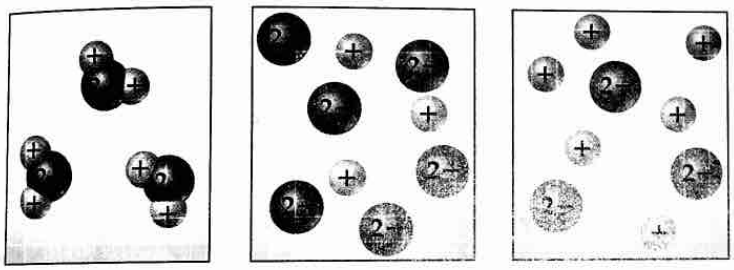
The products of these displacement reactions are always an element (H_2 or a metal) and a salt. Comparing such reactions allows us to rank metals according to their ease of oxidation. A list of metals arranged in order of decreasing ease of oxidation is called an **activity series**. Any metal on the list can be oxidized by ions of metals (or H^+) below it in the series.

Section 4.5 The composition of a solution expresses the relative quantities of solvent and solutes that it contains. One of the common ways to express the **concentration** of a solute in a solution is in terms of molarity. The **molarity** of a solution is the number of moles of solute per liter of solution. Molarity makes it possible to interconvert solution volume and number of moles of solute. Solutions of known molarity can be formed either by weighing out the solute and diluting it to a known volume or by the **dilution** of a more concentrated solution of known concentration (a stock solution). Adding solvent to the solution (the process of dilution) decreases the concentration of the solute without changing the number of moles of solute in the solution ($M_{conc} \times V_{conc} = M_{dil} \times V_{dil}$).

Section 4.6 In the process called **titration**, we combine a solution of known concentration (a **standard solution**) with a solution of unknown concentration in order to determine the unknown concentration or the quantity of solute in the unknown. The point in the titration at which stoichiometrically equivalent quantities of reactants are brought together is called the **equivalence point**. An **indicator** can be used to show the end point of the titration, which coincides closely with the equivalence point.

VISUALIZING CONCEPTS

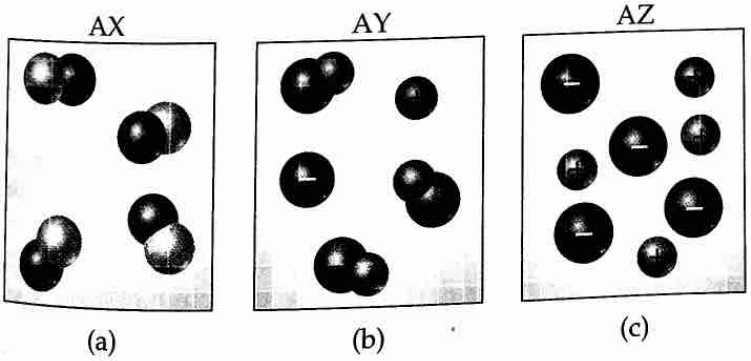
4.1 Which of the following schematic drawings best describes a solution of Li_2SO_4 in water (water molecules not shown for simplicity)? [Section 4.1]



(a) (b) (c)

4.2 Methanol, CH_3OH, and hydrogen chloride, HCl, are both molecular substances, yet an aqueous solution of methanol does not conduct an electrical current, whereas a solution of HCl does conduct. Account for this difference. [Section 4.1]

4.3 Aqueous solutions of three different substances, AX, AY, and AZ, are represented by the three diagrams below. Identify each substance as a strong electrolyte, weak electrolyte, or nonelectrolyte. [Section 4.1]



(a) (b) (c)

4.4 A 0.1 *M* solution of acetic acid, $HC_2H_3O_2$, causes the lightbulb in the apparatus of Figure 4.2 to glow about as brightly as a 0.001 *M* solution of HBr. How do you account for this fact? [Section 4.1]

4.5 You are presented with three white solids, A, B and C, which are glucose (a sugar substance), NaOH, and AgBr. Solid A dissolves in water to form a conducting solution. B is not soluble in water. C dissolves in water to form a nonconducting solution. Identify A, B and C. [Section 4.2]

4.6 We have seen that ions in aqueous solution are stabilized by the attractions between the ions and the water molecules. Why then do some pairs of ions in solution form precipitates? [Section 4.2]

4.7 Which of the following ions will *always* be a spectator ion in a precipitation reaction? **(a)** Cl^-, **(b)** NO_3^-, **(c)** NH_4^+, **(d)** S^{2-}, **(e)** SO_4^{2-}. Explain briefly. [Section 4.2]

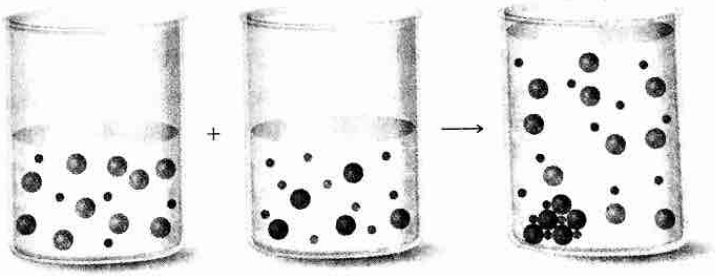
4.8 The labels have fallen off two bottles, one containing $Mg(NO_3)_2$ and the other containing $Pb(NO_3)_2$. You have a bottle of dilute H_2SO_4. How could you use it to test a portion of each solution to identify which solution is which? [Section 4.2]

4.9 Which of the following chemical equations is represented schematically in the drawing below? [Section 4.2]

(a) $BaCl_2(aq) + Na_2(SO)_4(aq) \longrightarrow BaSO_4(s) + 2\,NaCl(aq)$

(b) $SrCO_3(s) + 2\,HBr(aq) \longrightarrow SrBr_2(aq) + H_2O(l) + CO_2(g)$

(c) $2\,NaOH(aq) + CdCl_2(aq) \longrightarrow Cd(OH)_2(s) + 2\,NaCl(aq)$

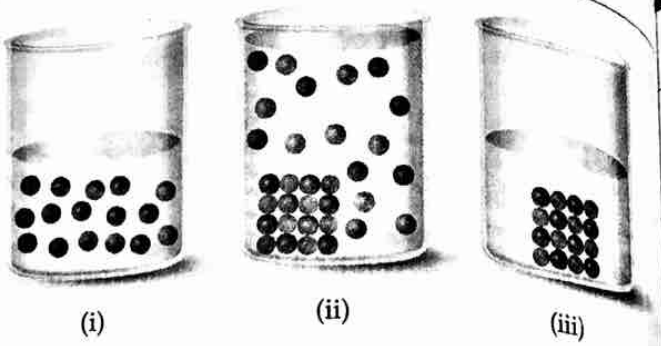


4.10 Which of the three solutions shown schematically to the right corresponds to the result of each of the following reactions: (Water molecules are excluded for clarity) [Section 4.3]

(a) $Ag_2O(s) + 2\,HCl(aq) \longrightarrow 2\,AgCl(s) + H_2O(l)$

(b) $NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$

(c) $AgNO_3(aq) + KCl(aq) \longrightarrow AgCl(s) + KCl(aq)$



(i) (ii) (iii)

EXERCISES

Electrolytes

4.11 When asked what causes electrolyte solutions to conduct electricity, a student responds that it is due to the movement of electrons through the solution. Is the student correct? If not, what is the correct response?

4.12 When methanol, CH_3OH, is dissolved in water, a nonconducting solution results. When acetic acid, $HC_2H_3O_2$, dissolves in water, the solution is weakly conducting and acidic in nature. Describe what happens upon dissolution in the two cases, and account for the different results.

4.13 We have learned in this chapter that many ionic solids dissolve in water as strong electrolytes, that is, as separated ions in solution. What properties of water facilitate this process?

4.14 What does it mean to say that ions are hydrated when an ionic substance dissolves in water?

4.15 Specify what ions are present in solution upon dissolving each of the following substances in water: **(a)** $ZnCl_2$, **(b)** HNO_3, **(c)** $(NH_4)_2SO_4$, **(d)** $Ca(OH)_2$.

4.16 Specify what ions are present upon dissolving each of the following substances in water: **(a)** MgI_2, **(b)** $Al(NO_3)_3$, **(c)** $HClO_4$, **(d)** $KC_2H_3O_2$.

4.17 Formic acid, $HCHO_2$, is a weak electrolyte. What solute particles are present in an aqueous solution of this compound? Write the chemical equation for the ionization of $HCHO_2$.

4.18 Acetone, CH_3COCH_3, is a nonelectrolyte; hypochlorous acid, HClO, is a weak electrolyte; and ammonium chloride, NH_4Cl, is a strong electrolyte. **(a)** What are the solute particles present in aqueous solutions of each compound? **(b)** If 0.1 mol of each compound is dissolved in solution, which one contains 0.2 mol of solute particles, which contains 0.1 mol of solute particles, and which contains somewhere between 0.1 and 0.2 mol of solute particles?

Precipitation Reactions and Net Ionic Equations

4.19 Using solubility guidelines, predict whether each of the following compounds is soluble or insoluble in water: **(a)** $NiCl_2$, **(b)** Ag_2S, **(c)** Cs_3PO_4, **(d)** $SrCO_3$, **(e)** $PbSO_4$.

4.20 Predict whether each of the following compounds is soluble in water: **(a)** $Ni(OH)_2$, **(b)** $PbBr_2$, **(c)** $Ba(NO_3)_2$, **(d)** $AlPO_4$, **(e)** $AgC_2H_3O_2$.

4.21 Will precipitation occur when the following solutions are mixed? If so, write a balanced chemical equation for the reaction. **(a)** Na_2CO_3 and $AgNO_3$, **(b)** $NaNO_3$ and $NiSO_4$, **(c)** $FeSO_4$ and $Pb(NO_3)_2$.

4.22 Identify the precipitate (if any) that forms when the following solutions are mixed, and write a balanced equation for each reaction. **(a)** $Ni(NO_3)_2$ and NaOH, **(b)** NaOH and K_2SO_4, **(c)** Na_2S and $Cu(C_2H_3O_2)_2$.

4.23 Name the spectator ions in any reactions that may be involved when each of the following pairs of solutions are mixed.

(a) $Na_2CO_3(aq)$ and $MgSO_4(aq)$

(b) $Pb(NO_3)_2(aq)$ and $Na_2S(aq)$

(c) $(NH_4)_3PO_4(aq)$ and $CaCl_2(aq)$

4.24 Write balanced net ionic equations for the reactions that occur in each of the following cases. Identify the spectator ion or ions in each reaction.

(a) $Cr_2(SO_4)_3(aq) + (NH_4)_2CO_3(aq) \longrightarrow$

(b) $Ba(NO_3)_2(aq) + K_2SO_4(aq) \longrightarrow$

(c) $Fe(NO_3)_2(aq) + KOH(aq) \longrightarrow$

4.25 Separate samples of a solution of an unknown salt are treated with dilute solutions of HBr, H_2SO_4, and NaOH. A precipitate forms in all three cases. Which of the following cations could the solution contain: K^+; Pb^{2+}; Ba^{2+}?

4.26 Separate samples of a solution of an unknown ionic compound are treated with dilute $AgNO_3$, $Pb(NO_3)_2$, and $BaCl_2$. Precipitates form in all three cases. Which of the following could be the anion of the unknown salt: Br^-; CO_3^{2-}; NO_3^-?

4.27 You know that an unlabeled bottle contains a solution of one of the following: $AgNO_3$, $CaCl_2$, or $Al_2(SO_4)_3$. A friend suggests that you test a portion of the solution with $Ba(NO_3)_2$ and then with NaCl solutions. Explain how these two tests together would be sufficient to determine which salt is present in the solution.

4.28 Three solutions are mixed together to form a single solution. One contains 0.2 mol $Pb(C_2H_3O_2)_2$, the second contains 0.1 mol Na_2S, and the third contains 0.1 mol $CaCl_2$. **(a)** Write the net ionic equations for the precipitation reaction or reactions that occur. **(b)** What are the spectator ions in the solution?

Acid-Base Reactions

4.29 Which of the following solutions has the largest concentration of solvated protons: **(a)** 0.1 *M* LiOH, **(b)** 0.1 *M* HI, **(c)** 0.5 *M* methyl alcohol (CH_3OH)? Explain.

4.30 Which of the following solutions is the most basic? **(a)** 0.5 *M* NH_3, **(b)** 0.1 *M* KOH, **(c)** 0.1 *M* $Ca(OH)_2$. Explain.

4.31 What is the difference between **(a)** a monoprotic acid and a diprotic acid, **(b)** a weak acid and a strong acid, **(c)** an acid and a base?

4.32 Explain the following observations: **(a)** NH_3 contains no OH^- ions, and yet its aqueous solutions are basic; **(b)** HF is called a weak acid, and yet it is very reactive; **(c)** although sulfuric acid is a strong electrolyte, an aqueous solution of H_2SO_4 contains more HSO_4^- ions than SO_4^{2-} ions.

4.33 It is said that $HClO_4$ is a strong acid, whereas $HClO_2$ is a weak acid. What does this mean in terms of the extent to which the two substances are ionized in solution?

4.34 What is the relationship between the solubility rules in Table 4.1 and the list of strong bases in Table 4.2? Another way of asking this question is, why is $Cd(OH)_2$, for example, not listed as a strong base in Table 4.2?

4.35 Label each of the following substances as an acid, base, salt, or none of the above. Indicate whether the substance exists in aqueous solution entirely in molecular form, entirely as ions, or as a mixture of molecules and ions. **(a)** HF; **(b)** acetonitrile, CH_3CN; **(c)** $NaClO_4$; **(d)** $Ba(OH)_2$.

4.36 An aqueous solution of an unknown solute is tested with litmus paper and found to be acidic. The solution is weakly conducting compared with a solution of NaCl of the same concentration. Which of the following substances could the unknown be: KOH, NH_3, HNO_3, $KClO_2$, H_3PO_3, CH_3COCH_3 (acetone)?

4.37 Classify each of the following substances as a nonelectrolyte, weak electrolyte, or strong electrolyte in water: **(a)** H_2SO_3, **(b)** C_2H_5OH (ethanol), **(c)** NH_3, **(d)** $KClO_3$, **(e)** $Cu(NO_3)_2$.

4.38 Classify each of the following aqueous solutions as a nonelectrolyte, weak electrolyte, or strong electrolyte: **(a)** $HClO_4$, **(b)** HNO_3, **(c)** NH_4Cl, **(d)** CH_3COCH_3 (acetone), **(e)** $CoSO_4$, **(f)** $C_{12}H_{22}O_{11}$ (sucrose).

4.39 Complete and balance the following molecular equations, and then write the net ionic equation for each:
(a) $HBr(aq) + Ca(OH)_2(aq) \longrightarrow$
(b) $Cu(OH)_2(s) + HClO_4(aq) \longrightarrow$
(c) $Al(OH)_3(s) + HNO_3(aq) \longrightarrow$

4.40 Write the balanced molecular and net ionic equations for each of the following neutralization reactions:
(a) Aqueous acetic acid is neutralized by aqueous potassium hydroxide.
(b) Solid chromium(III) hydroxide reacts with nitric acid.
(c) Aqueous hypochlorous acid and aqueous calcium hydroxide react.

4.41 Write balanced molecular and net ionic equations for the following reactions, and identify the gas formed in each: **(a)** solid cadmium sulfide reacts with an aqueous solution of sulfuric acid; **(b)** solid magnesium carbonate reacts with an aqueous solution of perchloric acid.

4.42 Because the oxide ion is basic, metal oxides react readily with acids. **(a)** Write the net ionic equation for the following reaction:

$$FeO(s) + 2\,HClO_4(aq) \longrightarrow Fe(ClO_4)_2(aq) + H_2O(l).$$

(b) Based on the equation in part (a), write the net ionic equation for the reaction that occurs between NiO(s) and an aqueous solution of nitric acid.

4.43 Write a balanced molecular equation and a net ionic equation for the reaction that occurs when **(a)** solid $CaCO_3$ reacts with an aqueous solution of nitric acid; **(b)** solid iron(II) sulfide reacts with an aqueous solution of hydrobromic acid.

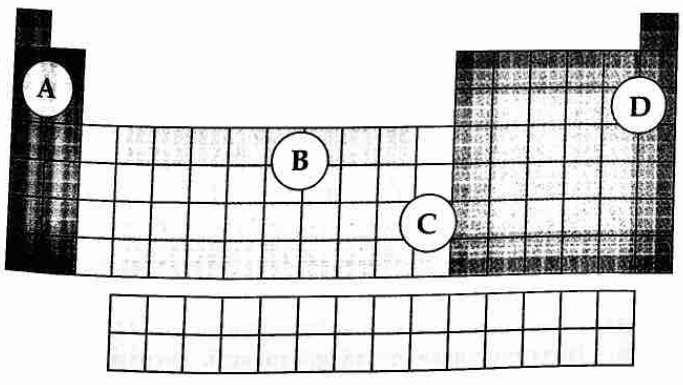
4.44 As K_2O dissolves in water, the oxide ion reacts with water molecules to form hydroxide ions. Write the molecular and net ionic equations for this reaction. Based on the definitions of acid and base, what ion is the base in this reaction? What is the acid? What is the spectator ion in the reaction?

Oxidation-Reduction Reactions

4.45 Define oxidation and reduction in terms of **(a)** electron transfer and **(b)** oxidation numbers.

4.46 Can oxidation occur without accompanying reduction? Explain.

4.47 Which circled region of the periodic table shown here contains the most readily oxidized elements? Which contains the least readily oxidized?



4.48 From the elements listed in Table 4.5, select an element that lies in region A of the periodic table shown to the left and an element that lies in region C. Write a balanced oxidation-reduction equation that shows the oxidation of one metal and reduction of an ion of the other. You will need to decide which element is oxidized and which is reduced.

4.49 Determine the oxidation number for the indicated element in each of the following substances: **(a)** S in SO_2, **(b)** C in $COCl_2$, **(c)** Mn in MnO_4^-, **(d)** Br in HBrO, **(e)** As in As_4, **(f)** O in K_2O_2.

4.50 Determine the oxidation number for the indicated element in each of the following compounds: **(a)** Ti in TiO_2, **(b)** Sn in $SnCl_3^-$, **(c)** C in $C_2O_4^{2-}$, **(d)** N in N_2H_4, **(e)** N in HNO_2, **(f)** Cr in $Cr_2O_7^{2-}$.

4.51 Which element is oxidized and which is reduced in the following reactions?
(a) $Ni(s) + Cl_2(g) \longrightarrow NiCl_2(s)$
(b) $3\,Fe(NO_3)_2(aq) + 2\,Al(s) \longrightarrow 3\,Fe(s) + 2\,Al(NO_3)_3(aq)$

(c) $Cl_2(aq) + 2\,NaI(aq) \longrightarrow I_2(aq) + 2\,NaCl(aq)$
(d) $PbS(s) + 4\,H_2O_2(aq) \longrightarrow PbSO_4(s) + 4\,H_2O(l)$

4.52 Which of the following are redox reactions? For those that are, indicate which element is oxidized and which is reduced. For those that are not, indicate whether they are precipitation or acid-base reactions.
(a) $Cu(OH)_2(s) + 2\,HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + 2\,H_2O(l)$
(b) $Fe_2O_3(s) + 3\,CO(g) \longrightarrow 2\,Fe(s) + 3\,CO_2(g)$
(c) $Sr(NO_3)_2(aq) + H_2SO_4(aq) \longrightarrow SrSO_4(s) + 2\,HNO_3(aq)$
(d) $4\,Zn(s) + 10\,H^+(aq) + 2\,NO_3^-(aq) \longrightarrow 4\,Zn^{2+}(aq) + N_2O(g) + 5\,H_2O(l)$

4.53 Write balanced molecular and net ionic equations for the reactions of **(a)** manganese with dilute sulfuric acid; **(b)** chromium with hydrobromic acid; **(c)** tin with hydrochloric acid; **(d)** aluminum with formic acid, $HCHO_2$.

4.54 Write balanced molecular and net ionic equations for the reactions of **(a)** hydrochloric acid with nickel; **(b)** dilute sulfuric acid with iron; **(c)** hydrobromic acid with magnesium; **(d)** acetic acid, $HC_2H_3O_2$, with zinc.

4.55 Using the activity series (Table 4.5), write balanced chemical equations for the following reactions. If no reaction occurs, simply write NR. **(a)** Iron metal is added to a solution of copper(II) nitrate; **(b)** zinc metal is added to a solution of magnesium sulfate; **(c)** hydrobromic acid is added to tin metal; **(d)** hydrogen gas is bubbled through an aqueous solution of nickel(II) chloride; **(e)** aluminum metal is added to a solution of cobalt(II) sulfate.

4.56 Based on the activity series (Table 4.5), what is the outcome (if any) of each of the following reactions?
(a) $Mn(s) + NiCl_2(aq) \longrightarrow$
(b) $Cu(s) + Cr(C_2H_3O_2)_3(aq) \longrightarrow$
(c) $Cr(s) + NiSO_4(aq) \longrightarrow$
(d) $Pt(s) + HBr(aq) \longrightarrow$
(e) $H_2(g) + CuCl_2(aq) \longrightarrow$

4.57 The metal cadmium tends to form Cd^{2+} ions. The following observations are made: (i) When a strip of zinc metal is placed in $CdCl_2(aq)$, cadmium metal is deposited on the strip. (ii) When a strip of cadmium metal is placed in $Ni(NO_3)_2(aq)$, nickel metal is deposited on the strip. **(a)** Write net ionic equations to explain each of the observations made above. **(b)** What can you conclude about the position of cadmium in the activity series? **(c)** What experiments would you need to perform to locate more precisely the position of cadmium in the activity series?

4.58 **(a)** Use the following reactions to prepare an activity series for the halogens:

$Br_2(aq) + 2\,NaI(aq) \longrightarrow 2\,NaBr(aq) + I_2(aq)$;

$Cl_2(aq) + 2\,NaBr(aq) \longrightarrow 2\,NaCl(aq) + Br_2(aq)$.

(b) Relate the positions of the halogens in the periodic table with their locations in this activity series. **(c)** Predict whether a reaction occurs when the following reagents are mixed: $Cl_2(aq)$ and $KI(aq)$; $Br_2(aq)$ and $LiCl(aq)$.

Solution Composition; Molarity

4.59 **(a)** Is the concentration of a solution an intensive or an extensive property? **(b)** What is the difference between 0.50 mol HCl and 0.50 *M* HCl?

4.60 **(a)** Suppose you prepare 500 mL of a 0.10 *M* solution of some salt and then spill some of it. What happens to the concentration of the solution left in the container? **(b)** A certain volume of a 0.50 *M* solution contains 4.5 g of a salt. What mass of the salt is present in the same volume of a 2.50 *M* solution?

4.61 **(a)** Calculate the molarity of a solution that contains 0.0345 mol NH_4Cl in exactly 400 mL of solution. **(b)** How many moles of HNO_3 are present in 35.0 mL of a 2.20 *M* solution of nitric acid? **(c)** How many milliliters of 1.50 *M* KOH solution are needed to provide 0.125 mol of KOH?

4.62 **(a)** Calculate the molarity of a solution made by dissolving 0.145 mol Na_2SO_4 in enough water to form exactly 750 mL of solution. **(b)** How many moles of $KMnO_4$ are present in 125 mL of a 0.0850 *M* solution? **(c)** How many milliliters of 11.6 *M* HCl solution are needed to obtain 0.255 mol of HCl?

4.63 The average adult human male has a total blood volume of 5.0 L. If the concentration of sodium ion in this average individual is 0.135 *M*, what is the mass of sodium ion circulating in the blood?

4.64 A person suffering from hyponatremia has a sodium ion concentration in the blood of 0.118 *M* and a total blood volume of 4.6 L. What mass of sodium chloride would need to be added to the blood to bring the sodium ion concentration up to 0.138 *M*, assuming no change in blood volume?

4.65 Calculate **(a)** the number of grams of solute in 0.250 L of 0.150 *M* KBr, **(b)** the molar concentration of a solution containing 4.75 g of $Ca(NO_3)_2$ in 0.200 L, **(c)** the volume of 1.50 *M* Na_3PO_4 in milliliters that contains 5.00 g of solute.

4.66 **(a)** How many grams of solute are present in 50.0 mL of 0.360 *M* $K_2Cr_2O_7$? **(b)** If 4.28 g of $(NH_4)_2SO_4$ is dissolved in enough water to form 300 mL of solution, what is the molarity of the solution? **(c)** How many milliliters of 0.240 *M* $CuSO_4$ contain 2.25 g of solute?

4.67 **(a)** Which will have the highest concentration of potassium ion: 0.20 *M* KCl, 0.15 *M* K_2CrO_4, or 0.080 *M* K_3PO_4? **(b)** Which will contain the greater number of moles of potassium ion: 30.0 mL of 0.15 M K_2CrO_4 or 25.0 mL of 0.080 *M* K_3PO_4?

4.68 In each of the following pairs, indicate which has the higher concentration of Cl^- ion: **(a)** 0.10 *M* $CaCl_2$ or 0.15 *M* KCl solution, **(b)** 100 mL of 0.10 *M* KCl solution or 400 mL of 0.080 *M* LiCl solution, **(c)** 0.050 *M* HCl solution or 0.020 *M* $CdCl_2$ solution.

4.69 Indicate the concentration of each ion or molecule present in the following solutions: **(a)** 0.22 *M* NaOH, **(b)** 0.16 *M* $CaBr_2$, **(c)** 0.15 *M* CH_3OH, **(d)** a mixture of 40.0 mL of 0.15 *M* $KClO_3$ and 35.0 mL of 0.22 *M* Na_2SO_4. Assume the volumes are additive.

4.70 Indicate the concentration of each ion present in the solution formed by mixing **(a)** 16.0 mL of 0.130 *M* HCl and 12.0 mL of 0.600 *M* HCl, **(b)** 18.0 mL of 0.200 *M* Na_2SO_4 and 15.0 mL of 0.150 *M* KCl, **(c)** 2.38 g of NaCl in 50.0 mL of 0.400 *M* $CaCl_2$ solution. (Assume that the volumes are additive.)

4.71 **(a)** You have a stock solution of 14.8 *M* NH_3. How many milliliters of this solution should you dilute to make 100.0 mL of 0.250 *M* NH_3? **(b)** If you take a 10.0-mL portion of the stock solution and dilute it to a total volume of 0.250 L, what will be the concentration of the final solution?

4.72 **(a)** How many milliliters of a stock solution of 10.0 *M* HNO_3 would you have to use to prepare 0.350 L of 0.400 *M* HNO_3? **(b)** If you dilute 25.0 mL of the stock solution to a final volume of 0.500 L, what will be the concentration of the diluted solution?

4.73 **(a)** Starting with solid sucrose, $C_{12}H_{22}O_{11}$, describe how you would prepare 125 mL of 0.150 *M* sucrose solution. **(b)** Describe how you would prepare 400.0 mL of 0.100 *M* $C_{12}H_{22}O_{11}$ starting with 2.00 L of 1.50 *M* $C_{12}H_{22}O_{11}$.

4.74 **(a)** How would you prepare 250.0 mL of 0.150 *M* $AgNO_3$ solution starting with pure solute? **(b)** An experiment calls for you to use 100 mL of 0.50 *M* HNO_3 solution. All you have available is a bottle of 6.0 *M* HNO_3. How would you prepare the desired solution?

[4.75] Pure acetic acid, known as glacial acetic acid, is a liquid with a density of 1.049 g/mL at 25°C. Calculate the molarity of a solution of acetic acid made by dissolving 20.00 mL of glacial acetic acid at 25°C in enough water to make 250.0 mL of solution.

[4.76] Glycerol, $C_3H_8O_3$, is a substance used extensively in the manufacture of cosmetics, foodstuffs, antifreeze, and plastics. Glycerol is a water-soluble liquid with a density of 1.2656 g/L at 15°C. Calculate the molarity of a solution of glycerol made by dissolving 50.000 mL glycerol at 15°C in enough water to make 250.00 mL of solution.

Solution Stoichiometry; Titrations

4.77 What mass of NaCl is needed to precipitate the silver ions from 20.0 mL of 0.100 *M* $AgNO_3$ solution?

4.78 What mass of NaOH is needed to precipitate the Cd^{2+} ions from 25.0 mL of 0.500 *M* $Cd(NO_3)_2$ solution?

4.79 **(a)** What volume of 0.115 *M* $HClO_4$ solution is needed to neutralize 50.00 mL of 0.0875 *M* NaOH? **(b)** What volume of 0.128 *M* HCl is needed to neutralize 2.87 g of $Mg(OH)_2$? **(c)** If 25.8 mL of $AgNO_3$ is needed to precipitate all the Cl^- ions in a 785-mg sample of KCl (forming AgCl), what is the molarity of the $AgNO_3$ solution? **(d)** If 45.3 mL of 0.108 *M* HCl solution is needed to neutralize a solution of KOH, how many grams of KOH must be present in the solution?

4.80 **(a)** How many milliliters of 0.120 *M* HCl are needed to completely neutralize 50.0 mL of 0.101 *M* $Ba(OH)_2$ solution? **(b)** How many milliliters of 0.125 *M* H_2SO_4 are needed to neutralize 0.200 g of NaOH? **(c)** If 55.8 mL of $BaCl_2$ solution is needed to precipitate all the sulfate ion in a 752-mg sample of Na_2SO_4, what is the molarity of the solution? **(d)** If 42.7 mL of 0.208 *M* HCl solution is needed to neutralize a solution of $Ca(OH)_2$, how many grams of $Ca(OH)_2$ must be in the solution?

4.81 Some sulfuric acid is spilled on a lab bench. It can be neutralized by sprinkling sodium bicarbonate on it and then mopping up the resultant solution. The sodium bicarbonate reacts with sulfuric acid as follows:

$$2\,NaHCO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2\,H_2O(l) + 2\,CO_2(g)$$

Sodium bicarbonate is added until the fizzing due to the formation of $CO_2(g)$ stops. If 27 mL of 6.0*M* H_2SO_4 was spilled, what is the minimum mass of $NaHCO_3$ that must be added to the spill to neutralize the acid?

4.82 The distinctive odor of vinegar is due to acetic acid, $HC_2H_3O_2$, which reacts with sodium hydroxide in the following fashion:

$$HC_2H_3O_2(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaC_2H_3O_2(aq)$$

If 3.45 mL of vinegar needs 42.5 mL of 0.115 *M* NaOH to reach the equivalence point in a titration, how many grams of acetic acid are in a 1.00-qt sample of this vinegar?

4.83 A sample of solid $Ca(OH)_2$ is stirred in water at 30°C until the solution contains as much dissolved $Ca(OH)_2$ as it can hold. A 100-mL sample of this solution is withdrawn and titrated with 5.00×10^{-2} *M* HBr. It requires 48.8 mL of the acid solution for neutralization. What is the molarity of the $Ca(OH)_2$ solution? What is the solubility of $Ca(OH)_2$ in water, at 30°C in grams of $Ca(OH)_2$ per 100 mL of solution?

4.84 In the laboratory 6.82 g of $Sr(NO_3)_2$ is dissolved in enough water to form 0.500 L. A 0.100-L sample is withdrawn from this stock solution and titrated with a 0.0335 *M* solution of Na_2CrO_4. What volume of Na_2CrO_4 solution is needed to precipitate all the $Sr^{2+}(aq)$ as $SrCrO_4$?

4.85 A solution of 100.0 mL of 0.200 *M* KOH is mixed with a solution of 200.0 mL of 0.150 *M* $NiSO_4$. **(a)** Write the balanced chemical equation for the reaction that occurs. **(b)** What precipitate forms? **(c)** What is the limiting reactant? **(d)** How many grams of this precipitate form? **(e)** What is the concentration of each ion that remains in solution?

4.86 A solution is made by mixing 12.0 g of NaOH and 75.0 mL of 0.200 *M* HNO_3. **(a)** Write a balanced equation for the reaction that occurs between the solutes. **(b)** Calculate the concentration of each ion remaining in solution. **(c)** Is the resultant solution acidic or basic?