16.2

1 FOCUS

Objectives

16.2.1 Solve problems involving the molarity of a solution.

16.2.2 Describe the effect of dilution on the total moles of solute in solution.

16.2.3 Define percent by volume and percent by mass solutions.

Guide for Reading

Build Vocabulary L2

Graphic Organizer Students can make a web diagram showing how *dilute solution, concentrated solution,* and *molarity* are related to *concentration.*

Reading Strategy L2

Identify Main Ideas/Details Have students identify the main ideas of this section by listing the key concepts under each heading.

2 INSTRUCT

Connecting to Your World

Have students study the photograph and read the text. Ask, **What substances may be contaminants in drinking water?** *(metals, pesticides, bacteria, water treatment by-products)* **How is the quality of drinking water assessed?** *(Federal and state governments set standards that limit the amount of contaminants allowed in drinking water.)*

16.2 Concentrations of Solutions

Guide for Reading

Key Concepts

- How do you calculate the molarity of a solution?
- What effect does dilution have on the total moles of solute in solution?
- What are two ways to express the percent concentration of a solution?

Vocabulary

concentration

dilute solution

concentrated solution

molarity (*M*)

Reading Strategy

Summarizing When you summarize, you restate the key ideas in your own words. As you read about molarity, making dilutions, and percent solutions, summarize the main ideas in the text. In your summary, be sure to include all the key terms and the sentences in boldfaced type.

Connecting to Your World A supply of clean drinking water is important for all communities. What constitutes clean water? The federal government, along with state governments, has set standards limiting the amount of contaminants allowed in drinking water. These contaminants include metals, pesticides, bacteria, and even the by-products of water treatment. Water must be tested continually to ensure that the concentrations of these contaminants do not exceed established limits. In this section, you will learn how solution concentrations are calculated.

Molarity

You have learned that a substance can dissolve to some extent in a particular solvent to form a solution. In this section, you will learn how to express the actual extent of dissolving, that is, the concentration of a solution. The **concentration** of a solution is a measure of the amount of solute that is dissolved in a given quantity of solvent. A **dilute solution** is one that contains a small amount of solute. By contrast, a **concentrated solution** contains a large amount of solute. An aqueous solution of sodium chloride containing 1 g NaCl per 100 g H_2O might be described as dilute when compared with a sodium chloride solution containing 30 g NaCl per 100 g H_2O. But the same solution might be described as concentrated when compared with a solution containing only 0.01 g NaCl per 100 g H_2O. You can see that the terms *concentrated* and *dilute* are only qualitative descriptions of the amount of a solute in solution.

How can concentration be expressed quantitatively? In chemistry, the most important unit of concentration is molarity. **Molarity (*M*)** is the number of moles of solute dissolved in one liter of solution. **To calculate the molarity of a solution, divide the moles of solute by the volume of the solution.**

$$\text{Molarity } (M) = \frac{\text{moles of solute}}{\text{liters of solution}}$$

Note that the volume involved is the total volume of the resulting solution, not the volume of the solvent alone. Molarity is also known as molar concentration. When the symbol *M* is accompanied by a numerical value, it is read as "molar." For example, a solution labeled 3*M* NaCl is read as three molar sodium chloride solution. Figure 16.8 demonstrates how to make a 0.5-molar solution, that is, a solution with a molarity of 0.5.

Section Resources

Print

- **Guided Reading and Study Workbook,** Section 16.2
- **Core Teaching Resources,** Section 16.2 Review
- **Laboratory Manual,** Lab 32
- **Lab Practical** 16-1
- **Transparencies,** T171–T174

Technology

- **Interactive Textbook with ChemASAP,** Problem Solving 16.8, 16.11, 16.12, 16.14; Assessment, 16.2

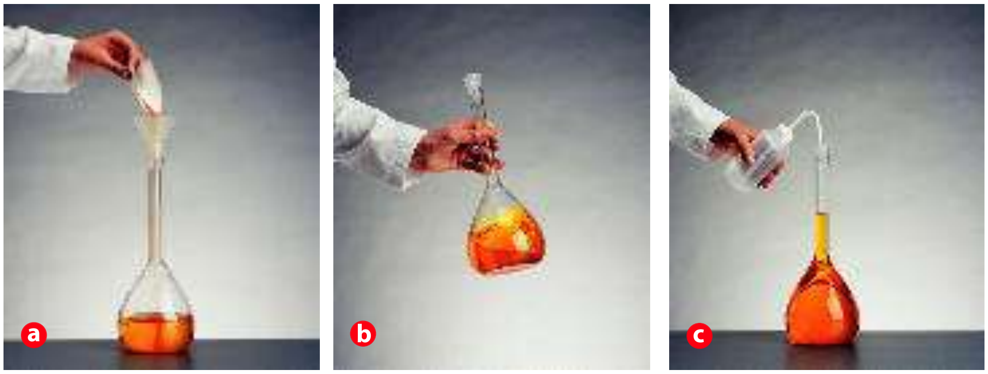

Figure 16.8 The photos show how to make a 0.5-molar (0.5*M*) solution. (a) Add 0.5 mol of solute to a 1-L volumetric flask half filled with distilled water. (b) Swirl the flask carefully to dissolve the solute. (c) Fill the flask with water exactly to the 1-L mark.

SAMPLE PROBLEM 16.2

Calculating the Molarity of a Solution

Intravenous (IV) saline solutions are often administered to patients in the hospital. One saline solution contains 0.90 g NaCl in exactly 100 mL of solution. What is the molarity of the solution?

1 Analyze ***List the knowns and the unknown.***

Knowns

- solution concentration = 0.90 g NaCl/100 mL
- molar mass NaCl = 58.5 g/mol

Unknown

- solution concentration = ?*M*

Convert the concentration from g/100 mL to mol/L. The sequence is g/100 mL → mol/100 mL → mol/L.

2 Calculate ***Solve for the unknown.***

Use the molar mass to convert g NaCl/100 mL to mol NaCl/100 mL. Then use the conversion factor between milliliters and liters to convert to mol/L, which is molarity.

$$\text{solution concentration} = \frac{0.90\ \text{g NaCl}}{100\ \text{mL}} \times \frac{1\ \text{mol NaCl}}{58.5\ \text{g NaCl}} \times \frac{1000\ \text{mL}}{1\ \text{L}}$$

$$= 0.15\ \text{mol/L} = 0.15M$$

3 Evaluate ***Does the result make sense?***

The answer should be less than 1*M* because a concentration of 0.90 g/100 mL is the same as 9.0 g/1000 mL (9.0 g/1 L), and 9.0 g is less than 1 mol NaCl. The answer is correctly expressed to two significant figures.

Practice Problems

8. A solution has a volume of 2.0 L and contains 36.0 g of glucose ($C_6H_{12}O_6$). If the molar mass of glucose is 180 g/mol, what is the molarity of the solution?

9. A solution has a volume of 250 mL and contains 0.70 mol NaCl. What is its molarity?

Math Handbook

For help with dimensional analysis, go to page R66.

Interactive Textbook

Problem-Solving 16.8 Solve Problem 8 with the help of an interactive guided tutorial.

with ChemASAP

Molarity

Discuss L2

To assess students' knowledge about chemical quantities ask, **How many moles are in each quantity of the following substances: 12.0 g NaCl** (0.205 mol NaCl)**; 53.8 g KNO_3** *(0.532 mol KNO_3)* **Find the mass in grams of each of these amounts of substances: 1.50 mol NaOH** (60.0 g)**; 0.575 mol $NaHCO_3$** (48.3 g) **Which contains more molecules: 1.00 mol SO_2 or 1.00 mol SO_3?** *(numbers are equal)* **Which contains more mass?** *(1.00 mol SO_3)*

Use Visuals L1

Figure 16.8 Students may think that solutions of given molarity can be correctly prepared by addition of the solute to a premeasured volume of solvent. They often forget that the solute will take up some of the available space in the volumetric flask. Explain that the sequence of steps is important when making up standard solutions because the solute plus the solvent may take up more volume than the solvent alone. Ask, **Why is it important that the solute be added to some of the solvent and dissolved, and then solvent be added up to the 1 L mark on the volumetric flask?** *(The total volume of the mixture is likely to exceed the desired volume.)*

Sample Problem 16.2

Answers

8. 36.0 g/2.0 L solution × 1 mol/180 g = $1.0 \times 10^{-1}M$

9. 0.70 mol/250 mL × 1000 mL/ 1 L = 2.8*M*

Math Handbook

For a math refresher and practice, direct students to dimensional analysis, page R66.

Facts and Figures

IV Solutions

A patient in a hospital is often administered an intravenous (IV) drip containing an aqueous solution. The patient may need the solution to prevent dehydration or to administer nutrients or medicines. Great care must be taken when fluids are introduced into the bloodstream. The balance of dissolved electrolytes inside and outside of the tissue cells could be disturbed. The effects of an imbalance in electrolytes and water can be harmful or could even cause the death of a patient. Aqueous solutions containing 0.85% - 0.9% (mass/mass) of sodium chloride or 5% (mass/mass) of glucose prevent undesired changes in the electrolyte balance.

Sample Problem 16.3

Answers

10. 335 mL × 1L/1000 mL × 0.425 mol/1L = 1.42×10^{-1} mol

11. 0.2 mol/L × 1L/1000 mL × 250 mL = 5.0×10^{-1} mol $CaCl_2$; 5.6×10^{1} g $CaCl_2$

Practice Problems Plus L2

How many grams of solute are in 2.40 L of 0.650*M* $HClO_2$? *(107 g)*

Math Handbook

For a math refresher and practice, direct students to conversion problems, page R66.

CLASS Activity

Preparing Solutions L2

Purpose Students learn how to prepare molar solutions.

Materials water; NaCl; sucrose; 50-mL, 100-mL, and 1-L volumetric flasks; balance; graph paper

Procedure Have students determine the mass of a 50-mL, 100-mL, and a 1-L volumetric flask. Review the definition of 1*M* and how to calculate the mass of 1 mol of NaCl (58.5 g). Add 500 mL of water to the 1-L volumetric flask and add 1 mol of NaCl. Swirl the flask until the NaCl dissolves. Add water up to the 1-L mark. Ask, **Does the flask contain a liter of water?** *(No, because the dissolved NaCl takes up some volume.)* Have students prepare 0.0625*M*, 0.125*M*, 0.250*M*, and 0.500*M* solutions of sucrose using the 100-mL and 50-mL volumetric flasks. Have students determine the mass of each solution and calculate the densities of the solutions. *[Density = (mass of flask + solution − mass of flask)/mL of solution.]* Have students make a graph of density versus concentration; include the density of pure water (1 g/mL).

Expected Outcome The graph shows that density is directly proportional to concentration.

Sometimes, you may need to determine the number of moles of solute dissolved in a given volume of solution. You can do this if the molarity of the solution is known. For example, how many moles are in 2.00 L of 2.5*M* lithium chloride (LiCl)? Rearrange the formula for molarity to solve for the number of moles.

$$\text{Molarity } M = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$\text{Moles of solute} = \text{molarity } (M) \times \text{liters of solution } (V)$$

$$\text{Moles of LiCl} = 2.5\ M \times 2.00\ \text{L} = \left(\frac{2.5\ \text{mol}}{1\ \cancel{\text{L}}}\right) \times 2.00\ \cancel{\text{L}}$$

$$= 5.0\ \text{mol}$$

Thus 2.00 L of 2.5 *M* lithium chloride solution contains 5.0 mol LiCl.

SAMPLE PROBLEM 16.3

Finding the Moles of Solute in a Solution

Household laundry bleach is a dilute aqueous solution of sodium hypochlorite (NaClO). How many moles of solute are present in 1.5 L of 0.70*M* NaClO?

1 Analyze ***List the knowns and the unknown.***

Knowns
- volume of solution = 1.5 L
- solution concentration = 0.70*M* NaClO
- moles solute = $M \times \text{L} = \frac{\text{mol}}{\text{L}} \times \text{L}$

Unknown
- moles solute = ? mol

The conversion is volume of solution ⟶ moles of solute. Molarity has the units mol/L and is a conversion factor between moles of solute and volume of solution. Multiply the given volume by the molarity expressed in mol/L.

2 Calculate ***Solve for the unknown.***

$$\text{moles solute} = \frac{0.70\ \text{mol NaClO}}{1\ \cancel{\text{L}}} \times 1.5\ \cancel{\text{L}}$$

$$= 1.1\ \text{mol NaClO}$$

3 Evaluate ***Does the result make sense?***

The answer should be greater than 1 mol but less than 1.5 mol because the solution concentration is less than 0.75 mol/L and the volume is less than 2 L. The answer is correctly expressed to two significant figures.

Practice Problems

10. How many moles of ammonium nitrate are in 335 mL of 0.425*M* NH_4NO_3?

11. How many moles of solute are in 250 mL of 2.0*M* $CaCl_2$? How many grams of $CaCl_2$ is this?

Math Handbook

For help with conversion problems, go to page R66.

Interactive Textbook

Problem-Solving 16.11 Solve Problem 11 with the help of an interactive guided tutorial.

with ChemASAP

Differentiated Instruction

Gifted and Talented L3

Have students imagine they are writing a recipe for someone else to follow who does not know much about chemistry. Have them write out the steps necessary to make a 0.5*M* aqueous solution of KOH and a 0.2*M* aqueous solution of $MgCl_2$. Have them include tips to ensure success.

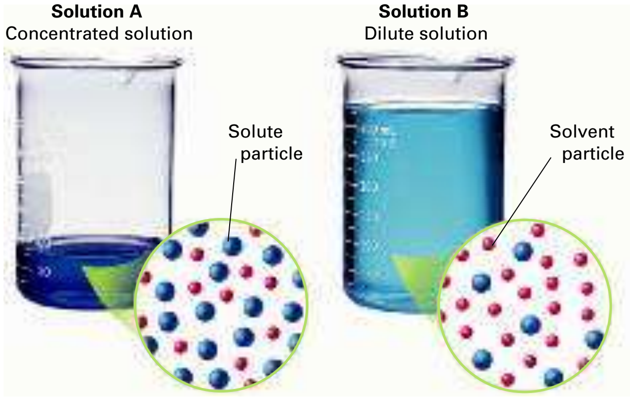

Figure 16.9 Adding solvent to a concentrated solution lowers the concentration, but the total number of moles of solute present remains the same.

Making Dilutions

Both solutions in Figure 16.9 contain the same amount of solute. You can tell by the color of solution A that it is more concentrated than solution B; that is, solution A has the greater molarity. The more dilute solution B was made from solution A by adding more solvent. The procedure for diluting a solution is shown in Figure 16.10. **Diluting a solution reduces the number of moles of solute per unit volume, but the total number of moles of solute in solution does not change.**

Moles of solute before dilution = moles of solute after dilution

Recall the definition of molarity.

$$\text{Molarity } (M) = \frac{\text{moles of solute}}{\text{liters of solution}}$$

Rearranging the equation gives an expression for moles of solute.

$$\text{Moles of solute} = \text{molarity } (M) \times \text{liters of solution } (V)$$

The total number of moles of solute remains unchanged upon dilution, so you can write this equation.

$$\text{Moles of solute} = M_1 \times V_1 = M_2 \times V_2$$

M_1 and V_1 are the molarity and volume of the initial solution, and M_2 and V_2 are the molarity and volume of the diluted solution. Volumes can be in liters or milliliters, as long as the same units are used for both V_1 and V_2.

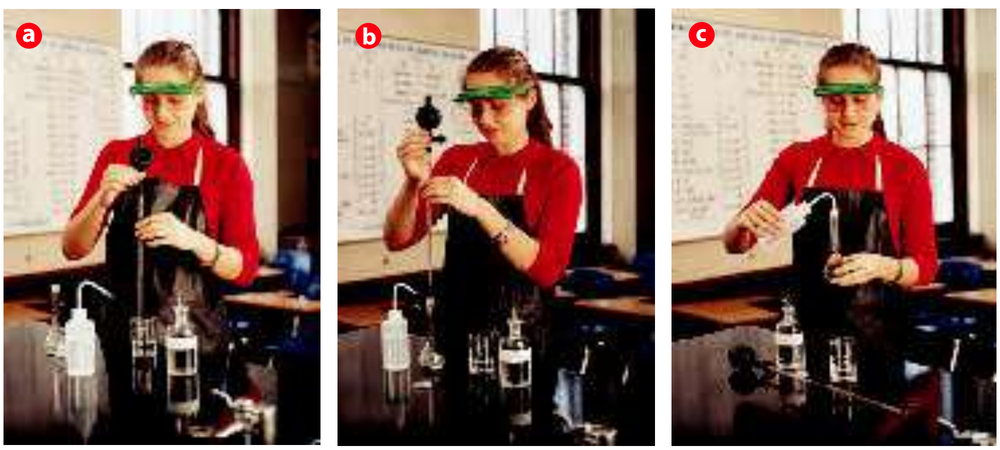

Figure 16.10 The student is preparing 100 mL of 0.40*M* $MgSO_4$ from a stock solution of 2.0*M* $MgSO_4$. **a** She measures 20 mL of the stock solution with a 20-mL pipet. **b** She transfers the 20 mL to a 100-mL volumetric flask. **c** She carefully adds water to the mark to make 100 mL of solution. **Inferring** ***How many significant figures does the new molarity have?***

Making Dilutions

Discuss L2

Remind students that when substances react, they do so as particles and that moles of different substances contain the same number of representative particles. Because many reactions occur in solution, a unit of concentration based on moles (such as molarity) is needed to provide information about the number of reactant particles in solution.

CLASS Activity

Solution Calculations L2

Purpose Students practice calculating the variables in the definition of molarity.

Materials calculator, paper, pencil

Procedure Divide students into groups of three. One student should name a solute; the other two should each specify one of three quantities: *solute mass*, *solution volume*, or *molarity*. The unspecified quantity should then be calculated with input from each member. For example, the first student may say "sodium chloride," the second may say "12 grams," and the third may say "2.5 liters." The group would then have to calculate the molarity of the resulting solution. Each group should carry out at least one calculation involving each of the possible unknown quantities.

Differentiated Instruction

Less Proficient Readers L1

Have students work in groups of three to explore dilution. Have each group bring in a shoe box and put 20 red beads into it. These red beads represent solute molecules. Then add 40 green beads. These beads represent solvent molecules. Students should see that the box contains twice as many green beads as red beads; thus, the concentration is 0.5 red/green.

Now add another 40 green beads. This is analogous to a dilution from 0.5 to 0.25 red/green. Although the concentration of red beads has been halved, the total number of red beads has not changed. If the 20 red beads represent moles of solute, 20 moles of solute would still be in solution.

Answers to...

Figure 16.10 two

Sample Problem 16.4

Answers

12. $V_1 = M_2 \times V_2 / M_1 = 0.760M \times 250.0\ \text{mL} / 4.00M = 4.75 \times 10^1\ \text{mL}$

13. Use a pipet to transfer 5.0×10^1 mL of the 1.0*M* solution to a 250-ml volumetric flask. Then add distilled water up to the mark.

Practice Problems Plus L2

What volume of 12.00*M* sulfuric acid is required to prepare 1.00 L of 0.400*M* sulfuric acid? *(33.3 mL)*

Math Handbook

For a math refresher and practice, direct students to algebraic equations, page R69.

Discuss L2

If students are having difficulty with the concepts of molarity and dilution, have them consider diluting a container of juice concentrate (frozen or liquid). No matter how much water is added to the concentrate, the initial quantity of concentrate does not change. What changes is the amount of concentrate in a given volume of the diluted solution. Then have students consider using only a fraction of the original concentrate. For example, a gallon of juice prepared from half a can will contain half as much concentrate as a gallon prepared from the entire can. Thus, the molarity would be cut in half.

Discuss L2

Write the dilution equation on the board. ($M_1 \times V_1 = M_2 \times V_2$) Show students that when mol/*V* is substituted for *M*, the volumes cancel out, leaving moles. Emphasize that, when diluting a solution, the number of moles you start with is the same as the number of moles you end with. Work through several examples using the dilution equation. Ask, **How many milliliters of a 6.00*M* stock solution of $NH_3(aq)$ would you need to prepare 100.0 mL of 0.30*M* $NH_3(aq)$?** *(5.0 mL)*

Figure 16.11 The photo shows a buret, a graduated cylinder, a volumetric flask, and a volumetric pipet. These are just some examples of volume-measuring devices.

SAMPLE PROBLEM 16.4

Preparing a Dilute Solution

How many milliliters of aqueous 2.00*M* $MgSO_4$ solution must be diluted with water to prepare 100.0 mL of aqueous 0.400*M* $MgSO_4$?

1 Analyze ***List the knowns and the unknown.***

Knowns
- $M_1 = 2.00M\ MgSO_4$
- $M_2 = 0.400M\ MgSO_4$
- $V_2 = 100.0$ mL of $0.400M\ MgSO_4$
- $M_1 \times V_1 = M_2 \times V_2$

Unknown
- $V_1 = ?$ mL of $2.00M\ MgSO_4$

2 Calculate ***Solve for the unknown.***

Solving for V_1 yields:

$$V_1 = \frac{M_2 \times V_2}{M_1} = \frac{0.400M \times 100.0\ \text{mL}}{2.00M}$$
$$= 20.0\ \text{mL}$$

Thus 20.0 mL of the initial solution must be diluted by adding enough water to increase the volume to 100.0 mL.

3 Evaluate ***Does the result make sense?***

The concentration of the initial solution is five times larger than the concentration of the diluted solution. Because the moles of solute in each solution are the same, the volume of the solution to be diluted (20.0 mL) should be one-fifth the final volume of the diluted solution. The answer is correctly expressed to three significant figures.

Practice Problems

12. How many milliliters of a solution of 4.00*M* KI are needed to prepare 250.0 mL of 0.760*M* KI?

13. How could you prepare 250 mL of 0.20*M* NaCl using only a solution of 1.0*M* NaCl and water?

Math Handbook

For help with algebraic equations, go to p. R69.

Interactive Textbook

Problem-Solving 16.12 Solve Problem 12 with the help of an interactive guided tutorial.

with ChemASAP

Which of the volume-measuring devices shown in Figure 16.11 should you use to make a dilution? Your choice depends upon how precise you want the concentration of the solution to be. The dilution described in Sample Problem 16.4 requires a molarity with three significant figures. For this you would need to measure 20.0 mL of the 2.00*M* $MgSO_4$ solution with a 20-mL volumetric pipet or a buret. A graduated cylinder could not provide the required precision. You would transfer the solution to a 100-mL volumetric flask and add distilled water to the flask exactly up to the etched line. The contents would then be exactly 100.0 mL of 0.400*M* $MgSO_4$. For measurements that require less precision, graduated cylinders are appropriate for measuring volumes.

Percent Solutions

Another way to describe the concentration of a solution is by the percent of a solute in the solvent. **The concentration of a solution in percent can be expressed in two ways: as the ratio of the volume of the solute to the volume of the solution or as the ratio of the mass of the solute to the mass of the solution.**

Concentration in Percent (Volume/Volume) If both the solute and the solvent are liquids, a convenient way to make a solution is to measure the volumes of the solute and the solution. The concentration of the solute is then expressed as a percent of the solution by volume. For example, isopropyl alcohol (2-propanol) is sold as a 91% solution, as shown in Figure 16.12. This solution consists of 91 mL of isopropyl alcohol mixed with enough water to make 100 mL of solution. The concentration can be expressed as 91 percent (volume/volume), or 91% (v/v). The relationship between percent by volume and the volumes of solute and solution is

$$\text{Percent by volume } (\%\ (v/v)) = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$$

Figure 16.12 The label clearly distinguishes this solution of isopropyl alcohol from rubbing alcohol which is a 70% solution of isopropyl alcohol. **Applying Concepts** ***How many milliliters of isopropyl alcohol are in 100 mL of 91% alcohol?***

SAMPLE PROBLEM 16.5

Calculating Percent (Volume/Volume)

What is the percent by volume of ethanol (C_2H_6O, or ethyl alcohol) in the final solution when 85 mL of ethanol is diluted to a volume of 250 mL with water?

1 Analyze ***List the knowns and the unknown.***

Knowns
- volume of ethanol = 85 mL
- volume of solution = 250 mL

Unknown
- % ethanol (v/v) = ? %

- $\text{Percent by volume } (\%\ (v/v)) = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$

2 Calculate ***Solve for the unknown.***

Substitute the known values into the equation and solve.

$$\%\ (v/v) = \frac{85 \text{ mL ethanol}}{250 \text{ mL}} \times 100\%$$
$$= 34\% \text{ ethanol } (v/v)$$

3 Evaluate ***Does the result make sense?***

The volume of the solute is about one-third the volume of the solution, so the answer is reasonable. The answer is correctly expressed to two significant figures.

Practice Problems

14. If 10 mL of propanone (or acetone (C_3H_6O)) is diluted with water to a total solution volume of 200 mL, what is the percent by volume of propanone in the solution?

15. A bottle of the antiseptic hydrogen peroxide (H_2O_2) is labeled 3.0% (v/v). How many mL H_2O_2 are in a 400.0-mL bottle of this solution?

Math Handbook
For help with percents, go to page R72.

Interactive Textbook
Problem-Solving 16.15 Solve Problem 15 with the help of an interactive guided tutorial.
with ChemASAP

Percent Solutions

Sample Problem 16.5

Answers

14. %(v/v) = 10 mL propanone/200 mL × 100% = 5.0 % v/v

15. mL H_2O_2 = 400.0 mL × 3% / 100% = 1.2×10^1 mL

Practice Problems Plus L2

Ethanol is mixed with gasoline to make gasohol. **What is the percent by volume of ethanol in gasohol when 95 mL of ethanol is added to sufficient gasoline to make 1.0 L of gasohol?** *(9.5% (v/v))*

Math Handbook
For a math refresher and practice, direct students to percents, page R72.

TEACHER Demo

Serial Dilutions L2

Purpose Students learn how to prepare standard solutions efficiently.

Materials four 20-mL test tubes, 10 mL of 0.5*M* surcose, 15 mL water, 10-mL pipet.

Procedure Remind students of the activity in which they prepared molar solutions of sucrose. Each solution was prepared independently. Ask, **Is there a more efficient way to prepare this same set of molar solutions?** *(Yes; make serial dilutions.)* Place 10 mL of 0.5*M* sucrose in one test tube and 5 mL water in each of three others. Using a 10-mL pipet, transfer 5 mL of the 0.5*M* solution to the second test tube; mix by pipeting up and down. Repeat this process for the third and fourth test tubes. Have students calculate the molarities of each of the resulting solutions. Tell students that serial dilutions are used to prepare extremely dilute solutions, such as 0.000001*M* sucrose. The procedure eliminates the error that would arise from having to measure out very small volumes of stock solutions.

Answers to...
Figure 16.12 91 mL

Facts and Figures

Calculating Percent by Volume

Percent by volume is easy to calculate because there is no need to calculate molar masses. However, because a volume change can occur when two liquids mix, a percent by volume can be misleading. When 20 mL of ethanol is mixed with 80 mL of water, the resulting volume is less than 100 mL; more water must be added.

3 ASSESS

Evaluate Understanding L2

Ask students to compare percent by mass and percent by volume with molarity as ways of expressing the concentration of a solution. Have students write out a numbered list of steps they would follow to prepare a 1*M* aqueous solution of KCl.

Reteach L1

Remind students that when making dilute solutions, the accuracy of the resulting solution's concentration is dependent upon the measuring devises used. Using a graduated cylinder to measure is much less accurate than using a volumetric pipet or buret. Review how to use all of these measuring devises.

Writing Activity

Students may find it hard to tell which percent method is used on labels. Have students consider whether one or the other method might present the product in a more favorable light. Even the name "fruit drink" can be misleading.

Interactive Textbook

If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 16.2.

with ChemASAP

Concentration in Percent (Mass/Mass) Another way to express the concentration of a solution is as a percent (mass/mass), which is the number of grams of solute in 100 grams of solution. Percent by mass is sometimes a convenient unit of concentration when the solute is a solid. For example, a solution containing 7 g of sodium chloride in 100 grams of solution is 7 percent (mass/mass), or 7% (m/m).

$$\text{Percent by mass (\% (m/m))} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

Suppose you want to make 2000 g of a solution of glucose in water that has a 2.8% (m/m) concentration of glucose. How much glucose should you use? In a 2.8 percent solution, each 100 g of solution contains 2.8 g of solute. Thus, to find the grams of solute, you can multiply the mass of the solution by the ratio of grams of solute to grams of solution.

$$2000\text{ g }\cancel{\text{solution}} \times \frac{2.8\text{ g glucose}}{100\text{ g }\cancel{\text{solution}}} = 56\text{ g glucose}$$

How much solvent (water) should be used? The mass of the solvent equals the mass of the solution minus the mass of the solute or 1944 g (2000 g – 56 g). Thus a 2.8% (m/m) glucose solution contains 56 g of glucose dissolved in 1944 g of water.

Information is often expressed as percent composition on food labels. For example, the label on a fruit drink or on maple-flavored pancake syrup should show the percent of fruit juice or maple syrup contained in the product. Such information can be misleading unless the units are given. When you use percentages to express concentration, be sure to state the units (v/v) or (m/m).

16.2 Section Assessment

16. **Key Concept** How do you calculate the molarity of a solution?
17. **Key Concept** Compare the number of moles of solute before dilution with the number of moles of solute after dilution.
18. **Key Concept** What are two ways of expressing the concentration of a solution as a percent?
19. Calculate the molarity of a solution containing 400 g $CuSO_4$ in 4.00 L of solution.
20. How many moles of solute are present in 50.0 mL of 0.20*M* KNO_3?
21. How many milliliters of a stock solution of 2.00*M* KNO_3 would you need to prepare 100.0 mL of 0.150*M* KNO_3?
22. What is the concentration, in percent (v/v), of a solution containing 50 mL of diethyl ether ($C_4H_{10}O$) in 2.5 L of solution?
23. How many grams of K_2SO_4 would you need to prepare 1500 g of 5.0% K_2SO_4 (m/m) solution?

Writing Activity

Report Write a report comparing the concentration of fruit juice in different types of juice drinks. Is the percent of fruit juice given by % (v/v), or % (m/m)? Explain why these concentrations can be confusing or misleading.

Interactive Textbook

Assessment 16.2 Test yourself on the concepts in Section 16.2.

with ChemASAP

Section 16.2 Assessment

16. If the number of moles and the volume of a solution is known, its molarity is determined by dividing the moles of solute by the volume of the solution.
17. Diluting a solution reduces the number of moles of solute per unit volume, but the total number of moles of solute in solution does not change.
18. Express the concentration as the ratio of the volume of the solute to the volume of the solution (v/v) or as the ratio of the mass of the solute to the mass of the solution (m/m)
19. $6.27 \times 10^{-1}M$ $CuSO_4$
20. 1.00×10^{-2} mol KNO_3
21. 7.50 mL
22. 2.0% (v/v) diethyl ether
23. 7.5×10^{1}g K_2SO_4