Chemistry 11

Solution Stoichiometry - Answers

1. Mercury salts have a number of important used in industry and in chemical analysis. Because mercury compounds are poisonous, the mercury ions must be removed from the wastewater, this is often accomplished by adding a substance that causes the mercury to precipitate. Calculate the mass of precipitate that forms when 25.0 mL of 0.0850 mol/L sodium sulfide is added to waste water that contains mercury(II) nitrate.

$$Hg(NO_3)_2(aq) + Na_2S(aq) \rightarrow HgS(s) + 2NaNO_3(aq)$$

$$n = CV = (0.0850 \text{ mol/L})(0.0250 \text{ L}) = 0.002125 \text{ mol } Na_2S$$

$$\frac{1 \text{ mol HgS}}{1 \text{ mol } Na_2S} \quad /mol) = 0.494 \text{ g HgS}$$

2. Silver plated tableware is popular because it is less expensive than sterling silver. Silver nitrate solution is used by an electroplating business to replate silver tableware for their customers. To test the purity of the solution, a technician observes 10.00 mL of 0.500 mol/L silver nitrate reacting with an excess quantity of 0.480 mol/L sodium hydroxide solution. Calculate the mass of precipitate that forms.

$$AgNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + AgOH\downarrow$$

$$n = CV = (0.0100 \text{ mol/L})(0.500 \text{ L}) = 0.00500 \text{ mol } AgNO_3$$

$$(0.00500 \text{ mol } AgNO_3)\frac{1 \text{ mol AgOH}}{1 \text{ mol } AgNO_3}(124.87554 \text{ g } /mol) = 0.624 \text{ g AgOH}$$

3. When silver nitrate is added to sodium chromate, a brick-red precipitate forms. Calculate the mass of precipitate that forms when 50.0 mL of 0.100 mol/L silver nitrate is added to excess sodium chromate.

$$2AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow 2NaNO_3(aq) + Ag_2CrO_4\downarrow$$

$$n = CV = (0.100 \text{ mol/L})(0.0500 \text{ L}) = 0.00500 \text{ mol } AgNO_3$$

$$\frac{1 \text{ mol } Ag_2CrO_4}{2 \text{ mol } AgNO_3} \quad /$$

4. Calculate the mass of precipitate that forms when 15.0 mL of 0.250 mol/L sodium hydroxide is added to a solution of aluminum nitrate.

$$3NaOH(aq) + Al(NO_3)_3(aq) \rightarrow 3NaNO_3(aq) + Al(OH)_3 \downarrow$$

$$\mathrm{n} = (0.250\,mol/L)(0.0150L) = 0.00375\,mol\ \mathrm{NaOH}$$

$$(0.00375\,mol\ \mathrm{NaOH})\left(\frac{1\,mol\ \mathrm{Al(OH)_3}}{3\,mol\ \mathrm{NaOH}}\right)(78.00356\,g/mol) = \mathbf{0.0975\ g}\ \mathrm{Al(OH)_3}$$

5. Suppose you want to remove the barium ions from 120.0 mL of a 0.0500 mol/L barium nitrate solution. What is the minimum mass of sodium carbonate that you should add?

$$Ba(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + BaCO_3\downarrow$$

$$\mathrm{n} = (0.0500\,mol/L)(0.1200L) = 0.00600\,mol\ \mathrm{Ba(NO_3)_2}$$

$$(0.00600\,mol\ \mathrm{Ba(NO_3)_2})\left(\frac{1\,mol\ \mathrm{Na_2CO_3}}{1\,mol\ \mathrm{Ba(NO_3)_2}}\right)(105.98874\ g/mol) = \mathbf{0.636\ g}\ \mathbf{Na_2CO_3}$$

6. One method of analyzing for arsenic in a pesticide is to treat the sample chemically to convert the arsenic into soluble sodium arsenate. Then a solution of silver nitrate is added until a precipitate of silver arsenate is no longer formed. If a 1.10 g sample of a pesticide required 23.7 mL of 0.0968 mol/L silver nitrate in a given analysis, what was the percentage of arsenic present in the pesticide?

$$Na_3AsO_4 + 3AgNO_3 \rightarrow Ag_3AsO_4 + 3NaNO_3$$

$$\mathrm{n} = \mathrm{CV} = (0.00968\ \mathrm{mol/L})(0.0237\ \mathrm{L}) = 0.00229\ \mathrm{mol\ AgNO_3}$$

$$\frac{1\ \mathrm{mol\ Na_3AsO_4}}{3\ \mathrm{mol\ AgNO_3}} = 0.000765\ \mathrm{mol\ Na_3AsO_4}$$

Na3AsO4 contains 1 mol of As, $\therefore$ 0.000765 mol Na3AsO4 = 0.000765 mol

As mass = $(0.000765\ \mathrm{mol\ As})(74.9216\ \mathrm{g/mol}) = 0.0573\ \mathrm{g\ As}$

$$\%\ \mathrm{Arsenic} = \frac{\mathrm{mass\ of\ Arsenic}}{\mathrm{mass\ of\ sample}} \times 100 = \frac{0.573\ \mathrm{g\ As}}{1.10\ \mathrm{g}} \times 100 = 5.21\%\ \mathrm{As}$$

7. When a clear, yellow solution of potassium chromate is added to a clear, colourless solution of silver nitrate, a brick-red precipitate forms. A laboratory technician added 30.0 mL of 0.150 mol/L potassium chromate to 45.0 mL of 0.145 mol/L silver nitrate.

   a) Write the chemical equation for the reaction.

   $K_2CrO_4(aq) + 2AgNO_3(aq) \rightarrow 2KNO_3(aq) + Ag_2CrO_4\downarrow$

   b) Perform calculations to show which of the two reagents is limiting.

$$\mathbf{K_2CrO_4} \qquad (0.150\, mol/L)(0.0300\, L) = 0.00450 \text{ mol } K_2CrO_4$$

$$(0.00450\, mol \text{ } K_2CrO_4)\left(\frac{1 \text{ mol } Ag_2CrO_4}{1 \text{ mol } K_2CrO_4}\right) = 0.00450 \text{ mol } Ag_2CrO_4$$

$$\mathbf{AgNO_3} \qquad (0.145\, mol/L)(0.0450\, L) = 0.006525 \text{ mol } AgNO_3$$

$$(0.006525 \text{ mol } AgNO_3)\left(\frac{1 \text{ mol } Ag_2CrO_4}{2 \text{ mol } K_2CrO_4}\right) = 0.0032625 \text{ mol } Ag_2CrO_4$$

   The AgNO3 is consumed first, therefore the **AgNO3 is the limiting reactant**.

   c) Calculate the theoretical yield of the precipitate in grams.

$$\text{Theoretical Yield} = (0.0032625 \text{ mol } Ag_2CrO_4)(169.8731\; g/mol) = \mathbf{0.554\; g\;\; Ag_2CrO_4}$$

   d) Only 0.220 g of dry precipitate is collected. What is the percent yield of the reaction?

$$\% \text{ Yield} = \frac{0.220\; g}{0.554\; g} \times 100 = \mathbf{39.7\%}$$

8. In an experiment, Kendra mixed 40.0 mL of 0.552 mol/L lead(II) nitrate with 50.0 mL of 1.22 mol/L hydrochloric acid. A white precipitate forms, which Kendra filtered and dried. She determined the mass of the precipitate to be 5.012 g.

a) Write the chemical equation for the reaction.

$Pb(NO_3)_2(aq) + 2HCl(aq) \rightarrow 2HNO_3(aq) + PbCl_2\downarrow$

b) What is the formula of the precipitate that formed? $PbCl_2$

c) Which is the limiting reactant?

$$\mathbf{PbNO_3} \qquad (0.552\ mol/L)(0.0400\ L) = 0.02208\ \text{mol PbNO}_3$$

$$(0.02208\ mol\ \text{K}_2\text{CrO}_4)\left(\frac{1\ \text{mol PbCl}_2}{1\ \text{mol PbNO}_3}\right) = 0.02208\ \text{mol PbCl}_2$$

$$\mathbf{HCl} \qquad (1.22\ mol/L)(0.0500\ L) = 0.0610\ \text{mol HCl}$$

$$(0.0610\ \text{mol HCl})\left(\frac{1\ \text{mol PbCl}_2}{2\ \text{mol HCl}}\right) = 0.0305\ \text{mol PbCl}_2$$

The $PbNO_3$ is consumed first, therefore the **$PbNO_3$ is the limiting reactant**.

d) What is the theoretical yield?

$$\text{Theoretical Yield} = (0.02208\ \text{mol PbCl}_2)(278.106\ g/mol) = \mathbf{6.14\ g\ PbCl_2}$$

e) Calculate the percentage yield.

$$\%\ \text{Yield} = \frac{5.012\ g}{6.14\ g} \times 100 = \mathbf{81.6\%}$$