SECTION 9.2

Solution Stoichiometry

Cookbook recipes involve chemistry. If you bake a cake, you need to assemble the ingredients, which are the reactants, in the correct quantities. If you add too little baking powder, the cake will not rise properly, as shown in **Figure 9.7**. If you add too much baking powder, the cake may be too crumbly. Similarly, for some chemical reactions, the proportions of the reactants are critical. Chemists and chemical engineers use stoichiometry calculations to determine the quantities they need for chemical reactions. In **solution stoichiometry**, known volumes and concentrations of reactants or products are used to determine the volumes, concentrations, or masses of other reactants or products.

Key Terms

solution stoichiometry
quantitative analysis

solution stoichiometry stoichiometry that is applied to substances in solutions

quantitative analysis an analysis that determines how much of a substance is in a sample

Figure 9.7 Accurate measurement is important in both cooking and chemistry. A cake made from improperly measured ingredients may not look good and may not taste good either!

Solution stoichiometry is often used in **quantitative analysis**, which involves determining how much of a substance is present in a sample. To solve solution stoichiometry problems, you need to use the same strategies you learned in Chapter 7. The rules below outline how to apply these strategies to reactants and products in solutions.

Rules for Solving Solution Stoichiometry Problems

1. Always use a balanced equation: either the balanced chemical equation or the net ionic equation. If a precipitate forms as the result of the reaction, the net ionic equation may be easier to use.
2. The concentration in moles per litre, c, the amount of a given substance in moles, n, and the volume of the solution in litres, V, are related by the following equation:
$$c = \frac{n}{V}$$
Thus, the amount of a substance is given by the equation $n = c \times V$.
3. Use the coefficients in the balanced net ionic equation (or the balanced chemical equation) to write the known mole ratio of the substances. Equate the known mole ratio to the mole ratio of the other substances in the reaction, which includes an unknown quantity. Then solve for the unknown quantity.

Sample Problem

Concentration of a Solution from the Mass of the Precipitate

Problem

A student carefully measured 100 mL of a silver nitrate solution, $AgNO_3$(aq), of unknown concentration. The student poured the solution into a beaker, added a coil of copper, and left the mixture for several days. When the reaction was complete, the student carefully scraped the silver from the copper wire and filtered the solution to obtain all the silver. The dry precipitate had a mass of 1.65 g. What was the molar concentration of the silver nitrate solution?

What Is Required?

You need to find the molar concentration, c, of the silver nitrate solution.

What Is Given?

You know the volume of the silver nitrate solution: 100 mL
You know the mass of silver precipitated: 1.65 g

Plan Your Strategy	Act on Your Strategy
Write the chemical equation for the single displacement reaction.	$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$
Look up the molar mass of silver in the periodic table, and use it to calculate the amount in moles of silver precipitated.	$M = 107.87$ g/mol amount of Ag $= 1.65\ g \times \frac{1\ mol}{107.87\ g} = 0.015\ 296$ mol
Equate the mole ratios and cross multiply to solve for n, the amount in moles of silver nitrate.	$\frac{2\ mol\ AgNO_3}{2\ mol\ Ag} = \frac{n}{0.015\ 296\ mol\ Ag}$ $n = \frac{2\ mol\ AgNO_3 \times 0.015\ 296\ \cancel{mol\ Ag}}{2\ \cancel{mol\ Ag}} = 0.015\ 296\ mol\ AgNO_3$
Calculate the concentration of silver nitrate.	$c = \frac{n}{v} = \frac{0.015\ 296\ mol}{100\ mL} = \frac{0.015\ 296\ mol}{0.100\ L} = 0.153$ mol/L The molar concentration of the silver nitrate solution was 0.153 mol/L.

Check Your Solution

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

Sample Problem

Concentration of Ions from the Mass of the Precipitate

Problem

When excess aqueous lead(II) nitrate, $Pb(NO_3)_2$(aq), was added to 125 mL of a solution of sodium iodide, NaI(aq), a bright yellow precipitate of lead(II) iodide formed. The dry precipitate had a mass of 4.13 g. What was the concentration of iodide ions in the solution of sodium iodide?

What Is Required?

You need to find the initial concentration of iodide ions in the sodium iodide solution.

What Is Given?

You know the volume of the sodium iodide solution: 125 mL
You know the mass of lead(II) iodide that was precipitated: 4.13 g

Plan Your Strategy	Act on Your Strategy
Write the net ionic equation for the double displacement reaction.	$Pb(NO_3)_2(aq) + 2NaI(aq) \longrightarrow PbI_2(s) + 2NaNO_3(aq)$ $Pb^{2+}(aq) + \cancel{2NO_3^-(aq)} + \cancel{2Na^+(aq)} + 2I^-(aq) \longrightarrow PbI_2(s) + \cancel{2Na^+(aq)} + \cancel{2NO_3^-(aq)}$ $Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI_2(s)$
Calculate the molar mass of lead(II) iodide, and use it to find the amount in moles of precipitate.	$M = M_{Pb} + 2M_I = 207.2\text{ g/mol} + 2(126.90\text{ g/mol})$ $= 461.0\text{ g/mol}$ amount of $PbI_2 = 4.13\text{ g} \times \frac{1\text{ mol}}{461.0\text{ g}} = 0.008\,958\,8\text{ mol}$
Equate the mole ratios and solve for n, the amount in moles of iodide ions, $I^-(aq)$.	$\frac{2\text{ mol I}^-}{1\text{ mol PbI}_2} = \frac{n}{0.008\,958\,8\text{ mol PbI}_2}$ $n = \frac{2\text{ mol I}^- \times 0.008\,958\,8\ \cancel{\text{mol PbI}_2}}{1\ \cancel{\text{mol PbI}_2}} = 0.017\,918\text{ mol I}^-$
Calculate the concentration of iodide ions.	$c = \frac{n}{V} = \frac{0.017\,918\text{ mol}}{125\text{ mL}} = \frac{0.017\,918\text{ mol}}{0.125\text{ L}} = 0.143\text{ mol/L}$ The concentration of iodide ions was 0.143 mol/L.

Check Your Solution

The units for amount and concentration are correct. The answer has three significant digits and appears to be reasonable.

Practice Problems

11. 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?

12. 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 solution of copper(II) nitrate.

13. When 75.0 mL of silver nitrate, $AgNO_3(aq)$, was treated with excess ammonium carbonate, $(NH_4)_2CO_3(aq)$, 2.47 g of dry precipitate was recovered. Write the net ionic equation for the reaction, and calculate the concentration of the original silver nitrate solution.

14. When an excess of sodium sulfide, $Na_2S(aq)$, was added to 125 mL of 0.100 mol/L iron(II) nitrate, $Fe(NO_3)_2(aq)$, a black precipitate formed. Identify the precipitate, and calculate the maximum mass of precipitate that can be collected from the reaction.

15. 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, $MgCl_2(aq)$?

16. 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, $NaBr(aq)$?

17. What mass of strontium carbonate, $SrCO_3(s)$, can be precipitated from 50.0 mL of 0.165 mol/L strontium nitrate, $Sr(NO_3)_2(aq)$, by adding excess sodium carbonate, $NaCO_3(aq)$?

18. Before it was banned in the 1970s due to its non-selective toxicity, thallium(I) sulfate, $Tl_2SO_4(s)$, was the active ingredient in some pesticides. A chemist measured 100.0 mL of a solution of thallium(I) sulfate and added excess aqueous potassium iodide to precipitate yellow thallium(I) iodide, $TlI(s)$. The mass of the dry precipitate was 2.45 g. Find the molar concentration of the thallium(I) sulfate solution.

19. A sample of a substance known to contain chloride ions was dissolved in distilled water in a 1 L volumetric flask. Then 25.00 mL of this solution was treated with excess silver nitrate, $AgNO_3(aq)$. The precipitate of silver chloride, $AgCl(s)$, was filtered and dried. The mass of the dry precipitate was 0.765 g.

a. Calculate the concentration of chloride ions.

b. If the original substance was sodium chloride, $NaCl(s)$, what mass of it was dissolved in the volumetric flask?

20. 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?

Limiting Reactant Problems

Suggested Investigation

Plan Your Own Investigation 9-B, Determining the Mass Percent Composition of a Mixture

The amount of any product in a chemical reaction is determined by the amount of the reactant that is completely consumed. In industrial chemical processes, the most expensive reactant is usually the limiting reactant, in order to minimize costs. In Chapter 7, you learned how to solve limiting reactant problems by using information about the reactants to determine which reactant is limiting. In solution stoichiometry, you usually find the amount of a reactant in moles, given the volume and concentration of the solution, and then find the limiting reactant.

Learning Check

7. Write an equation for molar concentration, *c*. Explain what each variable in the equation represents.

8. Why is a balanced chemical or net ionic equation essential for a stoichiometric calculation?

9. What information do you need if you want to convert a mass/volume percent concentration to a molar concentration?

10. What is a limiting reactant?

11. For some solutions of ionic compounds, the molar concentration of each ion is equal to the molar concentration of the compound. What can you infer about the charges on the ions in these solutions?

12. Explain what stoichiometric calculations for solutions have in common with the stoichiometric calculations in Chapter 7.

Sample Problem

Limiting Reactant and Mass of Precipitate

Problem

In one process for water purification, aluminum sulfate, $Al_2(SO_4)_3(aq)$, reacts with calcium hydroxide, $Ca(OH)_2(aq)$, to form a precipitate of aluminum hydroxide, $Al(OH)_3(s)$. Bacteria and dirt particles that were suspended in the impure water stick to the precipitate as it settles out of solution. Find the mass of aluminum hydroxide that precipitates when 20.0 mL of 0.0150 mol/L aqueous aluminum sulfate is mixed with 30.0 mL of 0.0185 mol/L aqueous calcium hydroxide.

What Is Required?

You need to find the mass of the aluminum hydroxide precipitate.

What Is Given?

You know the volume of the aluminum sulfate solution: 20.0 mL
You know the concentration of the aluminum sulfate solution: 0.0150 mol/L
You know the volume of the calcium hydroxide solution: 30.0 mL
You know the concentration of the calcium hydroxide solution: 0.0185 mol/L

Plan Your Strategy	Act on Your Strategy
Write the chemical equation for the reaction.	$Al_2(SO_4)_3(aq) + 3Ca(OH)_2(aq) \rightarrow 2Al(OH)_3(s) + 3CaSO_4(aq)$
Calculate the amount in moles of each reactant.	$n = cV$ amount of $Al_2(SO_4)_3(aq) = 0.0150\text{ mol/L} \times 0.0200\text{ L}$ $= 3.00 \times 10^{-4}\text{ mol}$ amount of $Ca(OH)_2(aq) = 0.0185\text{ mol/L} \times 0.0300\text{ L}$ $= 5.55 \times 10^{-4}\text{ mol}$
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.	$\frac{\text{amount of } Al_2(SO_4)_3}{\text{coefficient}} = \frac{3.00 \times 10^{-4}\text{ mol}}{1}$ $= 3.00 \times 10^{-4}\text{ mol}$ $\frac{\text{amount of } Ca(OH)_2}{\text{coefficient}} = \frac{5.55 \times 10^{-4}\text{ mol}}{3}$ $= 1.85 \times 10^{-4}\text{ mol}$ $Ca(OH)_2(aq)$ is the limiting reactant because it is the smaller amount.

Use the mole ratio of calcium hydroxide and aluminum hydroxide and the amount of calcium hydroxide to find n, the amount of precipitate.	$\frac{3\text{ mol Ca(OH)}_2}{2\text{ mol Al(OH)}_3} = \frac{5.55 \times 10^{-4}\text{ mol Ca(OH)}_2}{n}$ $n = \frac{2\text{ mol Al(OH)}_3 \times 5.55 \times 10^{-4}\cancel{\text{ mol Ca(OH)}_2}}{3\cancel{\text{ mol Ca(OH)}_2}} = 3.70 \times 10^{-4}\text{ mol Al(OH)}_3$
Calculate the molar mass of aluminum hydroxide, and use it to find the mass, m, of the precipitate.	$M_{Al(OH)_3} = 26.98\text{ g/mol} + 3(16.00\text{ g/mol}) + 3(1.01\text{ g/mol}) = 78.01\text{ g/mol}$ $m = nM = 3.70 \times 10^{-4}\cancel{\text{ mol}} \times 78.01\text{ g/}\cancel{\text{mol}} = 0.0289\text{ g}$ The mass of aluminum hydroxide precipitate is 0.0289 g.

Check Your Solution

The mass is in grams and appears reasonable. It has the correct number of significant digits.

Sample Problem

Finding the Minimum Volume for a Complete Reaction

Problem

A kidney stone is a hard mass that can form in the kidneys or urinary tract. The most common type of kidney stone contains primarily calcium oxalate, $CaC_2O_4(s)$. A chemist wants to react 60.0 mL of 0.135 mol/L sodium oxalate, $Na_2C_2O_4(aq)$, with 0.226 mol/L calcium chloride, $CaCl_2(aq)$, to precipitate calcium oxalate. What is the minimum volume of calcium chloride solution required? What mass of calcium oxalate will be precipitated?

What Is Required?

You need to find the volume of calcium chloride solution that is needed for a complete reaction and the mass of calcium oxalate that will be precipitated.

What Is Given?

You know the volume, V_1, of the sodium oxalate solution: 60.0 mL
You know the concentration, c_1, of the sodium oxalate solution: 0.135 mol/L
You know the concentration, c_2, of the calcium chloride solution: 0.226 mol/L

Plan Your Strategy	Act on Your Strategy
Write the chemical equation for the reaction.	$Na_2C_2O_4(aq) + CaCl_2(aq) \rightarrow CaC_2O_4(s) + 2NaCl(aq)$
Find n_1, the amount of sodium oxalate.	$n_1 = c_1 \times V_1 = 0.135\text{ mol/L} \times 0.0600\text{ L} = 0.008\ 10\text{ mol}$
Use the mole ratio of the reactants to find n_2, the amount of calcium chloride solution that is required for a complete reaction.	$\frac{1\text{ mol Na}_2\text{C}_2\text{O}_4}{1\text{ mol CaCl}_2} = \frac{0.008\ 10\text{ mol Na}_2\text{C}_2\text{O}_4}{n_2}$ $n_2 = \frac{1\text{ mol CaCl}_2 \times 0.008\ 10\cancel{\text{ mol Na}_2\text{C}_2\text{O}_4}}{1\cancel{\text{ mol Na}_2\text{C}_2\text{O}_4}} = 0.008\ 10\text{ mol CaCl}_2$
Use the known amount and concentration of the calcium chloride solution to find V_2, the volume that is needed.	$V_2 = \frac{n_2}{c_2} = \frac{0.008\ 10\text{ mol}}{0.226\text{ mol/L}} = 0.035\ 84\text{ L} = 35.8\text{ mL}$
Use mole ratios to find $n_{CaC_2O_4}$, the amount of calcium oxalate that will be precipitated.	$\frac{1\text{ mol Na}_2\text{C}_2\text{O}_4}{1\text{ mol CaC}_2\text{O}_4} = \frac{0.00810\text{ mol Na}_2\text{C}_2\text{O}_4}{n_3}$ $n_{(CaC_2O_4)_2} = \frac{1\text{ mol CaC}_2\text{O}_4 \times 0.008\ 10\cancel{\text{ mol Na}_2\text{C}_2\text{O}_4}}{1\cancel{\text{ mol Na}_2\text{C}_2\text{O}_4}} = 0.008\ 10\text{ ml CaC}_2\text{O}_4$
Find the molar mass of calcium oxalate.	$M_{CaC_2O_4} = M_{Ca} + 2M_C + 4M_O$ $= 40.08\text{ g/mol} + 2(12.01\text{ g/mol} + 4(16.00\text{ g/mol}) = 128.1\text{ g/mol}$
Use the amount of calcium oxalate and the molar mass to calculate the mass, m, of the precipitate.	$m = nM = 0.008\ 10\cancel{\text{ mol}} \times 128.1\text{ g/}\cancel{\text{mol}} = 1.04\text{ g}$ Therefore, 1.04 g of calcium oxalate will be precipitated.

Check Your Solution

The volume is in millilitres, and it appears reasonable compared with the volume of the other reactant. The mass of the precipitate also seems reasonable.

Practice Problems

21. 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, $Pb(NO_3)_2(aq)$.

22. Silver chromate, $Ag_2CrO_4(s)$, is a brick-red insoluble substance that is used to stain neurons so 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 sodium chromate.

23. Mercury compounds are poisonous, but mercury ions can be removed from a solution by precipitating insoluble mercury (II) sulfide, HgS(s). Determine the minimum volume of 0.0783 mol/L sodium sulfide, $Na_2S(aq)$, that is needed to precipitate all the mercury ions in 75.5 mL of 0.100 mol/L, $Hg(NO_3)_2(aq)$.

24. What is the minimum mass of sodium carbonate, $NaCO_3(s)$, that is needed to precipitate all the barium ions from 50.0 mL of 0.125 mol/L barium nitrate, $Ba(NO_3)_2(aq)$?

25. 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?

26. Carbonates react with dilute hydrochloric acid to generate carbon dioxide gas. What volume of 2.00 mol/L hydrochloric acid is needed to react with 3.35 g of calcium carbonate?

27. A 15.8 g strip of zinc metal was placed in 100.0 mL of silver nitrate, $AgNO_3(aq)$. When the reaction was complete, the strip of zinc had a mass of 13.1 g. What was the concentration of the silver nitrate solution?

28. Vinegar is an aqueous solution of acetic acid, $CH_3COOH(aq)$. What volume of 1.07 mol/L aqueous sodium hydroxide will completely react with 25.0 mL of 0.833 mol/L household vinegar?

29. Before toothpaste was invented, people sometimes used calcium carbonate, $CaCO_3(s)$, to clean their teeth. What mass of calcium carbonate can be precipitated by reacting 80.0 mL of a 0.100 mol/L solution of sodium carbonate, $Na_2CO_3(aq)$, with 50.0 mL of a 0.100 mol/L solution of calcium chloride, $CaCl_2(aq)$?

30. 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, $K_2CrO_4(aq)$.

Solution Stoichiometry versus Other Types of Stoichiometry

The purpose of solution stoichiometry is the same as the purpose of other types of stoichiometry: to determine the quantities involved in chemical reactions. Both kinds of stoichiometry can be used to calculate quantities of reactants or products, to identify limiting reactants and excess reactants, and to determine reaction yields. Solution stoichiometry differs only because the calculations involve concentrations and volumes. However, if you have the concentration and volume of a solution in a stoichiometry problem, you can find the amount (in moles) of a reactant or product involved in the given reaction. Once you find the amount of a substance, you can solve the problem like any other stoichiometry problem.

Section 9.2 REVIEW

Section Summary

- In solution stoichiometry, known volumes and concentrations of reactants or products are used to determine the volumes, concentrations, or masses of other reactants or products.
- The solution to a stoichiometry problem should always include a balanced chemical equation or the net ionic equation.

Review Questions

1. K/U Which solution has the greater concentration of chloride ions: 0.10 mol/L magnesium chloride, $MgCl_2$(aq), or 0.15 mol/L sodium chloride, NaCl(aq)? Explain your reasoning.
2. T/I Calculate the molar concentration of iodide ions in each aqueous solution.
   a. 15.0 g of potassium iodide dissolved in 200 mL of solution
   b. 12.0 g of calcium iodide dissolved in 180 mL of solution
3. T/I What is the minimum volume of 0.220 mol/L calcium chloride, $CaCl_2$(aq), that is needed to precipitate all the silver ions in 110 mL of 0.166 mol/L silver nitrate, $AgNO_3$(aq)?
4. T/I Lead(II) acetate is a poisonous compound. It is used as a colour additive in hair dyes. What volume of 1.25 mol/L lead(II) acetate, $Pb(CH_3COO)_2$(aq), contains 0.500 mol of lead(II) ions, Pb^{2+}(aq)?
5. T/I A piece of iron was added to a beaker that contained 0.585 mol/L copper(II) sulfate, $CuSO_4$(aq). The solid copper that precipitated was dried, and its mass was found to be 5.02 g. Some unreacted iron remained in the beaker. Calculate the minimum volume of the copper(II) sulfate solution.
6. T/I To generate hydrogen gas, a teacher added 25.0 g of mossy zinc to 220 mL of 3.00 mol/L hydrochloric acid in an Erlenmeyer flask.
   a. What mass of hydrogen gas was generated?
   b. After the reaction, what was the concentration of zinc chloride, $ZnCl_2$(aq), in the flask?
7. A A type of stomach medication is a tablet that contains a mixture of 1.00 g of sodium hydrogen carbonate, $NaHCO_3$(s), and 1.00 g of citric acid, $H_3C_6H_5O_7$(s). When dropped into water, the chemicals in the tablet react to produce carbon dioxide gas:
   $$3NaHCO_3(aq) + H_3C_6H_5O_7(aq) \rightarrow 3CO_2(g) + 3H_2O(\ell) + Na_3C_6H_5O_7(aq)$$
   a. Which substance is in excess?
   b. What mass of this substance remains unreacted when the tablet is dropped into a glass of water?
8. T/I When 50 mL of 0.20 mol/L sodium sulfate, Na_2SO_4(aq), was mixed with 80 mL of 0.10 mol/L lead(II) acetate, $Pb(CH_3COO)_2$(aq), a white precipitate formed. Identify the precipitate, and calculate the maximum mass of dry solid that can be collected.
9. T/I To measure the concentration of copper(II) sulfate in the water discharged from an industrial plant, a chemist measured 600 mL of the water and then added excess aqueous sodium sulfide. When dried, the precipitate of copper(II) sulfide, CuS(s), had a mass of 0.125 g. Calculate the molar concentration of copper ions in the water sample.
10. T/I Mixing solutions of calcium chloride, $CaCl_2$(aq), and potassium carbonate , K_2CO_3(aq), will cause calcium carbonate, $CaCO_3$(s), to precipitate. Suppose that you have the following solutions available: 0.500 mol/L $CaCl_2$(aq) and 1.00 mol/L K_2CO_3(aq). What volume of each solution should be mixed together to form 10.0 g of calcium carbonate?
11. C Suppose that you are given a white powder, known to contain a mixture of an alkali metal carbonate and magnesium carbonate, $Mg(CO_3)_2$(s). Outline the procedure you would use to identify the unknown alkali metal and determine the percent by mass of the alkali metal carbonate in the mixture.
12. A Lead poisoning can have long-lasting effects. One of the most effective treatments for lead poisoning is the ion called $EDTA^{4-}$, which stands for ethylenediaminetetraacetate. $EDTA^{4-}$ ions bond to lead(II) ions in a 1:1 ratio. A doctor determines that a child's blood has a dangerously high concentration of 1.0×10^{-5} mol/L of lead(II) ions. The doctor estimates that the child's total blood volume is about 1.6 L. Find the minimum volume of a 0.025 mol/L solution of $EDTA^{4-}$ ions that is needed to treat the child.
13. A Suppose that you need to determine the concentration of copper(II) ions in a sample of waste water by precipitating the metal ion. Outline a procedure you could use, and describe factors that could affect the accuracy of your measurements.