.11\ \text{g}$$

The maximum mass of lead(II) iodide that precipitates is 4.11 g.

One reason that the mass of $PbI_2(s)$ could be less than this amount is that a small amount of solid lead iodide dissolves. In addition, if the mass of precipitate was obtained by filtering, some of the precipitate could pass through the filter paper with the filtrate, resulting in a lower recovered mass of precipitate.

Check Your Solution

The mass of precipitate seems reasonable compared with the amount in moles of the reactant used in this reaction. The answer correctly shows three significant digits.

Amount in moles, n, of the precipitate, $CaCO_3(s)$:

$$\frac{1 \text{ mol } CaCl_2}{1 \text{ mol } CaCO_3} = \frac{5.000 \times 10^{-3} \text{ mol } CaCl_2}{n_{CaCO_3}}$$

$$n_{CaCO_3} = \frac{1 \text{ mol } CaCO_3 \times 5.000 \times 10^{-3} \cancel{\text{mol } CaCl_2}}{1 \cancel{\text{mol } CaCl_2}}$$

$$= 5.000 \times 10^{-3} \text{ mol}$$

Molar mass, M, of $CaCO_3(s)$:

$$M_{CaCO_3} = 1M_{Ca} + 1M_C + 3M_O$$

$$= 1(40.08 \text{ g/mol}) + 1(12.01 \text{ g/ mol}) + 3(16.00 \text{ g/mol})$$

$$= 100.09 \text{ g / mol}$$

Mass, m, of $CaCO_3(s)$:

$$m_{CaCO_3} = n \times M$$

$$= 5.000 \times 10^{-3} \cancel{\text{mol}} \times 100.09 \text{ g/} \cancel{\text{mol}}$$

$$= 0.500 \text{ g}$$

The mass of calcium carbonate that precipitates is 0.500 g.

Check Your Solution

The mass of precipitate seems reasonable compared with the amount in moles of reactant used. The answer correctly shows three significant digits.

30. Practice Problem (page 420)

Barium chromate, $BaCrO_4(s)$, is an insoluble yellow solid. Determine the concentration of barium ions in a solution made by mixing 50.0 mL of a 0.150 mol/L solution of barium nitrate, $Ba(NO_3)_2(aq)$, with 50.0 mL of a 0.120 mol/L solution of potassium chromate, $K_2CrO_4(aq)$.

What Is Required?

You need to find the concentration of barium ions remaining in a solution.

What Is Given?

You know the volume of the barium nitrate solution: 50.0 mL
You know the concentration of the barium nitrate solution: 0.150 mol/L
You know the volume of the potassium chromate solution: 50.0 mL
You know the concentration of the potassium chromate solution: 0.120 mol/L

Plan Your Strategy

Write the balanced chemical equation for the reaction.
Calculate the amount in moles of each reactant using the relationship $n = c \times V$.
To allow for the mole ratio of the reactants, divide the amount of each reactant by its coefficient in the chemical equation. The smaller result identifies the limiting reactant.
Determine the amount in moles of $Ba(NO_3)_2(aq)$ in excess.
Determine the amount in moles of $Ba^{2+}(aq)$ per mole of $Ba(NO_3)_2(aq)$.
Determine the amount in moles of Ba^{2+} in excess.
Calculate the total volume of the mixture and determine the concentration of $Ba^{2+}(aq)$.

Act on Your Strategy

Balanced equation: $Ba(NO_3)_2(aq) + K_2CrO_4(aq) \rightarrow 2KNO_3(aq) + BaCrO_4(s)$

Mole ratio	1 mole	1 mole	2 mole	1 mole

Amount in moles, n, of $Ba(NO_3)_2(aq)$:

$$n_{Ba(NO_3)_2} = c \times V$$
$$= 0.150 \text{ mol/}\cancel{L} \times 0.0500 \cancel{L}$$
$$= 7.50 \times 10^{-3} \text{ mol}$$

Amount in moles, n, of $K_2CrO_4(aq)$:

$$n_{K_2CrO_4} = c \times V$$
$$= 0.120 \text{ mol/}\cancel{L} \times 0.0500 \cancel{L}$$
$$= 6.00 \times 10^{-3} \text{ mol}$$
$$= 0.120 \text{ mol/}\cancel{L} \times 0.0500 \cancel{L}$$

Identification of the limiting reactant:

$$\frac{\text{amount of } Ba(NO_3)_2}{\text{coefficient}} = \frac{7.50 \times 10^{-3} \text{ mol}}{1}$$
$$= 7.50 \times 10^{-3} \text{ mol}$$

$$\frac{\text{amount of } K_2CrO_4}{\text{coefficient}} = \frac{6.00 \times 10^{-3} \text{ mol}}{1}$$
$$= 6.00 \times 10^{-3} \text{ mol}$$

$Ba(NO_3)_2(aq)$ is the limiting reactant because it is the smaller amount.

Since the mole ratio of $Ba(NO_3)_2(aq)$ to $K_2CrO_4(aq)$ is 1:1, the excess amount in moles, n, of $Ba(NO_3)_2(aq)$ is the difference between the amount in moles of the two reactants.

$$\begin{aligned} n_{\text{excess } Ba(NO_3)_2} &= n_{Ba(NO_3)_2} - n_{K_2CrO_4} \\ &= \left(7.50 \times 10^{-3}\text{mol}\right) - \left(6.00 \times 10^{-3}\text{mol}\right) \\ &= 1.5 \times 10^{-3}\text{ mol} \end{aligned}$$

Amount in moles, n, of $Ba^{2+}(aq)$:

$$\frac{n_{Ba^{2+}}}{1.50 \times 10^{-3}\text{ mol } Ba(NO_3)_2} = \frac{1\text{ mol } Ba^{2+}}{1\text{ mol } Ba(NO_3)_2}$$

$$n_{Ba^{2+}} = \frac{1.50 \times 10^{-3}\text{ mol } \cancel{Ba(NO_3)_2} \times 1\text{ mol } Ba^{2+}}{1\text{ mol } \cancel{Ba(NO_3)_2}}$$

$$= 1.50 \times 10^{-3}\text{ mol}$$

Total volume of mixture:

V = 50.0 mL + 50.0 mL
= 100.0 mL
= 0.100 L

Concentration of $Ba^{2+}(aq)$:

$$c = \frac{n}{V}$$

$$= \frac{1.50 \times 10^{-3}\text{ mol}}{0.100\text{ L}}$$

$$= 1.50 \times 10^{-2}\text{ mol/L}$$

The concentration of barium ions remaining in solution is 1.50×10^{-2} mol/L.

Check Your Solution

The units in the calculations have cancelled properly and the final unit is correct. The concentration of the barium ion in excess seems reasonable. The answer correctly shows three significant digits.