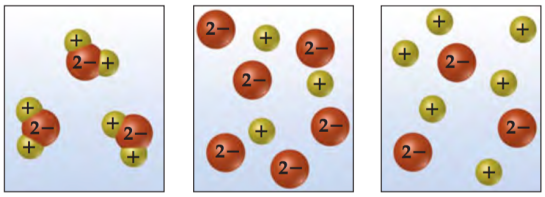
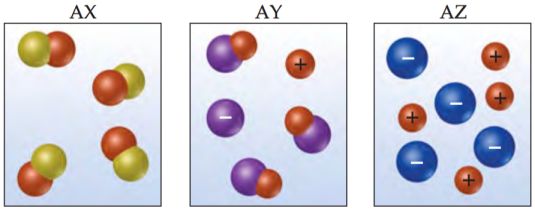
Reactions in Aqueous Solution
Problem Set

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)

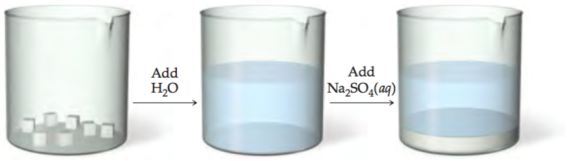
4.2 Aqueous solutions of three different substances, AX, AY, and AZ, are represented by the three accompanying diagrams. Identify each substance as a strong electrolyte, weak electrolyte, or nonelectrolyte. [Section 4.1]



(a) (b) (c)

4.4 A 0.1 *M* solution of acetic acid, CH_3COOH, 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?

4.5 You are presented with a white solid and told that due to careless labeling it is not clear if the substance is barium chloride, lead chloride, or zinc chloride. When you transfer the solid to a beaker and add water, the solid dissolves to give a clear solution. Next a $Na_2SO_4(aq)$ solution is added and a white precipitate forms. What is the identity of the unknown white solid? [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?

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 three bottles containing powdered samples of metals; one contains zinc, one lead, and the other platinum. You have three solutions at your disposal: 1 *M* sodium nitrate, 1 *M* nitric acid, and 1 *M* nickel nitrate. How could you use these solutions to determine the identities of each metal powder? [Section 4.4]

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, HCOOH.

4.9 Explain how a redox reaction involves electrons in the same way that a neutralization reaction involves protons. [Sections

4.10 If you want to double the concentration of a solution, how could you do it? [Section 4.5]

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, CH_3COOH, 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.

4.18 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?

4.20 Predict whether each of the following compounds is soluble in water: **(a)** AgI, **(b)** Na_2CO_3, **(c)** $BaCl_2$, **(d)** $Al(OH)_3$, **(e)** $Zn(CH_3COO)_2$.

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 $Pb(NO_3)_2$.

4.23 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+}?

4.27 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.

4.29 Which of the following solutions has the largest concentration of solvated protons: **(a)** 0.2 *M* LiOH, **(b)** 0.2 *M* HI, **(c)** 1.0 *M* methyl alcohol (CH_3OH)? Explain

4.30 Which of the following solutions is the most basic? **(a)** 0.6 *M* NH_3, **(b)** 0.150 *M* KOH, **(c)** 0.100 *M* $Ba(OH)_2$. Explain.

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 Is there any correlation between the anions that form when each of the strong acids in Table 4.2 dissociates and the anions that normally form soluble ionic compounds (Table 4.1)? Which anions if any are exceptions to the general trend?

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)** $Ba(OH)_2$.

4.37 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)** $Cu(NO_3)_2$.

4.39 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) $Al(OH)_3(s) + HNO_3(aq) \longrightarrow$

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

4.46 Can oxidation occur without oxygen? Can oxidation occur without reduction?

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 $KMnO_4$, **(d)** Br in HBrO, **(e)** As in As_4, **(f)** O in K_2O_2.

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 neutralization reactions.

(a) $P_4(s) + 10\ HClO(aq) + 6\ H_2O(l) \longrightarrow 4\ H_3PO_4(aq) + 10\ HCl(aq)$

(b) $Br_2(l) + 2\ K(s) \longrightarrow 2\ KBr(s)$

(c) $CH_3CH_2OH(l) + 3\ O_2(g) \longrightarrow 3\ H_2O(l) + 2\ CO_2(g)$

(d) $ZnCl_2(aq) + 2\ NaOH(aq) \longrightarrow Zn(OH)_2(s) + 2\ NaCl(aq)$

4.56 Using the activity series (Table 4.5), write balanced chemical equations for the following reactions. If no reaction occurs, simply write NR. **(a)** Nickel metal is added to a solution of copper(II) nitrate; **(b)** a solution of zinc nitrate is added to a solution of magnesium sulfate; **(c)** hydrochloric acid is added to gold metal; **(d)** chromium metal is immersed in an aqueous solution of cobalt(II) chloride; **(e)** hydrogen gas is bubbled through a solution of silver nitrate.

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?

4.61 **(a)** Calculate the molarity of a solution that contains 0.175 mol $ZnCl_2$ in exactly 150 mL of solution. **(b)** How many moles of HCl are present in 35.0 mL of a 4.50 *M* solution of nitric acid? **(c)** How many milliliters of 6.00 *M* NaOH solution are needed to provide 0.325 mol of NaOH?

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 The concentration of alcohol (CH_3CH_2OH) in blood, called the "blood alcohol concentration" or BAC, is given in units of grams of alcohol per 100 mL of blood. The legal definition of intoxication, in many states of the United States, is that the BAC is 0.08 or higher. What is the concentration of alcohol, in terms of molarity, in blood if the BAC is 0.08?

4.69 **(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?

4.74 **(a)** How many milliliters of a stock solution of 6.0 *M* HNO_3 would you have to use to prepare 110 mL of 0.500 *M* HNO_3? **(b)** If you dilute 10.0 mL of the stock solution to a final volume of 0.250 L, what will be the concentration of the diluted solution?

4.77 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.

4.82 **(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?

4.84 The distinctive odor of vinegar is due to acetic acid, CH_3COOH, which reacts with sodium hydroxide in the following fashion:

$$CH_3COOH(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaC_2H_3O_2(aq)$$

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?

4.87 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?

4.89 A 0.5895-g sample of impure magnesium hydroxide is dissolved in 100.0 mL of 0.2050 *M* HCl solution. The excess acid then needs 19.85 mL of 0.1020 *M* NaOH for neutralization. Calculate the percent by mass of magnesium hydroxide in the sample, assuming that it is the only substance reacting with the HCl solution.