Chem 170

Stoichiometric Calculations

Module Seven

Including Liquids and Solutions in Stoichiometric Calculations

Introduction to Module Seven

The examples and problems in Modules 5 and 6 assume that a compound's amount is provided in grams. This is not surprising as mass is perhaps the most fundamental of measurements (you might recall that it is one of seven base quantities in the SI system) and it is the most accurate and precise method for measuring the amount of a substance. And, of course, it is trivial to measure the mass of a solid using a laboratory balance.

What about reagents that are not solids, such as liquids and solutions?[†] The mass of a pure liquid can be measured directly in grams, although it is often more convenient to measure its volume and calculate its mass using the liquid's density. Solutions, however, are another matter entirely. A solution consists of one or more compounds, which are called solutes, dissolved in a liquid, which is also known as the solvent. The amount of solute in a given amount of solvent is the solute's concentration. Because a solution contains a minimum of two components (the solute and the solvent), we cannot directly measure a solute's mass using a balance. We can, however, measure the solution's volume and use its concentration as a unit conversion factor.

Clearly physical states are important. For this reason we need to be explicit about whether a reactant or product is a solid, a liquid, a gas, or a solute. To do this we now include the following descriptive symbols in chemical reactions: *(s)* – solid, *(l)* – liquid, *(g)* – gas, and *(aq)* – aqueous solute (dissolved in water).

Objectives for Module Seven

In this module you will learn how to express a solute's concentration, how to prepare a solution containing a known concentration of solute, and how to solve stoichiometry problems in which volumes are used to state the quantity of reagents that are liquids or solutes. In completing this module you will master the following objectives:

- to express a solute's concentration using molarity
- to calculate the moles of a solute given its molarity and volume
- to calculate the volume of solution containing a know amount of solute
- to determine how to prepare a solute of known molarity
- to calculate a solute's molarity following dilution
- to calculate the moles of a liquid given its volume and density
- to solve stoichiometry problems in which the amount of a liquid or solute is stated in terms of its volume and its density or molarity

[†] The treatment of gases is covered in the next module.

Expressing Concentrations Using Molarity

Perhaps you've read of the on-going debate involving the maximum levels of arsenic in drinking water. If so, then you may have noted that the current maximum level of arsenic is set to 50 parts-per-billion (ppb) and that there are efforts to decrease this to 10 ppb or less. But what is a part-per-billion? A ppb is defined as a nanogram of solute dissolved in a milliliter of solution; thus

$$\frac{50 \text{ ng As}}{1 \text{ mL water}} = 50 \text{ ppb As}$$

This is one example of a unit used to express a solute's concentration. Other common units include parts-per-million, molarity, molality, percent weight-to-weight, and percent weight-to-volume. Although each of these concentrations uses a different a set of units, each is a ratio expressing the amount of solute per amount of solution or solvent

$$\text{concentration} = \frac{\text{amount of solute}}{\text{amount of solution or solvent}}$$

The concentration unit of greatest interest to us in this course is molarity because it is defined in terms of the moles of solute; specifically

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

where n is the moles of solute and V is the solution's volume in liters. The symbol M is used to indicate molarity. Note that molarity is defined in terms of the solution's final volume and not the volume of solvent used to dissolve the solute. We'll return to this point in the section on preparing solutions of known molarity.

Example 1. What is the molarity of a solution prepared by dissolving 0.50 mol NaCl in enough water to give 2.5×10^2 mL of solution?

Solution. The molarity of NaCl is

$$\frac{0.50 \text{ mol NaCl}}{2.5 \times 10^2 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 2.0 \text{M NaCl}$$

As we've discussed before, laboratory balances weigh samples in grams, not moles. Calculating a solute's molarity starting with grams requires using its molar mass as a unit conversion factor.

Example 2. What is the molarity of a solution prepared by dissolving 13.67 g NaCl in enough water to give 0.1000 L of solution?

Solution. First, we find the moles of NaCl

$$13.67 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} = 0.23392 \text{ mol NaCl}$$

Next, we calculate the molarity of the resulting solution

$$\frac{0.23392 \text{ mol NaCl}}{0.1000 \text{ L}} = 2.339 \text{M NaCl}$$

Although a liquid can be weighed on a laboratory balance, it often is easier to measure its volume using a graduated cylinder or pipet. In this case the liquid's density allows us to convert the volume to moles.

Example 3. Glycerol, $C_3H_8O_3$, is a substance used extensively in the manufacture of cosmetics, foodstuffs, antifreeze, and plastics. What is the molarity of a solution prepared by using water to dilute 40.00 mL of glycerol to a total volume of 0.2500 L. Assume that the density of glycerol is 1.2656 g/mL.

Solution. We first find the moles of glycerol

$$40.00 \text{ mL } C_3H_8O_3 \times \frac{1.2656 \text{ g } C_3H_8O_3}{\text{mL } C_3H_8O_3} \times \frac{1 \text{ mol } C_3H_8O_3}{92.094 \text{ g } C_3H_8O_3} = 0.5497 \text{ mol } C_3H_8O_3$$

and then calculate the molarity of the resulting solution

$$\frac{0.5497 \text{ mol } C_3H_8O_3}{0.2500 \text{ L}} = 2.199 \text{ M NaCl}$$

Manipulating Molarity

Our equation for molarity provides a relationship between three units – molarity, moles, and volume. Examples 1-3 show how to calculate molarity given the moles, grams, or milliliters of solute and the solution's volume. Other manipulations of these units are possible. For example, we can calculate the moles of solute in a solution given its volume and molarity.

Example 4. How many moles of ammonia, NH_3, are in 35.0 mL of 2.20 M NH_3?

Solution. Solving

$$M = \frac{n}{V}$$

for moles and making appropriate substitutions gives

$$n = M \times V = 35.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{2.20 \text{ mol } NH_3}{\text{L}} = 0.0770 \text{ mol } NH_3$$

Note that molarity is a unit conversion factor for converting volume to moles.

As shown by the next example, we also can determine the volume of solution containing a desired amount of solute.

Example 5. How many milliliters of 1.50 M KOH are needed to supply 0.125 moles of KOH?

Solution. Solving

$$M = \frac{n}{V}$$

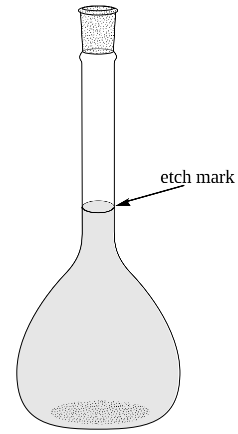
for volume and making appropriate substitutions gives

$$V = \frac{n}{M} = n \times M^{-1} = 0.125 \text{ mol KOH} \times \frac{1 \text{ L}}{1.50 \text{ mol KOH}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 83.3 \text{mL}$$

Note that the reciprocal of molarity is a unit conversion factor for converting moles to volume.

Preparing a Solution of Known Molarity

Molarity is defined as the moles of solute per liter of solution. To prepare a solution of known molarity we simply acquire the desired moles of solute and dilute to the desired volume with an appropriate solute. As noted earlier, molarity is defined in terms of the solution’s volume, not the volume of solvent. Because of this we can’t measure the necessary volume of solvent in a graduated cylinder or beaker. Instead, we transfer the solute to a special type of glassware called a volumetric flask (shown on the next page), which consists of a bulb-shaped bottom and a long neck. On the neck is an etch mark indicating the level where the flask contains its stated volume. The flask’s bulb is partially filled with solvent and swirled to dissolve the solute. Additional solvent is added to the flask until the bottom of the solvent's curved surface, which is called its meniscus, is even with the etch mark. The volumetric flask is then capped and inverted several times, while shaking, to ensure that the resulting solution is homogeneous. Volumetric flasks come in only specified volumes (5-mL, 10-mL, 25-mL, 50-mL, 100-mL, 250-mL, 500-mL, 1-L, and 2-L are commonly available) so solutions must be made to one of these volumes.



Solutes may be solids, liquids, or other solutions. When the solute is a solid then it is easy to calculate the amount needed, weigh it out using a balance, and bring it to volume in a suitable volumetric flask.

Example 6. How many grams of ammonium chloride, NH_4Cl, are needed to prepare 500.0 mL of 0.125 M NH_4Cl?

Solution. Using the same approach as in Example 4, we calculate the moles of NH_4Cl needed, converting this to grams using ammonium chloride's molar mass as an additional unit conversion factor.

$$500.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.125 \text{ mol NH}_4\text{Cl}}{1 \text{ L}} \times \frac{53.49 \text{ g NH}_4\text{Cl}}{\text{mol NH}_4\text{Cl}} = 3.343 \text{ g NH}_4\text{Cl}$$

When the solute is a pure liquid it is possible to weigh out the desired amount of solute, calculating the necessary amount in the same way as outlined in Example 6 for a solid. Often it is easier to obtain a known volume of a liquid or a solution using a graduated cylinder or a pipet. As shown in Example 7, a solution's density and mass percent provides a unit conversion factor for converting the volume to the corresponding mass (for a pure liquid you only need the density as its mass percent is 100%; see Example 3, for instance).

Example 7. How many milliliters of glacial acetic acid, $C_2H_4O_2$, are needed to prepare 0.250 L of a 2.00-M solution? The density of glacial acetic acid is 1.049 g/mL and it is 99.8% acetic acid by mass.

Solution. Using the same approach as the previous example, we calculate the moles of $C_2H_4O_2$ needed, converting this to grams using glacial acetic acid's molar mass and converting this mass to milliliters using the mass percent and density of glacial acetic acid.

$$0.250 \text{ L} \times \frac{2.00 \text{ mol C}_2\text{H}_4\text{O}_2}{\text{L}} \times \frac{60.05 \text{ g C}_2\text{H}_4\text{O}_2}{\text{mol C}_2\text{H}_4\text{O}_2} \times \frac{100 \text{ g sol'n}}{99.8 \text{ g C}_2\text{H}_4\text{O}_2} \times \frac{1 \text{ mL sol'n}}{1.049 \text{ g sol'n}} = 28.7 \text{ mL}$$

Another common way to prepare solutions is to begin with a stock solution of the solute whose concentration is greater than that we are trying to prepare. Many laboratories, for example, maintain a supply of stock acid solutions, such as 6 M HCl or 6 M HNO_3. To prepare a solution of HCl with a concentration of less than 6 M, we take a portion of the stock solution and place it in a suitable volumetric flask, diluting with water to the flask's etch mark. This process is called a dilution. It is easy to calculate the volume of stock solution needed. If we take a volume, V_1, of a stock solution of molarity M_1, the moles of solute taken, n, is

$$n = M_1 \times V_1$$

This solute is then transferred to a volumetric flask of volume V_2, giving a dilute solution of molarity M_2, where

$$M_2 = \frac{n}{V_2}$$

Because n is the same for both equations, we can combine them, giving

$$M_1 \times V_1 = M_2 \times V_2$$

Given any three of these variables, it is easy to calculate the fourth. Note that the units for volume are not critical; we may use milliliters or liters (or any other unit for expressing volume, such as the fluid ounce), provided that the same unit is used for both V_1 and V_2. As shown in Example 8, it is easy to find the molarity of a new solution prepared by diluting a more concentrated solution.

Example 8. What is the molarity of a solution prepared by diluting 15.00 mL of 6.00 M HCl to volume in a 250.0-mL volumetric flask.

Solution. Using the equation

$$M_1 \times V_1 = M_2 \times V_2$$

we solve for M_2; thus

$$M_2 = \frac{M_1 \times V_1}{V_2} = \frac{6.00 \text{ M HCl} \times 15.00 \text{ mL}}{250.0 \text{ mL}} = 0.360 \text{ M HCl}$$

In addition, we can calculate the volume of a concentrated stock solution that is needed to prepare a dilute solution.

Example 9. An experiment calls for a solution of 1.00 M HCl. How many milliliters of 6.00 M HCl are needed to make 500.0 mL of this solution?

Solution. Using the equation

$$\mathrm{M}_1 \times V_1 = \mathrm{M}_2 \times V_2$$

we solve for V_1; thus

$$V_1 = \frac{\mathrm{M}_2 \times V_2}{\mathrm{M}_1} = \frac{1.00 \text{ M HCl} \times 500.0 \text{ mL}}{6.00 \text{ M HCl}} = 83.3 \text{ mL}$$

Example 9 assumes that the stock solution is of a single chemical. In some cases the stock solution actually is a complicated mix of reagents. For example, a common reagent found in many biochemistry labs is an SDS-PAGE solution containing a Tris buffer, sodium dodecyl sulfate and glycine. Instead of listing the molar concentration of each component, the stock solution is simply identified as 10X, meaning its concentration is 10 times greater than the final concentration (which is 1X) that will be used in lab. As shown in the following example, it is relatively easy to incorporate this into a dilution calculation.

Example 10. How many mL of a 10X SDS-PAGE solution do you need to prepare 500.0 ml of a 1X solution?

Solution. Using the equation

$$\mathrm{M}_1 \times V_1 = \mathrm{M}_2 \times V_2$$

where M_1 is 10X and M_2 is 1X, we solve for V_1; thus

$$V_1 = \frac{\mathrm{M}_2 \times V_2}{\mathrm{M}_1} = \frac{\text{1X SDS-PAGE} \times 500.0 \text{ mL}}{\text{10X SDS-PAGE}} = 50.00 \text{ mL}$$

Don’t confuse the use of X in Example 10 as a variable for which you are solving. It simply serves as a shorthand notation for “fold.” The terms 1X and 10X, therefore, read as “one-fold” and “ten-fold,” respectively.

Liquids, Solutions and Stoichiometry Problems

Now that you know how to calculate and manipulate molarity, it is easy to include molarity in stoichiometry problems similar to those in Modules 5 and 6. For instance, in Example 6 of Module 5 we found the mass of water produced during the combustion of 790 g of octane. Because octane is a liquid, we can also solve the problem by starting with the volume of octane and its density.

Example 11. How many grams of water are expected from the combustion of 1.00 L of octane, C_3H_8, Octane has a density of 0.79 g/mL and the balanced combustion reaction is

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$$

Solution. Using octane's density, we first convert the volume of octane to grams and then continue as in Example 5 of Module 6.

$$1.0\ \text{L}\ C_8H_{18} \times \frac{1000\ \text{mL}\ C_8H_{18}}{1\ \text{L}\ C_8H_{18}} \times \frac{0.79\ \text{g}\ C_8H_{18}}{\text{mL}\ C_8H_{18}} = 7.90 \times 10^2\ \text{g}\ C_8H_{18}$$

$$7.90 \times 10^2\ \text{g}\ C_8H_{18} \times \frac{1\ \text{mol}\ C_8H_{18}}{114.2\ \text{g}\ C_8H_{18}} \times \frac{18\ \text{mol}\ H_2O}{2\ \text{mol}\ C_8H_{18}} \times \frac{18.02\ \text{g}\ H_2O}{1\ \text{mol}\ H_2O} = 1.12 \times 10^3\ \text{g}\ H_2O$$

Including solutions in a limiting reagent calculation also is straightforward.

Example 12. Many metals dissolve in hydrochloric acid, HCl, forming hydrogen, H_2, as a product. For example, the reaction of zinc, Zn, with HCl is

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

How many grams of H_2 are produced by reacting 3.56 g Zn with 45.0 mL of 2.00 M HCl?

Solution. We first find the limiting reagent by converting grams of Zn and mL of HCl to grams of H_2

$$3.56\ \text{g Zn} \times \frac{1\ \text{mol Zn}}{65.38\ \text{g Zn}} \times \frac{1\ \text{mol}\ H_2}{1\ \text{mol Zn}} \times \frac{2.016\ \text{g}\ H_2}{\text{mol}\ H_2} = 0.110\ \text{g}\ H_2$$

$$45.0\ \text{ml} \times \frac{1\text{L}}{1000\ \text{mL}} \times \frac{2.00\ \text{mol HCl}}{\text{L}} \times \frac{1\ \text{mol}\ H_2}{2\ \text{mol HCl}} \times \frac{2.016\ \text{g}\ H_2}{\text{mol}\ H_2} = 0.0907\ \text{g}\ H_2$$

Because 45.0 mL of 2.00 M HCl produces fewer grams of H_2 than 3.56 g Zn, HCl is the limiting reagent and the theoretical yield of H_2 is 0.0907 g.

An important class of reactions involving solutions is a titration. In a titration we react a solution containing a reactant whose molarity is known with a solution containing a reactant, also called the analyte, whose molarity is unknown. One solution is added to the other until the reaction between the reactants is just complete; that is, they are mixed stoichiometrically such that both are the limiting reagents. The moles of the two reactants are related by the reaction's stoichiometry.

Example 13. Find the molarity of a solution of sulfuric acid, H_2SO_4, if it takes 16.1 mL of 0.610 M NaOH to titrate 20.0 mL of the solution. The balanced titration reaction is

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow 2H_2O(l) + Na_2SO_4(aq)$$

Solution. The moles of H_2SO_4 reacting with the NaOH is

$$16.1\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{0.610\text{ mol NaOH}}{\text{L}} \times \frac{1\text{ mol } H_2SO_4}{2\text{ mol NaOH}} = 4.91 \times 10^{-3}\text{ mol } H_2SO_4$$

Substituting into the equation for molarity gives the concentration of H_2SO_4 as

$$\frac{4.91 \times 10^{-3}\text{ mol } H_2SO_4}{20.0\text{ mL} \times \dfrac{1\text{ L}}{1000\text{ mL}}} = 0.246\text{ M } H_2SO_4$$

Practice Problems

The following problems provide practice in meeting this module's objectives. Answers are provided in parentheses. Be sure to seek assistance if you experience difficulty with any of these problems. When you are ready, schedule an appointment for the module exam.

1. What is the molarity of a solution containing 0.0715 mol Na_2SO_4 in 635 mL of solution.

2. Ordinary household bleach is an aqueous solution of sodium hypochlorite, NaOCl. What is the molarity of sodium hypochlorite in a bleach solution containing 20.5 g NaOCl in a total volume of 375 mL?

3. Bottles of concentrated acids, such as phosphoric acid, H_3PO_4, often list the acid's density and its mass percent. For example, concentrated solutions of phosphoric acid have a density of 1.69 g/mL are 85.5% H_3PO_4. What is the molarity of a solution of concentrated phosphoric acid?

4. Sodium chloride, NaCl, and calcium chloride, $CaCl_2$, are soluble chloride salts; that is, solutions of these salts contain chloride ions, Cl^-. Which of the following solutions

   40.0 mL of 0.35 M NaCl or 40.0 mL of 0.25 M $CaCl_2$

   contains the most moles of chloride ion? How many grams of Cl^- are in that solution?

5. Muriatic acid is an industrial grade form of concentrated hydrochloric acid, HCl, that is used for cleaning masonry and etching cement prior to painting. Its concentration is 11.7 M HCl. How many milliliters of this solution are needed to obtain 9.55 g HCl?

6. Explain how you would prepare exactly 250 mL of 0.125 M Na_2SO_4 starting with solid Na_2SO_4.

7. A bottle of concentrated ammonia, NH_3, has a density of 0.90 g/mL and is 28.0% NH_3 by mass. How many milliliters of this solution are needed to prepare 0.50 L of 2.0 M NH_3?

8. Insulin is a hormone that controls the body's use of glucose. How many milliliters of a 0.0100 M stock solution are needed to prepare 50.00 mL of 4.80×10^{-3} M insulin?

9. When preparing a solution in which the reagent's concentration is very low, it is sometimes necessary to use a serial dilution. Here's how it works. First, you prepare

a more concentrated solution of the reagent. Then, you prepare a more dilute solution by performing one or more dilutions. For example, suppose that you prepare a stock solution by placing 1.123 g $K_2Cr_2O_7$ in a 1000-mL volumetric flask and dilute to volume. Next, 10.00 mL of this solution is placed in a 250.0-mL volumetric flask and diluted to volume. Finally, 1.00 mL of this solution is placed in a 100.0-mL volumetric flask and diluted to volume. What is the molar concentration of the last solution?

10. Solutions of approximate concentration can be prepared by diluting a measured portion of a stock solution with a known volume of water. Because we must assume that the volumes are additive, the calculated molarity of the resulting solution is considered approximate. What is the approximate concentration of a dilute solution of nitric acid, HNO_3, prepared by mixing together 50 mL of 6.0 M HNO_3 and 250 mL of water. Report your answer to two significant figures.

11. A solution of TBE, a common reagent in biochemistry, contains a Tris buffer, borate and EDTA. If you take a 75.0 mL portion of a 5X solution of TBE, to how many mL should you dilute it to obtain a 1X solution of TBE?

12. To visualize a clear solution, biochemists sometimes add a blue dye to the solution. The dye is purchased as a 6X solution. In preparing a sample for analysis you need to add enough of the 6X dye solution so that the final dye's final concentration is 1X. How many μL of the 6X dye solution and how many μL of water must you add to 5 μL of your sample if the total volume is to be 24 μL?

13. Commercial products for dissolving rust, Fe_2O_3, often are solutions containing oxalic acid, $H_2C_2O_4$. Washing the rusted surface with the oxalic acid solution dissolves the rust as shown by the following balanced chemical reaction

$$Fe_2O_3\mathit{(s)} + 6H_2C_2O_4\mathit{(aq)} \rightarrow 2Fe(C_2O_4)_3^{3-}\mathit{(aq)} + 3H_2O\mathit{(l)} + 6H^+\mathit{(aq)}$$

What is the maximum grams of rust that can be removed by 1.00×10^2 mL of 0.152 M $H_2C_2O_4$?

14. One of your farming friends asks for your assistance in preparing the phosphate fertilizer $Ca(H_2PO_4)_2$. A simple method for making this fertilizer is by the reaction of calcium phosphate, $Ca_3(PO_4)_2$, with phosphoric acid, H_3PO_4.

$$Ca_3(PO_4)_2\mathit{(aq)} + 4H_3PO_4\mathit{(aq)} \rightarrow 3Ca(H_2PO_4)_2\mathit{(aq)}$$

You have available 100.0 L of 3.50 M $Ca_3(PO_4)_2$ but need to purchase bottles of concentrated phosphoric acid, each bottle of which has a concentration of 14.7 M H_3PO_4 and a volume of 2.5 L. How many such bottles do you need to use up all the calcium phosphate?

15. When solutions of potassium hydroxide, KOH, and magnesium nitrate, $Mg(NO_3)_2$, are mixed, a precipitate of magnesium hydroxide, $Mg(OH)_2$, forms. The balanced chemical reaction is

$$2KOH(aq) + Mg(NO_3)_2(aq) \rightarrow Mg(OH)_2(s) + 2KNO_3(aq)$$

Suppose that you mix together 100.0 mL of 0.200 M KOH and 75.0 mL of 0.150 M $Mg(NO_3)_2$. What is the theoretical yield of $Mg(OH)_2$ in grams? How many grams of the excess reagent remain unreacted?

16. One of the methods for producing hydrofluoric acid, HF, is by the reaction of the mineral fluorite, CaF_2, with sulfuric acid, H_2SO_4. The balanced chemical reaction is

$$CaF_2(s) + H_2SO_4(aq) \rightarrow CaSO_4(s) + 2HF(aq)$$

Upon reacting 6.40 kg of CaF_2 with 25.0 L of 3.00 M H_2SO_4, a total of 2.50 kg of HF are obtained. What are the theoretical and percent yields for HF?

17. The concentration of a potassium hydroxide solution, which is a strong base, is often determined by titrating a sample of potassium hydrogen phthalate, $KHC_8H_4O_4$, which is a weak acid. The balanced chemical reaction is

$$KOH(aq) + KHC_8H_4O_4(s) \rightarrow H_2O(l) + K_2C_8H_4O_4(aq)$$

What is the concentration of KOH if 23.96 mL of the solution are required to react completely with 0.5627 g $KHC_8H_4O_4$?

18. The concentration of hydrogen peroxide, H_2O_2, in a solution may be determined by titrating with a solution containing the permanganate ion, MnO_4^-. The balanced reaction between them is

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(l)$$

Titrating a 10.00-mL sample of a drug store's hydrogen peroxide solution requires 15.22 mL of 0.1038 M MnO_4^- to reach completion. What is the molarity of the hydrogen peroxide solution?

Answers to Practice Problems

1. 0.113 M Na_2SO_4
2. 0.734 M NaOCl
3. 14.7 M H_3PO_4
4. $CaCl_2$, 0.71 g Cl^-
5. 22.4 mL
6. place 4.44 g Na_2SO_4 in a 250-mL volumetric flask and dilute to the flask's etch mark
7. 68 mL
8. 24.0 mL
9. 1.53×10^{-6} M $K_2Cr_2O_7$
10. 1.0 M HNO_3
11. 375 mL
12. 4 μL of 6X dye and 15 μL of H_2O
13. 0.405 g Fe_2O_3
14. minimum of 39 bottles
15. 0.583 g $Mg(OH)_2$, 0.185 g $Mg(NO_3)_2$
16. 3.00 kg HF, 83.3% yield
17. 0.1150 M KOH
18. 0.3950 M H_2O_2