84-1201

Carolina's Solution Preparation Manual

Instructions

Carolina Biological Supply Company has created this reference manual to enable you to prepare solutions. Although many types of solutions may be purchased from Carolina Biological Supply Company, you may wish to prepare these solutions yourself. The procedures in this manual will allow you to make almost any solution that you may require in your laboratory. Keep this manual in a convenient location and refer to it often.

Remember: Always follow appropriate lab safety procedures when mixing and storing chemicals.

Remember:

When mixing and repackaging chemicals, label properly.

Chemical Grades

In order of purity, from highest to lowest.

ACS

> Highest quality; often equals or exceeds the latest purity standards set by the American Chemical Society (ACS). This is the only universally accepted standard. Chemicals are of the highest purity attainable.

Reagent

> Purity is generally equal to ACS grade. This grade is suitable for analytical work and is more than adequate for general lab use.

USP

> A grade of sufficient purity to pass certain tests prescribed by the U.S. Pharmacopoeia (USP); acceptable for drug use. May be used for most laboratory purposes.

Lab

> An upper-level intermediate quality. Exact impurities may not be known; however, usually pure enough for most educational laboratories.

When a substance, called a *solute*, is dissolved in another substance, called the *solvent*, a *solution* is formed. A solution is a uniform distribution of solute in solvent. For example, vinegar is a solution of acetic acid (the solute) in water (the solvent). The amount of solute in a solvent is important and can be expressed in several different ways. Some common units of concentration will be discussed in this manual.

When making a solution, one must first decide what degree of chemical purity is needed. Many types of chemicals are available in several grades of purity. Most of the chemicals listed in our catalog belong to one of the following three categories, in order from least pure to most pure.

<div align="center">

Laboratory

Reagent

ACS

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Choose the most appropriate grade based on need and cost. Laboratory-grade chemicals, due to their low cost and good chemical purity, find wide use in educational applications, such as teaching laboratories at both the secondary school and college levels. Use reagent-grade chemicals when conducting quantitative analyses. ACS-grade chemicals are certified to

meet the stringent specifications for purity as set forth by the American Chemical Society Committee on Analytical Reagents.

Carolina also offers a choice of packaging for a limited number of chemicals. Corrosive chemicals, such as concentrated acids, are normally packaged in glass bottles. For safety and convenience, our customers can order these chemicals packaged in plastic-coated safety bottles. A plastic-coated safety bottle will not shatter when dropped, which helps to contain the spill and simplify cleanup. Look at the item descriptions in the chemical section of the catalog for those chemicals available in plastic-coated safety bottles.

For safety purposes, read a chemical's label twice before use. Read the label first when you take the chemical off the shelf, and again before you remove any chemical from the bottle. When preparing solutions using concentrated chemicals, slowly add the more concentrated solution to the less concentrated one. The reverse procedure can cause the solution to boil and spatter.

Solution Preparation

1. Molar solutions

   Molarity (M) means the number of moles of solute per liter of solution. To prepare a 1 M solution, slowly add 1 gram formula weight of compound to a clean 1-L volumetric flask half filled with distilled or deionized water. Allow the compound to dissolve completely, swirling the flask gently if necessary. Once the solute is completely dissolved and the solution is at room temperature, dilute to the mark with water. Invert the flask several times to mix.

   To make a 1 M solution of sodium hydroxide, slowly add 40 g sodium hydroxide to 500 mL distilled or deionized water in a 1000-mL volumetric flask. When all the solid is dissolved and the solution is at room temperature, dilute to the mark and invert the flask several times to mix.

   To make a 1 M solution acetic acid, dissolve 60.05 g acetic acid in 500 mL distilled or deionized water in a 1000-mL volumetric flask. Because acetic acid is a liquid, the acid may also be measured by volume. Divide the mass of acid by its density (1.049 g/mL) to determine the volume (57.24 mL). Use either 60.05 g or 57.24 mL acetic acid to make the solution. Swirl the flask gently to mix the solution. When the solution is at room temperature, dilute to the mark and invert the flask several times to mix.

2. Percent solutions

a. *Mass percent* means the number of grams of solute per 100 g of solution. For example, 10 g sodium chloride in 90 g water is a 10% by mass solution.

mass percent = mass of solute/mass of solution

$$= 10 \text{ g}/(10 \text{ g} + 90 \text{ g}) \times 100\%$$

$$= 10\%$$

b. *Volume percent* means the number of milliliters of solute per 100 mL of solution. The volume percent of a solution cannot be calculated directly from the volumes of its components because the final volume may not equal the sum of the components' volumes. To prepare volume percent solutions, first determine the final volume and concentration of solution desired and then determine the amount of solute. Dilute the solute in sufficient solvent to produce the final volume of solution desired. For example, to prepare 100 mL of a 10% by volume solution of acetic acid, dilute 10 mL acetic acid with distilled or deionized water to make 100 mL of solution.

Note: Solutions of concentrated reagents, such as 37% hydrochloric and 85% phosphoric acids, are percent solutions by mass. In general, percent solutions are by mass.

3. Dilutions

When preparing a dilution, decide the volume and molar concentration of the resulting solution you require. Use the following equation to determine how much of the concentrated reagent is needed to prepare the diluted solution,

$$M_{reagent} \times V_{reagent} = M_{dilution} \times V_{dilution}$$

where *M* is molarity and *V* is volume.

Slowly add the calculated volume of concentrated reagent to the proper-size volumetric flask half filled with distilled or deionized water and swirl the flask to mix. Once the solution is at room temperature, dilute to the mark with water and invert the flask several times to mix.

For example, what volume of 10 M acetic acid is required to prepare 1.0 L of 0.50 M acetic acid?

$$10 \text{ M} \times V_{reagent} = 0.50 \text{ M} \times 1.0 \text{ L}$$

$$V_{reagent} = 0.050 \text{ L} = 50 \text{ mL}$$

A volume of 50 mL of 10 M acetic acid is required to prepare 1.0 L of 0.50 M acetic acid.

4. Special cases

Often it is necessary to prepare solutions from chemicals that are less than 100% pure. To prepare solutions from these impure chemicals, first choose the volume and molarity of the resulting solution you require. Multiply the solution's volume by its molarity. The product *(n)* is the number of moles of pure chemical needed to produce that solution.

$$M_{pure} \times V_{pure} = n_{pure}$$

Because the percent purity of chemicals sold commercially is measured by mass, first calculate the mass of the pure chemical needed to make the solution. Multiply the number of moles of pure chemical times the gram formula weight of the chemical.

mass of pure chemical = $n_{pure} \times$ gram formula weight

(1) mass of pure chemical = $M_{pure} \times V_{pure} \times$ gram formula weight

The mass of the impure chemical times the percent purity equals the mass of the pure chemical. Divide the mass of pure chemical by the percent purity to yield the mass of the impure chemical.

mass of impure chemical $\times$ percent purity = mass of pure chemical

(2) mass of impure chemical = mass of pure chemical/percent purity

Substitute the expression for mass of pure chemical from equation (1) into equation (2).

mass of impure chemical = $M_{pure} \times V_{pure} \times$ gram formula weight/percent purity

For example, what mass of potassium hydroxide that is 85.9% pure is needed to prepare 1.0 L of a 0.25 M solution of potassium hydroxide? The gram formula weight of potassium hydroxide is 56.11 g/mol.

mass of impure chemical = $M_{pure} \times V_{pure} \times$ gram formula weight/percent purity

= 0.25 M $\times$ 1.0 L $\times$ 56.11 g/mol $\div$ 0.859

= 16 g

If the chemical in question is a liquid, then one more calculation is required. Divide the mass of impure chemical by its density to yield the volume of chemical.

volume of impure = mass of impure chemical in g/density of impure
  chemical in mL   chemical in grams per milliliter

Again, combine the previous equations.

volume of impure chemical = $M_{pure} \times V_{pure} \times$ gram formula weight/
(percent purity $\times$ density)

For example, what volume of hydrochloric acid that is 37.1% pure is needed to prepare 1.0 L of a 0.10 M solution of hydrochloric acid? The gram formula weight of hydrochloric acid is 36.46 g/mol and the density of 37.1% hydrochloric acid is 1.200 g/mL.

volume of impure chemical = $M_{pure} \times V_{pure} \times$ gram formula
weight/(percent purity $\times$ density)

$= 0.10 \text{ M} \times 1.0 \text{ L} \times 36.46 \text{ g/mol} \div$
$(0.371 \times 1.200 \text{ g/mL})$

$= 8.2 \text{ mL}$

5. Normal solutions

Another concentration term sometimes used is *normality.* Normality (N) means the number of equivalents of solute per liter of solution. An equivalent is defined separately for acid-base and reduction-oxidation (redox) chemistry. In acid-base chemistry, an equivalent is the mass of chemical that donates or accepts one mole of protons. For example, sulfuric acid is a diprotic acid. One-half mole of sulfuric acid therefore provides one mole of protons. To prepare a 1 N solution of sulfuric acid, slowly add one-half gram formula weight of sulfuric acid to a clean 1-L volumetric flask and fill to the mark with distilled or deionized water. In redox chemistry, an equivalent is the mass of chemical that donates or accepts one mole of electrons. Determine the number of electrons a chemical donates or accepts from its half-reaction. For example, one mole of aluminum (III) reacts with three moles of electrons to give one mole of aluminum metal.

$$Al^{3+} + 3e^- \rightarrow Al$$

To prepare a 1 N solution of aluminum (III), slowly add one-third gram formula weight of an aluminum (III) compound to a clean 1-L volumetric flask, and fill to the mark with distilled or deionized water.

Recipes for Common Solutions

Listed below are solutions of several common concentrated acids and ammonia.

Substance	Molarity	Mass Percentage
Acetic acid, $HC_2H_3O_2$	17.4 M	99.7%
Ammonia, NH_3	14.8 M	28.0%
Hydrochloric acid, HCl	12.1 M	38.7%
Nitric acid, HNO_3	15.8 M	69.7%
Sulfuric acid, H_2SO_4	18.1 M	98.0%

The following chart shows how one can mix various dilutions. To prepare one of these solutions, slowly add the necessary ingredients to a 1-L volumetric flask half filled with distilled or deionized water. Allow the ingredients to dissolve completely, swirling the flask gently if necessary. Once the solute is completely dissolved and the solution is at room temperature, dilute to the mark with water. Invert the flask several times to mix.

For your convenience, we have listed the Carolina Biological Supply Company catalog numbers for all reagents. For the liquids, we have referenced the 500-mL size of the reagent- (or ACS-) grade chemical packaged in a plastic-coated safety bottle, and for sodium hydroxide, the 500-g size of the reagent-grade chemical. Other sizes and grades may be available. Please consult our catalog for a complete listing.

Carolina Catalog #	Solution	Quantity to Add to 1 L Water	Final Concentration
84-1291	Acetic acid, glacial (17.4 M)	5.72 mL acetic acid	0.1 M
		57.2 mL acetic acid	1 M
		172 mL acetic acid	3 M
86-7791	Hydrochloric acid (12.1 M)	8.21 mL hydrochloric acid	0.1 M
		82.1 mL hydrochloric acid	1 M
		246 mL hydrochloric acid	3 M
		821 mL hydrochloric acid	10 M
88-9470	Sodium hydroxide	4.00 g sodium hydroxide	0.1 M
		40.0 g sodium hydroxide	1 M
		80.0 g sodium hydroxide	2 M
		120 g sodium hydroxide	3 M
		200 g sodium hydroxide	5 M
89-3301	Sulfuric acid (18.1 M)	2.67 mL sulfuric acid	0.05 M
		5.33 mL sulfuric acid	0.1 M
		53.3 mL sulfuric acid	1 M
		160 mL sulfuric acid	3 M
		267 mL sulfuric acid	5 M

Practice Problems

1. Molar solutions

   a. Describe how you would prepare 1 L of a 1 M solution of sodium chloride. The gram formula weight of sodium chloride is 58.44 g/mol.

      Answer: To make a 1 M solution sodium chloride, dissolve 58.44 g sodium chloride in 500 mL water in a 1000-mL volumetric flask. When all the solid is dissolved and the solution is at room temperature, dilute to the mark and then invert the flask several times to mix.

   b. Describe how you would prepare 1 L of a 2 M solution of acetic acid. The gram formula weight of acetic acid is 60.05 g/mol, and its density is 1.049 g/mL.

      Answer: To make a 2 M solution of acetic acid, dissolve 120.1 g acetic acid in 500 mL distilled or deionized water in a 1000-mL volumetric flask. Since acetic acid is a liquid, the acid may also be measured by volume. Divide the mass of acid by its density (1.049 g/mL) to determine the volume (114 mL). Use either 120.1 g or 114 mL acetic acid to make the solution. Swirl the flask gently to mix the solution. Once the solution is at room temperature, dilute to the mark and then invert the flask several times to mix.

2. Percent solutions

   a. Describe how you would prepare 100 g of a solution that is 0.5% phenolphthalein by mass.

      Answer: Mass percent means the number of grams of solute per 100 g of solution.

      $$\text{mass percent} = (\text{mass of solute/mass of solution}) \times 100\%$$

      $$\text{mass of solute} = \text{mass percent} \times \text{mass of solution}/100\%$$
      $$= 0.5\% \times 100 \text{ g}/100\%$$
      $$= 0.5 \text{ g}$$

   Since the total mass of the solution equals 100 g, the remaining 99.5 g of the solution is water. To prepare the solution, dissolve 0.5 g phenolphthalein in 99.5 g distilled or deionized water.

   b. Describe how you would prepare 100 mL of a solution that is 22% acetic acid by volume.

Answer: Volume percent means the number of milliliters of solute per 100 mL of solution. Dilute 22 mL acetic acid with distilled or deionized water to make 100 mL of solution.

3. Dilutions
   a. Describe how you would prepare 1.0 L of a 0.10 M solution of sulfuric acid from a 3.0 M solution of sulfuric acid.
      Answer: Calculate the volume of 3.0 M sulfuric acid needed to prepare the dilution.

$$M_{reagent} \times V_{reagent} = M_{dilution} \times V_{dilution}$$
$$3.0 \text{ M} \times V_{reagent} = 0.10 \text{ M} \times 1.0 \text{ L}$$
$$V_{reagent} = 0.033 \text{ L} = 33 \text{ mL}$$

   Slowly add 33 mL of 3.0 M sulfuric acid to a 1000-mL volumetric flask half filled with distilled or deionized water and swirl the flask to mix. Once the solution is at room temperature, dilute to the mark with water and then invert the flask several times to mix.
   b. Describe how you would prepare 500 mL of a 0.25 M solution of sodium hydroxide from a 5.0 M solution of sodium hydroxide.
      Answer: Calculate the volume of 5.0 M sodium hydroxide needed to prepare the dilution.

$$M_{reagent} \times V_{reagent} = M_{dilution} \times V_{dilution}$$
$$5.0 \text{ M} \times V_{reagent} = 0.25 \text{ M} \times 0.500 \text{ L}$$
$$V_{reagent} = 0.025 \text{ L} = 25 \text{ mL}$$

   Slowly add 25 mL of 5.0 M sodium hydroxide to a 500-mL volumetric flask half-filled with distilled or deionized water and swirl the flask to mix. Once the solution is at room temperature, dilute to the mark with water and then invert the flask several times to mix.

4. Special cases
   a. Describe how you would prepare 500 mL of a 1.0 M solution of potassium chloride that is 93.0% pure. The gram formula weight of potassium chloride is 74.56 g/mol.
      Answer: Calculate the mass of impure potassium chloride needed.

mass of impure potassium chloride = $M_{pure} \times V_{pure} \times$ gram formula weight/percent purity

$$= \frac{1.0\ M \times 0.500\ L \times 74.56\ g/mol}{0.930}$$

$$=\ 40\ g$$

Slowly add 40 g of 93% potassium chloride to a 500-mL volumetric flask half filled with distilled or deionized water and swirl the flask to mix. When all the solid is dissolved and the solution is at room temperature, dilute to the mark and invert the flask several times to mix.

b. Describe how you would prepare 500 mL of a 1.0 M solution of phosphoric acid from phosphoric acid that is 85.0% pure. The gram formula weight of phosphoric acid is 98.00 g/mol, and the density of 85.0% phosphoric acid is 1.685 g/mL.

Answer: Calculate the volume of 85.0% phosphoric acid needed.

volume of impure = $M_{pure} \times V_{pure} \times$ gram formula weight/
phosphoric acid   (percent purity $\times$ density)

$$= \frac{(1.0\ M \times 0.500\ L \times 98.00\ g/mol)}{0.850 \times 1.685\ g/mL}$$

$$= 34\ mL$$

Slowly add 34 mL of 85.0% phosphoric acid to a 500-mL volumetric flask half filled with distilled or deionized water and swirl the flask to mix. Once the solution is at room temperature, dilute to the mark with water and invert the flask several times to mix.

Remember:

Take the time to teach science safely.

Carolina Biological Supply Company