Section 9.2 Solution Stoichiometry

Solutions for Practice Problems

Student Edition page 417

11. Practice Problem (page 417)

If 8.5 g of pure ammonium phosphate, $(NH_4)_3PO_4(s)$, is dissolved in distilled water to make 400 mL of solution, what are the concentrations (in moles per litre) of the ions in the solution?

What Is Required?

You need to find the molar concentration, *c*, of the ions in a solution of ammonium phosphate.

What Is Given?

You know the volume of the ammonium phosphate solution: 400 mL
You know the mass of ammonium phosphate, $(NH_4)_3PO_4(s)$: 8.5 g

Plan Your Strategy

Write the balanced chemical equation for the dissolution of ammonium phosphate, $(NH_4)_3PO_4(s)$.
Determine the molar mass of $(NH_4)_3PO_4(s)$.

Calculate the amount in moles of $(NH_4)_3PO_4(s)$ using the relationship $n = \frac{n}{M}$.

Convert the volume from millilitres to litres: 1 mL = 1×10^{-3} L

Calculate the concentration of $(NH_4)_3PO_4(aq)$ using the relationship $c = \frac{n}{V}$.

Equate the mole ratios and cross multiply to solve for *n*, the amount in moles of $(NH_4)_3PO_4(s)$.

Act on Your Strategy

Balanced equation: $(NH_4)_3PO_4(s) \rightarrow 3NH_4^{+}(aq) + PO_4^{3-}(aq)$
Mole ratio: 1 mole 3 moles 1 mole

Molar mass, *M*, of $(NH_4)_3PO_4(s)$:

$$\begin{aligned}
M_{(NH_4)_3PO_4} &= 3M_N + 12M_H + 1M_P + 4M_O \\
&= 3(14.01\text{g/mol}) + 12(1.01\text{ g/mol}) + 1(30.97\text{ g/mol}) + 4(16.00\text{ g/mol}) \\
&= 149.12\text{ g/mol}
\end{aligned}$$

Amount in moles, n, of $(NH_4)_3PO_4(s)$:

$$n_{(NH_4)_3PO_4} = \frac{m}{M}$$
$$= \frac{8.5 \cancel{g}}{149.12 \cancel{g}/mol}$$
$$= 5.700 \times 10^{-2} mol$$

Amount in moles, n, of $NH_4^+(aq)$:

$$\frac{1 \text{ mol } (NH_4)_3PO_4}{3 \text{ mol } NH_4^+} = \frac{0.005700 \text{ mol } (NH_4)_3PO_4}{n_{NH_4^+}}$$
$$n_{NH_4^+} = \frac{3 \text{ mol } NH_4^+ \times 0.005700 \cancel{\text{mol } (NH_4)_3PO_4}}{1 \cancel{\text{mol } (NH_4)_3PO_4}}$$
$$= 0.0171 \text{ mol}$$

Amount in moles, n, of $PO_4^{3-}(aq)$:

$$\frac{1 \text{ mol } (NH_4)_3PO_4}{1 \text{ mol } PO_4^{3-}} = \frac{0.005700 \text{ mol } (NH_4)_3PO_4}{n_{PO_4^{3-}}}$$
$$n_{PO_4^{3-}} = \frac{1 \text{ mol } PO_4^{3-} \times 0.005700 \cancel{\text{mol } (NH_4)_3PO_4}}{1 \cancel{\text{mol } (NH_4)_3PO_4}}$$
$$= 0.005700 \text{ mol}$$

Volume of solution:

$$V = 400 \cancel{mL} \times 1 \times 10^{-3} \text{ L}/\cancel{mL}$$
$$= 0.400 \text{ L}$$

Concentration of NH_4^+(aq):

$$c = \frac{n}{V}$$
$$= \frac{1.71 \times 10^{-2} \text{ mol}}{0.400 \text{ L}}$$
$$= 0.04275 \text{ mol/L}$$
$$= 0.04 \text{ mol/L}$$

Concentration of $PO_4^{3-}(aq)$:

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

$$= \frac{0.005700 \times 10^{-2}\ \text{mol}}{0.400\ \text{L}}$$

$$= 0.01425\ \text{mol/L}$$

$$= 0.01\ \text{mol/L}$$

The concentration of the ammonium ion, $NH_4^+(aq)$, is 0.04 mol/L.
The concentration of the phosphate ion, $PO_4^{3-}(aq)$, is 0.01 mol/L.

Check Your Solution
The units for amount and concentration are correct. The answer has one significant digit and seems reasonable.

12. Practice Problem (page 417)
A strip of zinc metal was placed in a beaker that contained 120 mL of a solution of copper(II) nitrate, $Cu(NO_3)_2(aq)$. The mass of the copper produced was 0.813 g. Find the initial concentration of the copper(II) nitrate solution.

What Is Required?
You need to find the molar concentration, c, of the copper(II) nitrate solution.

What Is Given?
You know the volume of the copper(II) nitrate solution: 120 mL
You know the mass of copper precipitated: 0.813 g
You know the other reactant: zinc

Plan Your Strategy
Write the chemical equation for the single displacement reaction.
Use the periodic table to determine the atomic molar mass of Cu(s).
Calculate the amount in moles of Cu(s) using the relationship $n = \frac{n}{M}$.
Calculate the amount in moles of copper(II) nitrate using the mole ratio in the balanced equation.
Convert the volume from millilitres to litres: 1 mL = 1×10^{-3} L
Calculate the concentration of copper(II) nitrate using the relationship $c = \frac{n}{V}$.

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

$$\frac{1\ \text{mol FeS}}{1\ \text{mol Fe(NO}_3)_2} = \frac{n_{\text{FeS}}}{0.0125\ \text{mol Fe(NO}_3)_2}$$

$$\begin{aligned} n_{\text{FeS}} &= \frac{1\ \text{mol FeS} \times 0.0125\ \cancel{\text{mol Fe(NO}_3)_2}}{1\ \cancel{\text{mol Fe(NO}_3)_2}} \\ &= 0.0125\ \text{mol} \end{aligned}$$

Molar mass, *M*, of the precipitate, FeS(s):

$$\begin{aligned} M_{\text{FeS}} &= 1M_{\text{Fe}} + 1M_{\text{S}} \\ &= 1(55.85\ \text{g/mol}) + 1(32.07\ \text{g/mol}) \\ &= 87.92\ \text{g/mol} \end{aligned}$$

Mass, *m*, of FeS(s):

$$\begin{aligned} m_{\text{FeS}} &= n \times M \\ &= 0.0125\ \cancel{\text{mol}} \times 87.92\ \text{g/}\cancel{\text{mol}} \\ &= 1.099\ \text{g} \\ &= 1.10\ \text{g} \end{aligned}$$

The precipitate is iron(II) sulfide, FeS(s), and the maximum mass that can be collected from the reaction is 1.10 g.

Check Your Solution
The units for amount and concentration are correct. The answer has three significant digits and seems reasonable.

15. Practice Problem (page 417)
What mass of silver chloride, AgCl(s), can be precipitated from 75 mL of 0.25 mol/L silver nitrate, $AgNO_3$(aq), by adding excess magnesium chloride, $MgCl_2$(aq)?

What Is Required?
You need to calculate the mass of silver chloride that will precipitate in a reaction.

What Is Given?
You know the volume of the silver nitrate solution: 75 mL
You know the initial concentration of silver nitrate: 0.25 mol/L
You know the other reactant is aqueous magnesium chloride, $MgCl_2$(aq).

Plan Your Strategy
Predict the other product that forms in this double displacement reaction.
Write the balanced equation for the reaction.
Convert the volume to litres: 1 mL = 1×10^{-3} L
Calculate the amount in moles of silver nitrate using the relationship $n = c \times V$.
Equate the mole ratios and solve for the amount in moles of precipitate.
Use the periodic table to determine the molar mass of the precipitate.
Calculate the mass of precipitate using the relationship $m = n \times M$.

Act on Your Strategy
The other product is magnesium nitrate, $Mg(NO_3)_2(aq)$.

Balanced equation:	$MgCl_2(aq)$ +	$2AgNO_3(aq)$ →	$Mg(NO_3)_2(aq)$ +	$2AgCl(s)$
Mole ratio:	1 mole	2 moles	1 mole	2 moles

Volume of solution:

$$\begin{aligned} V &= 75\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.075\ \text{L} \end{aligned}$$

Amount in moles, *n*, of $AgNO_3(aq)$:

$$\begin{aligned} n_{AgNO_3} &= c \times V \\ &= 0.25\ \text{mol}/\cancel{\text{L}} \times 0.075\ \cancel{\text{L}} \\ &= 0.01875\ \text{mol} \end{aligned}$$

Amount in moles, *n*, of precipitate, AgCl(s):

$$\frac{2\ \text{mol AgCl}}{2\ \text{mol AgNO}_3} = \frac{n_{AgCl}}{0.01875\ \text{mol AgNO}_3}$$

$$\begin{aligned} n_{AgCl} &= \frac{2\ \text{mol AgCl} \times 0.01875\ \cancel{\text{mol AgNO}_3}}{2\ \cancel{\text{mol AgNO}_3}} \\ &= 0.01875\ \text{mol} \end{aligned}$$

Molar mass, *M*, of the precipitate, AgCl(s):

$$\begin{aligned} M_{AgCl} &= 1M_{Ag} + 1M_{Cl} \\ &= 1(107.87\ \text{g/mol}) + 1(35.45\ \text{g/mol}) \\ &= 143.32\ \text{g/mol} \end{aligned}$$

Mass, *m*, of AgCl(s):

$$m_{AgCl} = n \times M$$
$$= 0.01875\ \cancel{mol} \times 143.32\ g/\cancel{mol}$$
$$= 2.687\ g$$
$$= 2.7\ g$$

The mass of silver chloride that can be precipitated is 2.7 g.

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

16. Practice Problem (page 417)
What mass of bromine gas can be collected by bubbling excess chlorine gas through 850 mL of a 0.350 mol/L solution of sodium bromide, NaBr(aq)?

What Is Required?
You need to calculate the mass of bromine gas that will collect in a reaction.

What Is Given?
You know the volume of the sodium bromide solution: 850 mL
You know the initial concentration of the sodium bromide solution: 0.350 mol/L
You know the other reactant: chlorine gas, Cl_2(aq)

Plan Your Strategy
Predict the name and formula for the other product that forms in this single displacement reaction.
Write the balanced equation for the reaction.
Convert the volume from millilitres to litres: 1 mL = 1×10^{-3} L
Calculate the amount in moles of sodium bromide solution using the relationship $n = c \times V$.
Equate the mole ratios and solve for the amount in moles of bromine gas.
Use the periodic table to determine the molar mass of the bromine gas, Br_2(g).
Calculate the mass of bromine gas using the relationship $m = n \times M$.

Act on Your Strategy
The other product that forms in this single displacement reaction is sodium chloride, NaCl(aq).

Balanced equation:	$Cl_2(g)$ +	$2NaBr(aq) \rightarrow$	$2NaCl(aq)$ +	$Br_2(g)$
Mole ratio:	1 mole	2 moles	2 moles	1 mole

Mass, *m*, of NaCl(s):

$$\begin{aligned} m_{NaCl} &= 0.213508\ \cancel{mol} \times 58.44\ g/\cancel{mol} \\ &= 12.477\ g \\ &= 12.5\ g \end{aligned}$$

The mass of sodium chloride in the 1.0 L volumetric flask is 12.5 g.

Check Your Solution
The units for amount and concentration are correct. The answer has three significant digits and seems reasonable.

20. Practice Problem (page 417)
Food manufacturers sometimes add calcium acetate, $Ca(CH_3COO)_2(s)$, to sauces as a thickening agent. When analyzed, a 250 mL solution of calcium acetate was found to contain 0.200 mol of acetate ions.
a. Find the molar concentration of the calcium acetate solution.
b. What mass of calcium acetate was dissolved to make the solution?

a. molar concentration
What Is Required?
You need to find the molar concentration of a calcium acetate solution.

What Is Given?
You know the chemical formula for calcium acetate: $Ca(CH_3COO)_2(s)$
You know the amount in moles of acetate ions, $CH_3COO^-(aq)$: 0.200 mol
You know the volume of the solution: 250 mL

Plan Your Strategy
Use the mole ratio of acetate ions to calcium acetate to determine the amount in moles of calcium acetate.
Convert the volume from millilitres to litres: 1 mL = 1×10^{-3} L
Calculate the concentration of calcium acetate using the relationship $c = \dfrac{n}{V}$.

Act on Your Strategy
The chemical formula for calcium acetate, $Ca(CH_3COO)_2(s)$, indicates that there are two CH_3COO^- ions for one formula unit of $Ca(CH_3COO)_2(s)$.

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

$$\frac{1\ \text{mol Ca(CH}_3\text{COO)}_2}{2\ \text{mol CH}_3\text{COO}^-} = \frac{n_{\text{Ca(CH}_3\text{COO)}_2}}{0.200\ \text{mol CH}_3\text{COO}^-}$$

$$n_{\text{Ca(CH}_3\text{COO)}_2} = \frac{1\ \text{mol Ca(CH}_3\text{COO)}_2 \times 0.200\ \cancel{\text{mol CH}_3\text{COO}^-}}{2\ \cancel{\text{mol CH}_3\text{COO}^-}}$$

$$= 0.100\ \text{mol}$$

Volume of solution:

$$V = 250\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}}$$
$$= 0.250\ \text{L}$$

Concentration of $Ca(CH_3COO)_2(aq)$:

$$c = \frac{n}{V}$$
$$= \frac{0.100\ \text{mol}}{0.250\ \text{L}}$$
$$= 0.40\ \text{mol/L}$$

The concentration of calcium acetate is 0.40 mol/L.

b. mass of calcium acetate

What Is Required?

You need to find the mass of calcium acetate in 250 mL of solution.

What Is Given?

You know the molar concentration: 0.40 mol/L

You know the volume of solution: 0.250 L

Plan Your Strategy

Calculate the amount in moles of calcium acetate using the relationship the relationship $n = c \times V$.

Use the periodic table to find the molar mass of $Ca(CH_3COO)_2(s)$.

Calculate the mass of calcium acetate using the relationship $m = n \times M$.

Act on Your Strategy

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

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

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

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

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

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

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.