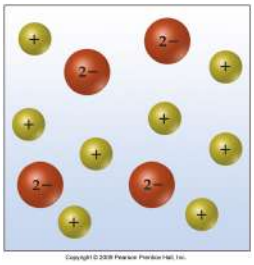
Chapter 4. Aqueous Reactions and Solution Stoichiometry

Sample Exercise 4.1 (p. 127)

The diagram below represents an aqueous solution of one of the following compounds: $MgCl_2$, KCl, or K_2SO_4. Which solution does it best represent?



Practice Exercise 1 (4.1)

If you have an aqueous solution that contains 1.5 moles of HCl, how many moles of ions are in the solution?

a) 1.0
b) 1.5
c) 2.0
d) 2.5
e) 3.0

Practice Exercise 2 (4.1)

If you were to draw diagrams (such as that shown on the left of p. 128) representing aqueous solutions of each of the following ionic compounds, how many anions would you show if the diagram contained six cations?

a) $NiSO_4$

b) $Ca(NO_3)_2$

c) Na_3PO_4

d) $Al_2(SO_4)_3$

Sample Exercise 4.2 (p. 130)

Classify the following ionic compounds as soluble or insoluble in water:

a) sodium carbonate (Na_2CO_3)

b) lead sulfate ($PbSO_4$)

Practice Exercise 1 (4.2)

Which of the following compounds is insoluble in water?

a) $(NH_4)_2S$
b) $CaCO_3$
c) $NaOH$
d) Ag_2SO_4
e) $Pb(CH_3COO)_2$

Practice Exercise 2 (4.2)

Classify the following compounds as soluble or insoluble in water:

a) cobalt(II) hydroxide

b) barium nitrate

c) ammonium phosphate

Sample Exercise 4.3 (p. 131)

a) Predict the identity of the precipitate that forms when solutions of $BaCl_2$ and K_2SO_4 are mixed.

b) Write the balanced chemical equation for the reaction.

Practice Exercise 1 (4.3)

Yes or No: Will a precipitate form when solutions of $Ba(NO_3)_2$ and KOH are mixed?

Practice Exercise 2 (4.3)

a) What compound precipitates when solutions of $Fe_2(SO_4)_3$ and LiOH are mixed?

b) Write a balanced equation for the reaction.

c) Will a precipitate form when solutions of $Ba(NO_3)_2$ and KOH are mixed?

Sample Exercise 4.4 (p. 132)

Write the molecular, total ionic and net ionic equation for the precipitation reaction that occurs when solutions of calcium chloride and sodium carbonate are mixed.

Practice Exercise 1 (4.4)

What happens when you mix an aqueous solution of sodium nitrate with an aqueous solution of barium chloride?

a) There is no reaction; all possible products are soluble.
b) Only barium nitrate precipitates.
c) Only sodium chloride precipitates.
d) Both barium nitrate and sodium chloride precipitate.
e) Nothing; barium chloride is not soluble and it stays as a precipitate.

Practice Exercise 2 (4.4)

Write the net ionic equation for the precipitation reaction that occurs when aqueous solutions of silver nitrate and potassium phosphate are mixed.

Sample Exercise 4.5 (p. 134)

The diagrams below represent aqueous solutions of three acids (HX, HY, and HZ) with water molecules omitted for clarity. Rank them from strongest to weakest.

Practice Exercise 1 (4.5)

A set of aqueous solutions are prepared containing different acids at the same concentration: acetic acid, chloric acid and hydrobromic acid. Which solution(s) are the most electrically conductive?

a) chloric acid
b) hydrobromic acid
c) acetic acid
d) both chloric acid and hydrobromic acid
e) all three solutions have the same electrical conductivity

Practice Exercise 2 (4.5)

Imagine a diagram showing 10 Na^+ ions and 10 OH^- ions. If this solution were mixed with the one pictured above for HY, what would the diagram look like that represents the solution after any possible reaction?

Sample Exercise 4.6 (p. 135)

Classify these dissolved substances as a strong electrolyte, weak electrolyte, or nonelectrolyte:

$CaCl_2$

HNO_3

C_2H_5OH (ethanol)

HCHOOH (formic acid)

KOH

Practice Exercise 1 (4.6)

Which of these substances, when dissolved in water, is a strong electrolyte?

a) ammonia
b) hydrofluoric acid
c) folic acid
d) sodium nitrate
e) sucrose

Practice Exercise 2 (4.6)

Consider solutions in which 0.1 mol of each of the following compounds is dissolved in 1 L of water: $Ca(NO_3)_2$ (calcium nitrate), $C_6H_{12}O_6$ (glucose), $NaC_2H_3O_2$ (sodium acetate), and $HC_2H_3O_2$ (acetic acid). Rank the solutions in order of **increasing electrical conductivity**, knowing that the greater the number of ions in solution, the greater the conductivity.

Sample Exercise 4.7 (p. 136)

For the reaction between aqueous solutions of acetic acid (CH_3COOH) and barium hydroxide ($Ba(OH)_2$), write

a) the balanced molecular equation

b) the complete (total) ionic equation

c) Write the net ionic equation for this reaction.

Practice Exercise 1 (4.7)

Which is the correct **net ionic equation** for the reaction of aqueous ammonia with nitric acid?

a) $NH_4^+{}_{(aq)} + H^+{}_{(aq)} \rightarrow NH_5^{2+}{}_{(aq)}$
b) $NH_{3(aq)} + NO_{3(aq)} \rightarrow NH_2^-{}_{(aq)} + HNO_{3(aq)}$
c) $NH_2^-{}_{(aq)} + H^+{}_{(aq)} \rightarrow NH_{3(aq)}$
d) $NH_{3(aq)} + H^+{}_{(aq)} \rightarrow NH_4^+{}_{(aq)}$
e) $NH_4^+{}_{(aq)} + NO_{3(aq)} \rightarrow NH_4NO_{3(aq)}$

Practice Exercise 2 (4.7)

For the reaction of phosphorous acid (H_3PO_4) and potassium hydroxide (KOH), write

a) the balanced molecular equation

b) the net ionic equation

Sample Exercise 4.8 (p. 141)

Determine the oxidation state of sulfur in each of the following:

a) H_2S

b) S_8

c) SCl_2

d) Na_2SO_3

e) SO_4^{2-}

Practice Exercise 1 (4.8)

In which compound is the oxidation state of oxygen -1?

a) O_2
b) H_2O
c) H_2SO_4
d) H_2O_2
e) KCH_3COO

Practice Exercise 2 (4.8)

What is the oxidation state of the boldfaced element in each of the following:

a) $\mathbf{P}_2O_5$

b) Na**H**

c) $\mathbf{Cr}_2O_7^{2-}$

d) $\mathbf{Sn}Br_4$

e) $Ba\mathbf{O}_2$

Sample Exercise 4.9 (p. 143)

Write the balanced molecular and net ionic equations for the reaction of aluminum with hydrobromic acid.

Practice Exercise 1 (4.9)

Which of the following statements is true about the reaction between zinc and copper(II) sulfate?

a) Zinc is oxidized, and copper ion is reduced.
b) Zinc is reduced, and copper ion is oxidized.
c) All reactants and products are soluble strong electrolytes.
d) The oxidation state of copper in copper(II) sulfate is 0.
e) More than one of the previous choices is true.

Practice Exercise 2 (4.9)

a) Write the balanced molecular and net ionic equations for the reaction between magnesium and cobalt(II) sulfate.

b) What is oxidized and what is reduced in the reaction?

Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^-$	

Sample Exercise 4.10 (p. 145)

Will an aqueous solution of iron(II) chloride oxidize magnesium metal? If so, write the balanced molecular and net ionic equations for the reaction.

Practice Exercise 1 (4.10)

Which of these metals is the easiest to oxidize?

a) gold
b) lithium
c) iron
d) sodium
e) aluminum

Practice Exercise 2 (4.10)

Which of the following metals will be oxidized by $Pb(NO_3)_2$: Zn, Cu, Fe?

Sample Exercise 4.11 (p. 146)

Calculate the molarity of a solution made by dissolving 23.4 g of sodium sulfate (Na_2SO_4) in enough water to form 125 mL of solution.

(1.32 M)

Practice Exercise 1 (4.11)

What is the molarity of a solution that is made by dissolving 3.68 g of sucrose ($C_{12}H_{22}O_{11}$) in sufficient water to form 275.0 mL of solution?

a) 13.4 M
b) 7.43×10^{-2} M
c) 3.91×10^{-2} M
d) 7.43×10^{-5} M
e) 3.91×10^{-5} M

Practice Exercise 2 (4.11)

Calculate the molarity of a solution made by dissolving 5.00 g of glucose ($C_6H_{12}O_6$) in sufficient water to form exactly 100.0 mL of solution.

(0.278 M)

Sample Exercise 4.12 (p.148)

What is the molar concentration of each ion present in a 0.025 M aqueous solution of calcium nitrate?
(0.050 M)

Practice Exercise 1 (4.12)

What is the ratio of the concentration of potassium ions to the concentration of carbonate ions in a 0.015 M soluton of potassium carbonate?

a) 1:0.015
b) 0.015:1
c) 1:1
d) 1:2
e) 2:1

Practice Exercise 2 (4.12)

What is the molar concentration of K^+ ions in a 0.015 M solution of potassium carbonate?
(0.030 M)

Sample Exercise 4.13 (p. 149)

How many grams of Na_2SO_4 are required to make 0.350 L of 0.500 M Na_2SO_4?
(24.9 g)

Practice Exercise 1 (4.13)

What is the concentration of ammonia in a solution made by dissolving 3.75 g of ammonia in 120.0 L of water?

a) 1.84×10^{-3} M
b) 3.78×10^{-2} M
c) 0.0313 M
d) 1.84 M
e) 7.05 M

Practice Exercise 2 (4.13)

a) How many grams of Na_2SO_4 are there in 15 mL of 0.50 M Na_2SO_4?
(1.1g)

b) How many milliliters of 0.50 M Na_2SO_4 solution are needed to provide 0.038 mol of this salt?
(76 mL)

Sample Exercise 4.14 (p. 150)

How many milliliters of 3.0 M H_2SO_4 are needed to make 450 mL of 0.10 M H_2SO_4?

(15 mL)

Practice Exercise 1 (4.14)

What volume of a 1.00 M stock solution of glucose must be used to make 500.0 mL of a 1.75×10^{-2} M glucose solution in water?

a) 1.75 mL
b) 8.75 mL
c) 48.6 mL
d) 57.1 mL
e) 28,570 mL

Practice Exercise 2 (4.14)

a) What volume of 2.50 M lead(II) nitrate solution contains 0.0500 mol of Pb^{2+}?
(20.0 mL)

b) How many milliliters of 5.0 M $K_2Cr_2O_7$ solution must be diluted to prepare 250 mL of 0.10 M solution?
(5.0 mL)

c) If 10.0 mL of a 10.0 M sotck solution of NaOH is diluted to 250 mL, what is the concentration of the resulting stock solution?
(0.40 M)

Laboratory units **Chemical units** **Laboratory units**

Stoichiometry Reminder

1. **Write the equation.**
2. **Get to moles (of known) ASAP**
3. **Switch to unknown via mole ratio**
4. **Put answer in required units**

Sample Exercise 4.15 (p. 152)

How many grams of calcium hydroxide are needed to neutralize 25.0 mL of 0.100 M HNO_3?

1. Write the equation:

$$2\ HNO_{3(aq)} + Ca(OH)_{2(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2\ H_2O_{(l)}$$

2. Get to moles (of known) ASAP (i.e. M → mol, in this example)

3. Switch to moles of unknown, using mole ratio.

$$25.0\ mL \left(\frac{1\ L}{10^3\ mL}\right)\left(\frac{0.100\ mol\ HNO_3}{1\ L}\right)\left(\frac{1\ mol\ Ca(OH)_2}{2\ mol\ HNO_3}\right) = 1.25 \times 10^{-3}\ mol\ Ca(OH)_2$$

4. a) How many grams of calcium hydroxide are needed to neutralize 25.0 mL of 0.100 M HNO_3?

$$1.25 \times 10^{-3}\ mol\ Ca(OH)_2 \left(\frac{74.10\ g\ Ca(OH)_2}{1\ mol\ Ca(OH)_2}\right) = 9.26 \times 10^{-2}\ g\ Ca(OH)_2$$

b) How many mL of 0.50 M $Ca(OH)_2$ are needed to completely neutralize 25.0 mL of 0.100 M HNO_3?

$$1.25 \times 10^{-3}\ mol\ Ca(OH)_2 \left(\frac{1\ L}{0.50\ mol\ Ca(OH)_2}\right)\left(\frac{10^3\ mL}{1\ L}\right) = 2.5\ mL$$

d) 15.0 mL of a $Ca(OH)_2$ solution are needed to neutralize 25.0 mL of 0.100 M HNO_3. What is the molarity of the solution?

$$\frac{1.25 \times 10^{-3}\ mol\ Ca(OH)_2}{15.0\ mL}\left(\frac{10^3\ mL}{1\ L}\right) = 0.0833\ M$$

Practice Exercise 1 (4.15)

How many milligrams of sodium sulfide are needed to completely react with 25.00 mL of a 0.0100 M aqueous solution of cadmium nitrate, to form a precipitate of $CdS_{(s)}$?

a) 13.8 mg
b) 19.5 mg
c) 23.5 mg
d) 32.1 mg
e) 39.0 mg

Practice Exercise 2 (4.15)

a) How many grams of NaOH are needed to neutralize 20.0 mL of 0.150 M H_2SO_4 solution?
(0.240 g)

b) How many liters of 0.500 M HCl(aq) are needed to react completely with 0.100 mol of $Pb(NO_3)_{2(aq)}$, forming a precipitate of $PbCl_{2(s)}$?
(0.400 L)

Titration Practice Problems
Remember: Moles are central!

1. In the titration of 35 mL of liquid drain cleaner containing NaOH, 50. mL of 0.40 M HCl must be added to reach the equivalence point. What is the molarity of the base in the cleaner? (0.57 M)

2. A 20.0 mL sample of an HCl solution is titrated with 27.4 mL of a standard solution of $Ba(OH)_2$. The concentration of the standard is 0.0154 M. What is the molarity of the HCl? (0.0422 M)

3. How many mL of 0.25 M $Ca(OH)_2$ must be added to titrate 46 mL of 0.40 M $HClO_4$? (37 mL)

Sample Exercise 4.16 (p. 153)

One commercial method used to peel potatoes is to soak them in a solution of NaOH for a short time, remove them from the NaOH, and spry off the peel. The concentration of NaOH is normally in the range of 3 to 6 M. The NaOH is analyzed periodically. In one such analysis, 45.7 mL of 0.500 M H_2SO_4 is required to neutralize a 20.0 mL sample of NaOH solution. What is the concentration of the NaOH solution?

(2.28 M)

Practice Exercise 1 (4.16)

What is the molarity of an HCl solution if 27.3 mL of it neutralizes 134.5 mL of 0.0165 M $Ba(OH)_2$?

a) 0.0444 M
b) 0.0813 M
c) 0.163 M
d) 0.325 M
e) 3.35 M

Practice Exercise 4.16

What is the molarity of an NaOH solution if 48.0 mL is needed to neutralize 35.0 mL of 0.144 M H_2SO_4?

(0.210 M)

Sample Exercise 4.17 (p. 154)

The quantity of Cl^- in a water supply is determined by titrating the sample with Ag^+:

$$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$$

a) How many grams of chloride ion are in a sample of the water if 20.2 mL of 0.100 M Ag^+ is needed to react with all the chloride in the sample?

(7.17×10^{-2} g Cl^-)

b) If the sample has a mass of 10.0 g, what percent Cl^- does it contain?
(0.717% Cl^-)

Practice Exercise 1 (4.17)

A mysterious white powder is found at a crime scene. A simple chemical analysis concludes that the powder is a mixture of sugar and morphine (C17H19NO3), a weak base similar to ammonia. The crime lab takes 10.00 mg of the mysterious white powder, dissolves it in 100.00 mL water, and titrates it to the equivalence point with 2.84 mL of a standard 0.0100 M HCl solution. What is the percentage of morphine in the white powder?

a) 8.10%
b) 17.3%
c) 32.6%
d) 49.7%
e) 81.0%

Practice Exercise 2 (4.17)

A sample of an iron ore is dissolved in acid, and the iron is converted to Fe^{2+}. The sample is then titrated with 47.20 mL of 0.02240 M MnO_4^-. The oxidation-reduction reaction that occurs during titration is as follows:
$MnO_4^-{}_{(aq)} + 5\ Fe^{2+}{}_{(aq)} + 8\ H^+{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + 5\ Fe^{3+}{}_{(aq)} + 4\ H_2O_{(l)}$

a) How many moles of MnO_4^- were added to the solution?
(1.057×10^{-3} mol MnO_4^-)

b) How many moles of Fe^{2+} were in the sample?
(5.286×10^{-3} mol Fe^{2+})

c) How many grams of iron were in the sample? (0.2952 g)

d) If the sample had a mass of 0.8890 g, what is the percentage of iron in the sample? (33.21%)

Sample Integrative Exercise 4 (p. 153)

A sample of 70.5 mg potassium phosphate is added to 15.0 mL of 0.050 M silver nitrate, resulting in the formation of a precipitate.

a) Write the molecular equation for the reaction.

b) What is the limiting reactant in the reaction?

c) Calculate the theoretical yield, in grams, of the precipitate that forms.
(0.10 g Ag_3PO_4)