Preparing Dilutions

8.7

Have you ever purchased products, perhaps cleaners or fruit juice, in concentrated form? If so, you probably diluted them before use. This is usually the most economical way to purchase the product because it is in a smaller container (therefore requiring less packaging) and you do not have to pay for transporting the extra water (therefore being cheaper to ship). These factors also make the concentrated product a more environmentally friendly choice over the diluted product.

Solutions that are frequently used in a laboratory are also often purchased in a concentrated form. Not only is this the most economical way to purchase these chemicals, but it also saves valuable storage space in the lab. These solutions are rarely used directly in the laboratory. Instead, they are first diluted with water prior to use in individual investigations.

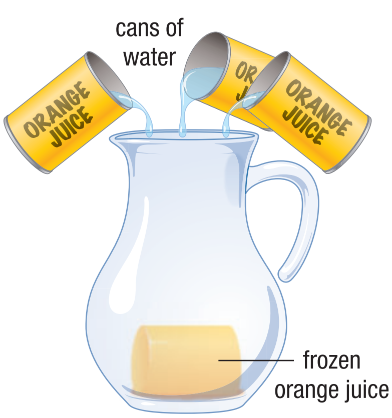

Figure 1 Three cans of water are added to one can of orange juice concentrate. The final volume is four times the original volume. The final concentration is one-fourth the original concentration.

Dilution

SKILLS HANDBOOK A3.3, A3.4

Dilution is the process of reducing the concentration of a solution by adding more solvent. A familiar example of dilution is preparing orange juice from a can of frozen concentrate. This usually involves diluting the concentrate with three cans of water (**Figure 1**). After dilution, the concentrate is diluted to four times its original volume (the original can + 3 cans of water = 4 cans). Therefore, the starting juice concentration is reduced by a factor of 4. Similarly, diluting 1.0 L of a 12 mol/L hydrochloric acid solution to 4.0 L decreases its concentration by a factor of 4. Therefore, the final concentration is 3.0 mol/L. **Figure 2** shows the steps involved in diluting an existing solution of potassium chromate, K_2CrO_4.

dilution the process of reducing the concentration of a solution; usually done by adding more solvent

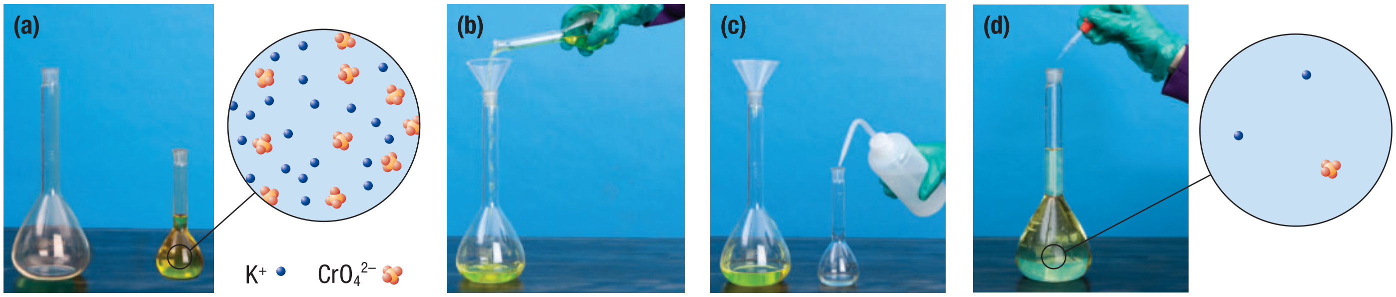

Figure 2 Preparing a dilute potassium chromate solution from concentrate (a) The concentrated potassium chromate solution in the small flask contains a relatively large quantity of dissolved solute per unit volume, giving the solution an intense yellow colour. (b) The concentrated solution is added to the larger volumetric flask. (c) The small flask is rinsed with distilled water and the rinse water is transferred to the larger flask. (d) The concentrated solution is diluted to a larger volume by adding water. The dilute solution contains less solute per unit volume, so the colour is less intense.

Volumetric Glassware

Dilutions often involve transferring precise volumes of a concentrated solution into another container. You have probably used a graduated cylinder to measure and transfer solutions. However, a graduated cylinder is not precise enough for analytical work involving small volumes. Instead, pipettes are used. There are several types of pipettes (**Figure 3**). A volumetric pipette is used to deliver a fixed volume of solution. For example, a 10 mL volumetric pipette delivers 10.00 +/− 0.02 mL of solution. A graduated pipette has volume markings or graduations, much like a graduated cylinder. This type of pipette can deliver a range of volumes, from 0.1 mL to 10.0 mL. Note that the graduated pipette is not as precise as a volumetric pipette.

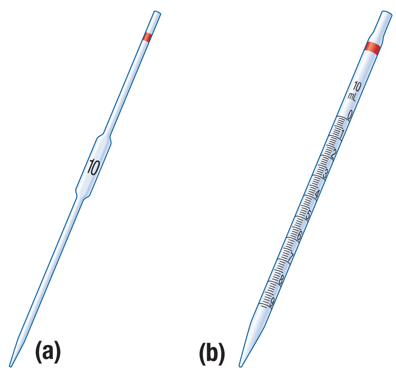

Figure 3 (a) A volumetric pipette can deliver only one specific volume. (b) A graduated pipette can deliver a range of volumes.

Dilution Calculations

Many dilute solutions can be prepared by simply applying some common sense. For example, doubling the volume of the solution by adding water decreases its concentration by a factor of 2. Similarly, increasing the volume by ten times decreases the concentration by a factor of 10.

Investigation 8.7.1

Preparing a Standard Solution by Dilution (p. 413)
In this investigation you will learn the skills necessary to dilute an aqueous solution of known concentration to make a less concentrated solution.

For less obvious situations, we need to develop a mathematical equation that can be used to determine the final concentration of the dilute solution. During dilution, the amount (in moles) of solute present does not change. The concentration changes because the volume of the solution increases (**Figure 4**).

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

decreases (because volume increases) ↓ c

n → remains constant

V ↑ increases (because water is added)

Figure 4 During a dilution, the concentration of a solution decreases due to an increase of its volume. The amount of solute remains unchanged.

The amount of solute in a solution is given by $n = cV$. We can use subscripts to differentiate between the two solutions: subscript "c" represents the initial concentrated solution, and subscript "d" represents the final diluted solution. We can therefore describe the amount of solute in the initial concentrated solution by the equation

$$n = c_c V_c$$

The value of n, the amount of solute, remains unchanged after dilution. The amount of solute in the dilute solution is given by

$$n = c_d V_d$$

Since n remains constant, we can combine the two equations.

The Dilution Equation

$$c_c V_c = c_d V_d$$

LEARNING TIP

Dilution Equation

$c_c V_c = c_d V_d$

c_c is the concentration of the concentrated solution

V_c is the volume of the concentrated solution

c_d is the concentration of the dilute solution

V_d is the volume of the dilute solution

Tutorial 1 Dilution Calculations

Solve dilution problems using the strategy for solving for an unknown variable.

Sample Problem 1: Determining Amount Concentration

What is the final concentration when 250 mL of a 16.0 mol/L nitric acid solution is diluted to 4.5 L?

Given: concentration of initial concentrated solution, $c_c = 16.0$ mol/L; volume of initial concentrated solution, $V_c = 250$ mL; volume of final diluted solution, $V_d = 4.5$ L

Required: concentration of diluted solution, c_d

Analysis:

$c_c V_c = c_d V_d$

Solution:

Step 1. If necessary, convert the volume of solution to litres.

$$V_c = 250\ \cancel{\text{mL}} \times \frac{1\ \text{L}}{1000\ \cancel{\text{mL}}}$$

$$= 0.250\ \text{L}$$

Step 2. Rearrange the concentration equation in the appropriate form. Then substitute in the values and solve the equation.

$$c_d = \frac{c_c V_c}{V_d}$$

$$= \frac{16.0\ \frac{\text{mol}}{\text{L}} \times (0.250\ \cancel{\text{L}})}{4.5\ \cancel{\text{L}}}$$

$$c_d = 0.89\ \frac{\text{mol}}{\text{L}}$$

Statement: The final concentration of the nitric acid solution is 0.89 mol/L.

Practice

SKILLS HANDBOOK A6

1. What is the final concentration when 4.5 L of 3.0 mol/L car battery acid is diluted to 20.0 L? T/I [ans: 0.68 mol/L]
2. What volume of a 6.0 mol/L sodium hydroxide solution is required to produce 850 mL of a 0.100 mol/L solution? T/I [ans: 14 mL]
3. A teacher needs to prepare 4.5 L of 1.0 mol/L ethanoic acid (acetic acid) for an investigation. What volume of concentrated 17.4 mol/L ethanoic acid is required? T/I [ans: 0.26 L or 260 mL]
4. 250 mL of a 0.100 mol/L iron(III) nitrate solution is prepared using 75 mL of a stock solution. What is the amount concentration of the stock solution? T/I [ans: 0.33 mol/L]

LEARNING TIP

Dilution Factors

A quick way to determine the final concentration of a dilute solution is by multiplying c_c by a dilution factor. The dilution factor is the volume of the concentrated solution divided by the volume of the dilute solution. In Sample Problem 1 the dilution factor is 0.250/4.5 (see Step 2). Chemists routinely use dilution factors when preparing solutions.

8.7 Summary

- Dilutions involve adding more solvent to a solution to decrease the concentration.
- The dilution equation, $c_c V_c = c_d V_d$, is useful when solving dilution problems.
- Volumetric glassware is required to prepare dilutions.

8.7 Questions

1. Describe two applications of the use of dilutions at home. A
2. 25 mL of a 0.6 mol/L cobalt(II) chloride solution is added to each of three beakers. No water is added to the first beaker, 25 mL of water is added to the second beaker, and 50 mL of water is added to the third beaker (**Figure 5**). T/I

Figure 5

   (a) What volume of solution is in each of the beakers?
   (b) Why is there a difference in the intensity of the colour of the solutions?
   (c) Compare the amount of solute in the three beakers.
3. How does the number of entities in a solution change when more water is added to the solution? K/U
4. Describe how to prepare a 0.25 mol/L solution of hydrochloric acid from a 1.0 mol/L solution. T/I
5. What effect do the following changes have on the final concentration of a solution? T/I
   (a) doubling the original volume by adding water
   (b) doubling the original volume by adding more of an identical solution
   (c) increasing the original volume by a factor of 10 by adding water
6. How would you prepare 250 mL of 0.40 mol/L sodium chloride solution, using an available 1.5 mol/L solution? T/I
7. An experiment requires 100 mL each of 0.50 mol/L HCl(aq), 0.25 mol/L HCl(aq), and 0.1 mol/L HCl(aq). How could you prepare these solutions using an available 2.0 mol/L hydrochloric acid solution? T/I
8. Millions of tonnes of concentrated chemicals such as sulfuric acid are transported across North America annually. Why can the transport of chemicals in concentrated form be more environmentally friendly than the transport of the diluted form? What are the environmental risks?
9. Dilution was "the solution to pollution" for much of human history. Research the meaning of this expression. Why is dilution no longer a viable option for disposing of the pollution we generate? A

GO TO NELSON SCIENCE