Organic Chemist

Would you like to create molecular models, using state-of-the-art computers? That is one role of organic chemists, who study molecules based on carbon.

Organic chemists and chemists in related fields use computers to analyze the structure and motion of molecules. Sometimes they build a visual model of one molecule. Other times they examine entire molecular systems. This information is essential in finding new drugs and in mapping human genes. Molecular modeling is one of the fastest-growing fields in science.

Naming Acids

Water solutions of some molecules are acidic and are named as acids. Acids are important compounds with specific properties that will be discussed at length in Chapter 19. If the compound produces hydrogen ions (H^+) in solution, it is an acid. For example, HCl produces H^+ in solution and is an acid. Two common types of acids exist—binary acids and oxyacids.

Naming binary acids A binary acid contains hydrogen and one other element. When naming a binary acid, use the prefix *hydro-* to name the hydrogen part of the compound. The rest of the name consists of a form of the root of the second element plus the suffix *-ic*, followed by the word *acid*. For example, HBr in a water solution is called hydrobromic acid.

Although the term *binary* indicates exactly two elements, a few acids that contain more than two elements are named according to the rules for naming binary acids. If no oxygen is present in the formula for the acidic compound, the acid is named in the same way as a binary acid, except that the root of the second part of the name is the root of the polyatomic ion that the acid contains. For example, HCN, which is composed of hydrogen and the cyanide ion, is called hydrocyanic acid.

Naming oxyacids Another set of rules is used to name an acid that contains an oxyanion. An oxyanion is a polyatomic ion that contains oxygen. Any acid that contains hydrogen and an oxyanion is referred to as an **oxyacid.**

Because the name of an oxyacid depends on the oxyanion present in the acid, you must first identify the anion present. The name of an oxyacid consists of a form of the root of the anion, a suffix, and the word *acid*. If the anion suffix is *-ate*, it is replaced with the suffix *-ic*. When the anion ends in *-ite*, the suffix is replaced with *-ous*. Consider the oxyacid HNO_3. Its oxyanion is nitrate (NO_3^-). Following this rule, HNO_3 is named nitric acid. The anion of HNO_2 is the nitrite ion (NO_2^-). HNO_2 is nitrous acid. Notice that the hydrogen in an oxyacid is not part of the name.

It's important to remember that these hydrogen-containing compounds are named as acids only when they are in water solution. For example, at room temperature and pressure HCl is hydrogen chloride, a gas. When HCl is dissolved in water, it is hydrochloric acid.

For more practice with naming acids, go to **Supplemental Practice Problems** in Appendix A.

PRACTICE PROBLEMS

Name the following acids. Assume each compound is dissolved in water.

18. HI

19. $HClO_3$

20. $HClO_2$

21. H_2SO_4

22. H_2S

Writing Formulas from Names

The name of a molecular compound reveals its composition and is important in communicating the nature of the compound. **Figure 9-9** can help you determine the name of a molecular covalent compound.

The name of any binary molecule allows you to write the correct formula with ease. Subscripts are determined from the prefixes used in the name because the name indicates the exact number of each atom present in the molecule. The formula for an acid can be derived from the name as well.

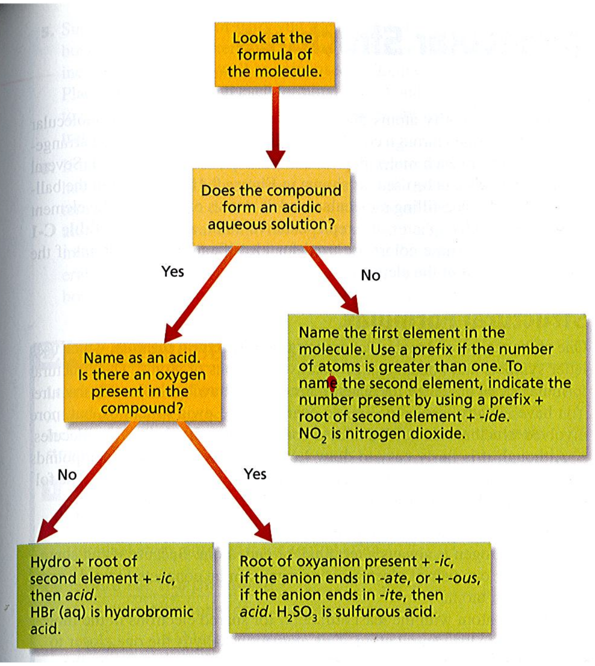


Figure 9-9

This flow chart summarizes how to name molecular compounds when their formulas are known.

Figure 15-12

The composition of this isopropyl alcohol is given in percent by volume, which is often expressed as % (v/v). What does each v in the expression 70% (v/v) refer to?

Molarity

As you have learned, percent by volume and percent by mass are only two of the commonly used ways to quantitatively describe the concentrations of liquid solutions. One of the most common units of solution concentration is molarity. **Molarity** (M) is the number of moles of solute dissolved per liter of solution. Molarity also is known as molar concentration. The unit M is read as molar. A liter of solution containing one mole of solute is a $1M$ solution, which is read as a one molar solution. A liter of solution containing 0.1 mole of solute is a $0.1M$ solution.

To calculate a solution's molarity, you must know the volume of the solution and the amount of dissolved solute.

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

For example, suppose you need to calculate the molarity of 100.0 mL of an aqueous solution containing 0.085 mole of dissolved potassium chloride (KCl). You would first convert the volume of the solution from milliliters to liters using the conversion factor 1 L = 1000 mL.

$$(100 \text{ mL})\left(\frac{1 \text{ L}}{1000 \text{ mL}}\right) = 0.1000 \text{ L}$$

Then, to determine the molarity, you would divide the number of moles of solute by the solution volume in liters.

$$\frac{0.085 \text{ mol KCl}}{0.1000 \text{ L solution}} = \frac{0.85 \text{ mol}}{\text{L}} = 0.85M$$

Do the **CHEMLAB** at the end of this chapter to learn about an experimental technique for determining solution concentration.

EXAMPLE PROBLEM 15-3

Calculating Molarity

A 100.5-mL intravenous (IV) solution contains 5.10 g of glucose ($C_6H_{12}O_6$). What is the molarity of this solution? The molar mass of glucose is 180.16 g/mol.

1. Analyze the Problem

You are given the mass of glucose dissolved in a volume of solution. The molarity of the solution is the ratio of moles of solute per liter of solution. Glucose is the solute and water is the solvent.

Known

mass of solute = 5.10 g $C_6H_{12}O_6$

molar mass of $C_6H_{12}O_6$ = 180.16 g/mol

volume of solution = 100.5 mL

Unknown

solution concentration = ?M

2. Solve for the Unknown

Use the molar mass to calculate the number of moles of $C_6H_{12}O_6$.

g	5.10
g/mol	180.16
mol	0.0283

Convert mL to L 100.5 mL = 0.1005 L

Substitute the known values into the equation for molarity and solve.

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

$$\text{molarity} = \frac{0.0283 \text{ mol } C_6H_{12}O_6}{0.1005 \text{ L solution}} = \frac{0.282 \text{ mol } C_6H_{12}O_6}{\text{L solution}} = 0.282M$$

3. Evaluate the Answer

The molarity is a small value, which is expected because only a small mass of glucose was dissolved in the solution. The mass of glucose used in the problem contained three significant figures, and therefore, the value of the molarity also has three significant figures.

To prevent dehydration, intravenous (IV) drips are administered to many hospital patients. A solution containing sodium chloride and glucose is commonly used.

PRACTICE PROBLEMS

14. What is the molarity of an aqueous solution containing 40.0 g of glucose ($C_6H_{12}O_6$) in 1.5 L of solution?
15. What is the molarity of a bleach solution containing 9.5 g of NaOCl per liter of bleach?
16. Calculate the molarity of 1.60 L of a solution containing 1.55 g of dissolved KBr.

For more practice with molarity problems, go to Supplemental Practice Problems in Appendix A.

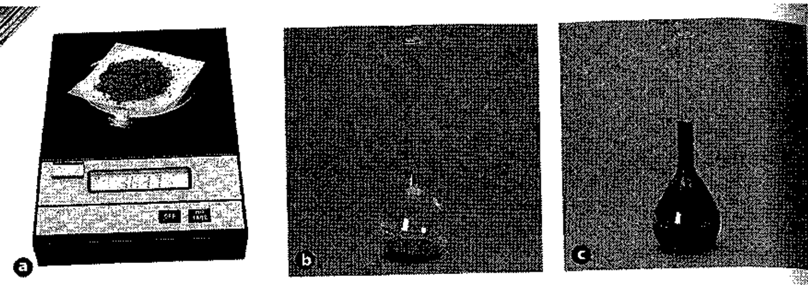


Figure 15-13

Accurately preparing a solution takes care. (a) In step 1, the mass of solute to be used is measured out. (b) In step 2, the solute is placed in a volumetric flask of the correct volume. (c) In step 3, distilled water is added to the flask to bring the solution level up to the calibration mark on the flask.

$1.5\ M = \frac{x}{1\ L}$

$1.5\ mol = x$

	$C_{12}H_{22}O_{11}$
g	513 ×
g/mol	342
mol	1.5

Preparing Molar Solutions

Now that you know how to calculate the molarity of a solution, how do you think you would prepare 1 L of a 1.50*M* aqueous solution of sucrose ($C_{12}H_{22}O_{11}$) for an experiment? A 1.50*M* aqueous solution of sucrose contains 1.50 moles of sucrose dissolved in a liter of solution. The molar mass of sucrose is 342 g. Thus, 1.50 moles of sucrose has a mass of 513 g, an amount that you can measure on a balance.

Unfortunately, you cannot simply add 513 g of sugar to one liter of water to make the 1.50*M* solution. Do you know why? Like all substances, sugar takes up space and will add volume to the solution. Therefore, you must use slightly less than one liter of water to make one liter of solution. Follow the steps shown in **Figure 15-13** to learn how to prepare the correct volume of the solution.

You often will do experiments that call for only small quantities of solution. For example, you may need only 100 mL of a 1.50*M* sucrose solution for an experiment. How do you determine the amount of sucrose to use? Look again at the definition of molarity. As calculated above, 1.50*M* solution of sucrose contains 1.50 mol of sucrose per one liter of solution. Therefore, one liter of solution contains 513 g of sucrose.

This relationship can be used as a conversion factor to calculate how much solute you need for your experiment.

$$100\ \text{mL} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times \frac{513\ \text{g}\ C_{12}H_{22}O_{11}}{1\ \text{L solution}} = 51.3\ \text{g}\ C_{12}H_{22}O_{11}$$

Thus, you would need to measure out 51.3 g of sucrose to make 100 mL of a 1.50*M* solution.

PRACTICE PROBLEMS

17. How many grams of $CaCl_2$ would be dissolved in 1.0 L of a 0.10*M* solution of $CaCl_2$?

18. A liter of 2*M* NaOH solution contains how many grams of NaOH?

19. How many grams of $CaCl_2$ should be dissolved in 500.0 mL of water to make a 0.20*M* solution of $CaCl_2$?

20. How many grams of NaOH are in 250 mL of a 3.0*M* NaOH solution?

Practice! For more practice with molarity problems, go to Supplemental Practice Problems in Appendix A.

Diluting solutions In the laboratory, you may use concentrated solutions of standard molarities called stock solutions. For example, concentrated hydrochloric acid (HCl) is 12*M*. Recall that a concentrated solution has a large amount of solute. You can prepare a less concentrated solution by diluting the stock solution with solvent. When you add solvent, you increase the number of solvent particles among which the solute particles move, as shown in **Figure 15-14**, thereby decreasing the solution's concentration. Would you still have the same number of moles of solute particles that were in the stock solution? Why?

How do you determine the volume of stock solution you must dilute? You know that

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

You can rearrange the expression of molarity to solve for moles of solute.

$$\text{Moles of solute} = \text{molarity} \times \text{liters of solution}$$

Because the total number of moles of solute does not change during dilution,

$$\text{Moles of solute in the stock solution} = \text{moles of solute after dilution}$$

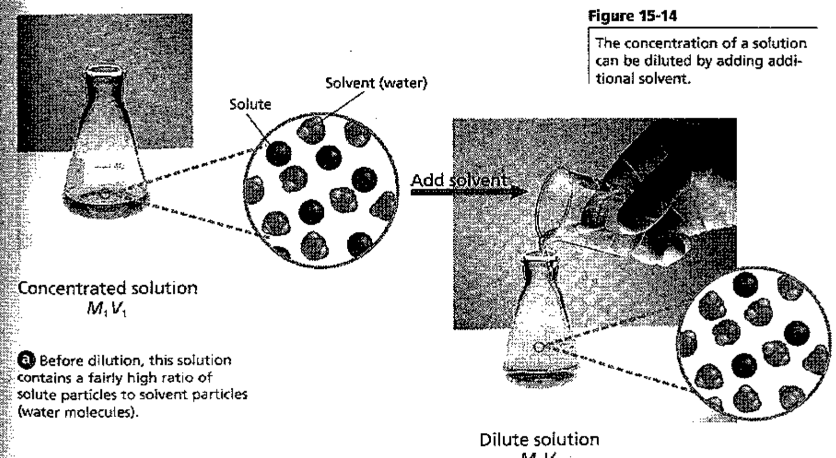
You can write this relationship as the expression

$$M_1V_1 = M_2V_2$$

where M_1 and V_1 represent the molarity and volume of the stock solution and M_2 and V_2 represent the molarity and volume of the dilute solution.

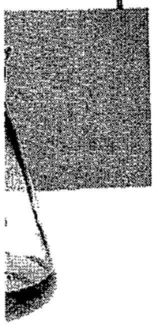
Figure 15-14

The concentration of a solution can be diluted by adding additional solvent.



(a) Before dilution, this solution contains a fairly high ratio of solute particles to solvent particles (water molecules).

(b) After adding additional solvent to the solution, the ratio of solute particles to solvent particles (water molecules) has decreased. This solution is less concentrated than the solution in (a).



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EXAMPLE PROBLEM 15-4

Diluting Stock Solutions

What volume, in milliliters of 2.00*M* calcium chloride ($CaCl_2$) stock solution would you use to make 0.50 L of 0.300*M* calcium chloride solution?

1 Analyze the Problem

You are given the molarity of a stock solution of $CaCl_2$ and the volume and molarity of a dilute solution of $CaCl_2$. Use the relationship between molarities and volumes to find the volume, in liters, of the stock solution required. Then convert the volume to milliliters.

Known	Unknown
M_1 = 2.00*M* $CaCl_2$	V_1 = ? L 2.00*M* $CaCl_2$
M_2 = 0.300*M*	
V_2 = 0.50 L	

2 Solve for the Unknown

Solve the molarity–volume relationship for the volume of the stock solution, V_1.

$M_1V_1 = M_2V_2$

Substitute the known values into the equation and solve.

(2.00)(x)=(0.300)(0.50)

2.00x = 0.15
2.00   2.00

x = 0.075 L

ers

To make the dilution, measure out 0.075 L of the stock solution and dilute it with enough water to make the final volume 0.50 L.

3 Evaluate the Answer

The volume V_1 was calculated and then its value was converted to milliliters. Of the given information, V_2 had the fewest number of significant figures with two. Thus, the volume V_1 should also have two significant figures, as it does.

21. What volume of a 3.00M KI stock solution would you use to make 0.300 L of a 1.25M KI solution?

22. How many liters of a 5.0M H SO stock solution would you need to prepare 0.1 L of a 0.25M H SO ?

23. If you dilute 20.0 mL of a 3.5M solution to make 100.0 mL of a solution, what is the molarity of the dilute solution?