Chapter 8

Solutions and Their Concentrations

Solutions for Practice Problems

Section 8.3

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1. Problem

What is the concentration in percent (m/v) of each solution?

(a) 14.2 g of potassium chloride, KCl (used as a salt substitute), dissolved in 450 mL of solution

(b) 31.5 g of calcium nitrate, $Ca(NO_3)_2$,(used to make explosives), dissolved in 1.80 L of solution

(c) 1.72 g of potassium permanganate, $KMnO_4$, (used to bleach stone-washed blue jeans), dissolved in 60 mL of solution

What Is Required?

(a) Find the mass of solute (KCl) in 100 mL of solution.

(b) Find the mass of solute ($Ca(NO_3)_2$) in 100 mL of solution.

(c) Find the mass of solute ($KMnO_4$) in 100 mL of solution.

What Is Given?

In (a), (b), and (c) the mass solute and a volume of solution are given.

Plan Your Strategy

(a) Method 1 (Formula)

Use the formula: Mass/volume percent = $\frac{\text{Mass of solute (g)}}{\text{Volume of solution (mL)}} \times 100\%$

Method 2 (Ratio)

The ratio of the mass of dissolved solute in 100 mL of solution must be the same as the ratio of 14.2 g of KCl in 450 mL of solution. Let x represent the mass of dissolved solute in 100 mL of solution.

(b) Method 1 (Formula)

Use the formula: Mass/volume percent = $\frac{\text{Mass of solute (g)}}{\text{Volume of solution (mL)}} \times 100\%$

Method 2 (Ratio)

The ratio of the mass of dissolved solute in 100 mL of solution must be the same as the ratio of 31.5 g of $Ca(NO_3)_2$ in 1 800 mL of solution. Let x represent the mass of dissolved solute in 100 mL of solution.

(c) Method 1 (Formula)

Use the formula: Mass/volume percent = $\frac{\text{Mass of solute (g)}}{\text{Volume of solution (mL)}} \times 100\%$

Method 2

The ratio of the mass of dissolved solute in 100 mL of solution must be the same as the ratio of 1.72 g of KCl in 60 mL of solution. Let x represent the mass of dissolved solute in 100 mL of solution.

Act on Your Strategy

(a) Method 1

Percent (m/v) $= \frac{14.2\text{ g}}{450\text{ mL}} \times 100\% = 3.16\%$

Method 2 (Ratio)

$\frac{x}{100\text{ mL}} = \frac{14.2\text{ g}}{450\text{ mL}}$ $\qquad x = \frac{14.2\text{ g}}{450\text{ mL}} \times 100\text{ mL} = 3.16\text{ g}$

The concentration of the solution is 3.16% (m/v)

(b) Method 1 (Formula)

Percent (m/v) $= \frac{31.5\text{ g}}{1\,800\text{ mL}} \times 100\% = 1.75\%$

Method 2 (Ratio)

$\frac{x}{100\text{ mL}} = \frac{31.5\text{ g}}{1\,800\text{ mL}}$ $\qquad x = \frac{31.5\text{ g}}{1\,800\text{ mL}} \times 100\text{ mL} = 1.75\text{ g}$

The concentration of the solution is 1.75% (m/v)

(c) Method 1 (Formula)

Percent (m/v) $= \frac{1.72\text{ g}}{60\text{ mL}} \times 100\% = 2.9\%$

Method 2 (Ratio)

$\frac{x}{100\text{ mL}} = \frac{1.72\text{ g}}{60\text{ mL}}$ $\qquad x = \frac{1.72\text{ g}}{60\text{ mL}} \times 100\text{ mL} = 2.9\text{ g}$

The concentration of the solution is 2.9% (m/v).

Check Your Solution

(a) The units are correct. Estimating roughly that 0.03×450 is about 14, this approximates the given mass of solute.

(b) The units are correct. Estimating roughly that 0.02×1800 is about 36, this approximates the given mass of solute

(c) The units are correct. Estimating roughly that 0.03×60 is about 1.8, this approximates the given mass of solute.

2. Problem

A solution of hydrochloric acid was formed by dissolving 1.52 g of hydrogen chloride gas in enough water to make 24.1 mL of solution. What is the concentration in percent (m/v) of the solution?

What Is Required?

Find the mass of solute in 100 mL of solution.

What Is Given?

You are given a mass of solute and a volume of solution.

Plan Your Strategy

Method 1 (Formula)

Use the formula: Mass/volume percent $= \frac{\text{Mass of solute (g)}}{\text{Volume of solution (mL)}} \times 100\%$

Method 2 (Ratio)

The ratio of the mass of dissolved solute in 100 mL of solution must be the same as the ratio of 1.52 g of HCl in 24.1 mL of solution. Let x represent the mass of dissolved solute in 100 mL of solution.

Act on Your Strategy

Method 1 (Formula)

Percent (m/v) $= \frac{1.52\text{ g}}{24.1\text{ mL}} \times 100\% = 6.31\%$

Method 2 (Ratio)

$\frac{x}{100\text{ mL}} = \frac{1.52\text{ g}}{24.1\text{ mL}}$ $\qquad x = \frac{1.52\text{ g}}{24.1\text{ mL}} \times 100\text{ mL} = 6.31\text{ g}$

The concentration of the solution is 6.31% (m/v).

Check Your Solution
The units are correct. Estimating roughly that 0.06×25 is about 1.5, this approximates the given mass of HCl that is given solute.

3. Problem
At 25°C, a saturated solution of carbon dioxide gas in water has a concentration of 0.145% (m/v). What mass of carbon dioxide is present in 250 mL of the solution?

What Is Required?
Find the mass of CO_2 in 250 mL of a solution of known concentration.

What Is Given?
You are given a concentration of 0.145% (m/v) and a solution volume of 250 mL.

Plan Your Strategy
Method 1 (Formula)
Rearrange the formula for (m/v) percent to solve for mass (m). Substitute the known values.
Method 2 (Ratio)
Let x represent the mass of dissolved HCl in 250 mL of solution. The ratio of dissolved solute in 100 mL of solution must be the same as the ratio of the mass of solute, x, dissolved in 250 mL of solution.

Act on Your Strategy
Method 1 (Formula)

$$\text{mass of solute} = \frac{\text{(m/v) percent} \times \text{volume of solution}}{100\ \%} = \frac{0.145\ \% \times 250\ \text{mL}}{100\ \%} = 0.362\ \text{g}$$

Method 2 (Ratio)

$$\frac{x}{250\ \text{mL}} = \frac{0.145}{100\ \text{mL}} \qquad x = \frac{0.145}{100\ \text{mL}} \times 250\ \text{mL} = 0.362\ \text{g}$$

Check Your Solution
The units are correct. Use rounded off values to estimate. 250 is 2.5 times 100; 2.5 times .15 is about 0.38 which is close to the answer.

4. Problem
Ringer's solution contains three dissolved salts in the same proportions as they are found in blood. The salts and their concentrations (m/v) are as follows: 0.86% NaCl, 0.03% KCl, and 0.033% $CaCl_2$. Suppose that a patient needs to receive 350 mL of Ringer's solution by an intravenous drip. What mass of each salt does the pharmacist need to make the solution?

What Is Required?
Find the mass of each solute in 350 mL of solution.

What Is Given?
You are given the volume of solution and the (m/v) percent concentration of each component of the solution.

Plan Your Strategy
Method 1 (Formula)
Rearrange the formula for (m/v) percent to solve for mass (m). Substitute the known values.
Method
Method 2 (Ratio)
Let x represent the mass of dissolved solute in 350 mL of solution. The ratio of dissolved solute in 100 mL of solution must be the same as the ratio of the mass of solute, x, dissolved in 350 mL of solution.

Act on Your Strategy

Method 1 (NaCl)

$$\text{mass of NaCl} = \frac{\text{(m/v) percent} \times \text{volume of solution}}{100\%} = \frac{0.86\% \times 350\text{ mL}}{100\%} = 3.0\text{ g}$$

Method 2 (NaCl)

$$\frac{x}{350\text{ mL}} = \frac{0.86\text{ g}}{100\text{ mL}} \qquad x = \frac{0.86\text{ g}}{100\text{ mL}} \times 350\text{ mL} = 3.0\text{ g}$$

Method 1 (KCl)

$$\text{mass of KCl} = \frac{\text{(m/v) percent} \times \text{volume of solution}}{100\%} = \frac{0.03\% \times 350\text{ mL}}{100\%} = 0.1\text{ g}$$

Method 2 (KCl)

$$\frac{x}{350\text{ mL}} = \frac{0.03\text{ g}}{100\text{ mL}} \qquad x = \frac{0.03\text{ g}}{100\text{ mL}} \times 350\text{ mL} = 0.1\text{ g}$$

Method 1 ($CaCl_2$)

$$\text{mass of } CaCl_2 = \frac{\text{(m/v) percent} \times \text{volume of solution}}{100\%} = \frac{0.033\% \times 350\text{ mL}}{100\%} = 0.12\text{ g}$$

Method 2 ($CaCl_2$)

$$\frac{x}{350\text{ mL}} = \frac{0.033\text{ g}}{100\text{ mL}} \qquad x = \frac{0.033\text{ g}}{100\text{ mL}} \times 350\text{ mL} = 0.12\text{ g}$$

Check Your Solution

The units are correct. Approximating the answers, you have 3.5 times 100 mL of solution and therefore there should be about 3.5 times the mass of solute as is found in 100 mL. This appears to be the case.

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5. Problem

Calculate the mass/mass percent of solute for each solution.

(a) 17 g of sulfuric acid in 65 g of solution

(b) 18.37 g of sodium chloride dissolved in 92.2 g of water

Hint: Remember that a solution consists of both solute and solvent.

(c) 12.9 g of carbon tetrachloride dissolved in 72.5 g of benzene

What Is Required?

In each of (a), (b), and (c) you must calculate the mass of solute in 100 g of solution.

What Is Given?

(a) You are given a mass of solute and a mass of solution.

(b) You are given a mass of solute and a mass of solvent

(c) You are given a mass of solute and a mass of solvent

Plan Your Strategy

Method 1 (Formula)

Use the formula: $\text{mass/mass percent} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$

Method 2 (Ratio)

Let the mass of solute in 100 g of soltion be represented by x. Equate the ratio of the given mass of solute in the mass of solution to the ratio of the unknown mass of solute, x, in 100 g of solution. Solve for x.

Act on Your Strategy

(a) Method 1 (Formula)

$$\text{percent (m/m)} = \frac{17\text{ g}}{65\text{ g}} \times 100\% = 26\%\text{ sulfuric acid}$$

Method 2 (Ratio)

$$\frac{x}{100\text{ g}} = \frac{17\text{ g}}{65\text{ g}} \qquad x = \frac{17\text{ g}}{65\text{ g}} \times 100\text{ g} = 26\text{ g sulfuric acid}$$

Therefore the percent (m/m) sulfuric acid is 26%

(b) Method 1 (Formula)

mass of solution = mass of solute + mass of solvent
= 18.37 g + 92.2 g
= 110.6 g

percent (m/m) = $\frac{18.37\text{ g}}{110.6\text{ g}} \times 100\% = 16.61$ g sodium chloride

Therefore the percent (m/m) sodium chloride is 16.61%

Method 2 (Ratio)

$\frac{x}{100\text{ g}} = \frac{18.37\text{ g}}{110.6\text{ g}}$ $\qquad x = \frac{18.37\text{ g}}{110.6\text{ g}} \times 100\text{ g} = 16.61\text{ g}$

Therefore the percent (m/m) sodium chloride is 16.61%

(c) Method 1 (Formula)

mass of solution = mass of solute + mass of solvent
= 12.9 g + 72.5 g
= 85.4 g

percent (m/m) = $\frac{12.9\text{ g}}{85.4\text{ g}} \times 100\% = 15.1\%$ carbon tetrachloride

Method 2 (Ratio)

$\frac{x}{100\text{ g}} = \frac{12.9\text{ g}}{85.4\text{ g}}$ $\qquad x = \frac{12.9\text{ g}}{85.4\text{ g}} \times 100\text{ g} = 15.1\text{ g}$

Therefore the percent (m/m) carbon tetrachloride is 15.1%

Check Your Solution

The units in each answer are correct and the final answer has the correct number of significant figures. The magnitude of the answer seems reasonable.

6. Problem

If 55 g of potassium hydroxide are dissolved in 100 g of water, what is the concentration of the solution expressed as mass/mass percent?

What Is Required?

Find the mass of solute in 100 g of solution.

What Is Given?

You are given the mass of solute and the mass of solvent.

Plan Your Strategy

Method 1 (Formula)

Use the formula: mass/mass percent = $\frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$

Method 2 (Ratio)

Let the mass of solute in 100 g of solution be represented by *x*. Equate the ratio of the given mass of solute in the mass of solution to the ratio of the unknown mass of solute, *x*, in 100 g of solution. Solve for *x*.

Act on Your Strategy

Method 1 (Formula)

mass of solution = mass of solute + mass of solvent
= 55 g + 100 g
= 155 g

percent (m/m) = $\frac{55\text{ g}}{155\text{g}} \times 100\% = 35\%$ potassium hydroxide

Method 2 (Ratio)

$\frac{x}{100\text{ g}} = \frac{55\text{ g}}{155\text{ g}}$ $\qquad x = \frac{55\text{ g}}{155\text{ g}} \times 100\text{ g} = 35\text{ g}$

Therefore the mass/mass percent potassium hydroxide is 35%

Check Your Solution

The units divide out properly and the correct number of significant figures appear in the final answer. Approximating, 55 is about $\frac{1}{3}$ of 155. The answer seems reasonable.

7. Problem

Steel is an alloy of iron and about 1.7% carbon. It also contains small amounts of other materials, such as manganese and phosphorus. What mass of carbon is needed to make a 5.0 kg sample of steel?

What Is Required?

Find the mass of carbon in a given mass of steel.

What Is Given?

You are given the mass of steel and the percent by mass of carbon in the steel.

Plan Your Strategy

Method 1 (Formula)

Rearrange the formula mass/mass percent = $\frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$ to find mass.

Method 2 (Ratio)

Let the mass of carbon in 5 000 g of steel be represented by x. Equate the ratio of the unknown mass of carbon in the 5 000 g of steel to the ratio of the known mass of carbon, 1.7 g, in 100 g of steel. Solve for x.

Act on Your Strategy

Method 1 (Formula)

5.0 kg of carbon = 5 000 g carbon

$$\text{mass of carbon} = \frac{\text{(m/m) percent} \times \text{mass of solution}}{100\%}$$
$$= \frac{1.7 \times 5\,000\text{ g}}{100}$$
$$= 85\text{ g carbon}$$

Method 2 (Ratio)

$$\frac{x}{5\,000\text{ g}} = \frac{1.7\text{ g}}{100\text{ g}} \qquad x = \frac{1.7\text{ g}}{100\text{ g}} \times 5\,000\text{ g} = 85\text{ g}$$

Check Your Solution

The units divide out properly and the final answer has the correct number of significant figures. Approximating, 5 000 is 50 times 100. 50 times approximately 2 g is 100 g which is near the answer that was calculated. The answer seems reasonable.

8. Problem

Stainless steel is a variety of steel that resists corrosion. Your cutlery at home may be made of this material. Stainless steel must contain at least 10.5% chromium. What mass of chromium is needed to make a stainless steel fork with a mass of 60.5 g?

What Is Required?

Find the mass of chromium in a given mass of steel.

What Is Given?

You know the percent mass/mass of chromium in steel and the mass of steel.

Plan Your Strategy

Method 1 (Formula)

Rearrange the formula mass/mass percent = $\frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$ to find mass.

Method 2 (Ratio)

Let the mass of chromium in 60.5 g of steel be represented by x. Equate the ratio of the unknown mass of chromium in the 60.5 g of steel to the ratio of the known mass of chromium, 10.5 g, in 100 g of steel. Solve for x.

Act on Your Strategy

Method 1 (Formula)

$$\text{mass of chromium} = \frac{\text{(m/m) percent} \times \text{mass of solution}}{100\%}$$
$$= \frac{10.5\% \times 60.5\text{ g}}{100\%}$$
$$= 6.35\text{ g chromium}$$

Method 2 (Ratio)

$$\frac{x}{60.5\text{ g}} = \frac{10.5\text{ g}}{100\text{ g}} \qquad x = \frac{10.5\text{ g}}{100\text{ g}} \times 60.5\text{ g} = 6.35\text{ g chromium}$$

Therefore the mass of chromium is 6.35 g

Check Your Solution

The units in the final answer divide out correctly and the correct number of significant figures are in this answer. 10% of 60 is 6 g which is approximately the answer. This answer seems to be reasonable.

9. Problem

18-carat white gold is an alloy. It contains 75% gold, 12.5% silver, and 12.5% copper. A piece of jewelry, made of 18-carat white gold, has a mass of 20g. How much pure gold does it contain?

What Is Required?

Find the mass of pure gold present in 20 g of white gold.

What Is Given?

You know the mass of white gold and the percent mass/mass of gold in white gold.

Plan Your Strategy

Method 1 (Formula)

Rearrange the formula $\text{mass/mass percent} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$ to find mass.

Method 2 (Ratio)

Let the mass of gold in 20 g of white gold be represented by x. Equate the ratio of the unknown mass of gold in the 20 g of white gold to the ratio of the known mass of gold, 75 g, in 100 g of white gold. Solve for x.

Act on Your Strategy

Method 1 (Formula)

$$\text{mass of pure gold} = \frac{\text{(m/m) percent} \times \text{mass of solution}}{100\%}$$
$$= \frac{75\text{ g} \times 20\text{ g}}{100\text{ g}}$$
$$= 15\text{ g pure gold}$$

Method 2 (Ratio)

$$\frac{x}{20\text{ g}} = \frac{75\text{ g}}{100\text{ g}} \qquad x = \frac{75\text{ g}}{100\text{ g}} \times 20\text{ g} = 15\text{ g pure gold}$$

Therefore the mass of pure gold in 20 g of white gold is 15 g

Check Your Solution

The units divide out correctly and the final answer has the correct number of significant figures. $\frac{3}{4}$ of 20 is 15. The answer seems to be reasonable.

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10. Problem

60 mL of ethanol is diluted with water to a final volume of 400 mL. What is the percent by volume of ethanol in the solution?

What Is Required?

Find the volume of ethanol in 100 mL of ethanol solution.

What Is Given?
You know a volume of ethanol and a volume of ethanol solution.

Plan a Strategy
Method 1 (Formula)
Use the formula volume/volume percent = $\frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$
Method 2 (Ratio)
Let the volume of pure ethanol in 100 mL of solution be represented by *x*. Use ratios to solve for the unknown volume.

Act on Your Strategy
Method 1 (Formula)
(v/v) percent = $\frac{60 \text{ mL}}{400 \text{ mL}} \times 100\% = 15\%$ ethanol

Method 2 (Ratio)
$\frac{x}{100 \text{ mL}} = \frac{60 \text{ mL}}{400 \text{ mL}}$ $\qquad x = \frac{60 \text{ mL}}{400 \text{ mL}} \times 100 \text{ mL} = 15 \text{ mL}$
Therefore the (v/v) percent ethanol is 15%

Check Your Solution
The units divide out and the final answer has the correct number of significant figures. 15% of 400 is 60. The answer is reasonable.

11. Problem
Milk fat is present in milk. Whole milk usually contains about 5.0% milk fat by volume. If you drink a glass of milk with a volume of 250 mL, what volume of milk fat have you consumed?

What Is Required?
Find the volume of milk fat in a given volume of whole milk.

What Is Given?
You know the volume/volume percent of milk fat in whole milk and the volume of the milk.

Plan Your Strategy
Method 1 (Formula)
Rearrange the formula,
v/v percent = $\frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$ to find the volume of solute.
Method 2 (Ratio)
Let the volume of milk fat be represented by *x*. Use ratios to solve for the unknown volume.

Act on Your Strategy
Method 1 (Formula)
volume of ethanol = $\frac{\text{(v/v) percent} \times \text{volume of solution}}{100\%} = \frac{5.0\% \times 250 \text{ mL}}{100\%} = 12 \text{ mL}$
Method 2 (Ratio)
$\frac{x}{250 \text{ mL}} = \frac{5.0 \text{ mL}}{100 \text{ mL}}$
$x = \frac{5.0 \text{ mL}}{100 \text{ mL}} \times 250 \text{ mL} = 12.5 \text{ mL}$ or 12 mL
Therefore the volume of milk fat in 250 mL of whole milk is 12 mL.

Check Your Solution
The units divide our correctly and the correct number of significant figures are in the final answer. The answer seems reasonable.

12. Problem

Both antifreeze (shown in figure 8.18) and engine coolant contain ethylene glycol. A manufacturer sells a concentrated solution that contains 75% (v/v) ethylene glycol in water. According to the label, a 1:1 mixture of the concentrate with water will provide protection against freezing down to a temperature of −37°C. A motorist adds 1 L of diluted solution to a car radiator. What is the percent (v/v) of ethylene glycol in the diluted solution?

What Is Required?

Find the volume of ethylene glycol in 100 mL of antifreeze.

What Is Given?

You know the volume/volume percent concentration of the antifreeze and the volume of diluted solution.

Plan Your Strategy

Calculate the volume of ethylene glycol in 500 mL of antifreeze. This volume of ethylene glycol will be in 100 mL of diluted 1:1 antifreeze.

Act on Your Strategy

$$\text{volume of ethylene glycol in 500 mL of antifreeze} = \frac{75}{100} \times 500 \text{ mL}$$
$$= 375 \text{ mL}$$
$$= 3.8 \times 10^2 \text{ mL}$$

$$\text{volume/volume percent} = \frac{\text{volume of ethylene glycol}}{\text{volume of antifreeze}} \times 100\%$$
$$= \frac{3.8 \times 10^2 \text{ mL}}{1000 \text{ mL}} \times 100\%$$
$$= 38\% \text{ ethylene glycol}$$

Check Your Solution

The answer seems reasonable. If a solution is diluted 1:1, its concentration should be cut in half.

13. Problem

The average adult human body contains about 5 L of blood. Of this volume, only about 0.72% consists of leukocytes (white blood cells). These essential blood cells fight infection in the body. What volume of pure leukocyte cells is present in the body of a small child, with only 2.5 L of blood?

What Is Required?

Find the volume of leukocytes in 2.5 L of blood.

What Is Given?

The volume of blood and the (volume/volume) percent of leukocytes.

Plan Your Strategy

The (volume/volume) percentage of leukocytes in blood is assumed to be constant at 0.72%. Let the volume of leukocytes be x and solve this ratio for x.

Act on Your Strategy

$$\frac{x}{2.5 \text{ L}} = \frac{0.72}{100} \qquad x = \frac{0.72}{100} \times 2.5 \text{ L} = 0.018 \text{ L or } 18 \text{ mL}$$

Check Your Solution

The answer seems reasonable based upon the given (v/v) percent concentration.

14. Problem

Vinegar is sold as a 5% (v/v) solution of acetic acid in water. How much water should be added to 15 mL of pure acetic acid (a liquid at room temperature) to make

a 5%(v/v) solution of acetic acid. **Note:** Assume that when water and acetic acid are mixed, the total volume of the solution is the sum of the volumes of each.

What Is Required?
Find the volume of water that must be added to a given volume of pure acetic acid to make the concentration 5% (v/v).

What Is Given?
The volume of pure acetic acid and the final (v/v) percent concentration are known.

Plan Your Strategy
Let the volume of water that must be added be represented by *x*. The final volume of the solution will be the volume of pure acetic + volume of water (x). Use the formula for the (v/v) percent concentration of a solution to solve for *x*.

Act on Your Strategy
$$\text{volume/volume percent} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$$
$$5\% = \frac{15\ \text{mL}}{x\ + 15\ \text{mL}} \times 100\%$$
$$x = 285\ \text{mL or } 3 \times 10^2\ \text{mL}$$

Check Your Solution
The final answer has the correct unit and number of significant figures. In round numbers, 5% of 300 is close to the calculated answer. This answer seems to be reasonable.

15. Problem
Symptoms of mercury poisoning become apparent after a person has accumulated more than 20 mg of mercury in the body.
(a) Express this amount as parts per million for a 60 kg person.
(b) Express this amount as parts per billion.
(c) Express this amount as a (m/m) percent.

What Is Required?
(a) Express a mass of 20 mg mercury in a 60 kg person as ppm.
(b) Express a mass of 20 mg of mercury in a 60 kg person as ppb.
(c) Express a mass of 20 mg of mercury in a 60 kg person as (m/m) percent.

What Is Given?
You know the mass of mercury and the mass of the person.

Plan Your Strategy
(a) Assume that the mercury is spread out in the body as a solute in a solution. Apply the formula for concentration in parts per million.
$$\text{parts per million} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$$
(b) Apply the relationship that $1\ \text{ppb} = 1 \times 10^3\ \text{ppm}$
(c) Apply the formula
$$\text{(m/m) percent} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

Act on Your Strategy
(a) $$\text{ppm} = \frac{20\ \text{mg Hg} \times \frac{1\ \text{g}}{1\ 000\ \text{mg}}}{60\ \text{kg} \times \frac{1\ 000\ \text{g}}{\text{kg}}} \times 10^6 = 0.33\ \text{ppm}$$
(b) $$\text{ppb} = 1 \times 10^3 \times \text{ppm} = 0.33\ \text{ppm} \times 1 \times 10^3 = 3.3 \times 10^2\ \text{ppb}$$
(c) $$\text{(m/m)percent} = \frac{20\ \text{mg Hg} \times \frac{1\ \text{g}}{1\ 000\ \text{mg}}}{60\ \text{kg} \times \frac{1\ 000\ \text{g}}{\text{kg}}} \times 100\% = 3.3 \times 10^{-5}\%$$

Check Your Solution
The answers have the correct units and significant figures and seem reasonable.

16. Problem

The use of the pesticide DDT has been banned in Canada since 1969 because of its damaging effect on wildlife. In 1967, the concentration of DDT in an average lake trout, taken from Lake Simcoe in Ontario, was 16 ppm. Today it is less than 1 ppm. What mass of DDT would have been present in a 2.5 kg trout with DDT present at 16 ppm?

What Is Required?

Find the mass of DDT in a 2.5 kg fish.

What Is Given?

The concentration of DDT in ppm and the mass of the fish are given.

Plan Your Strategy

Assume that the DDT is spread evenly through the fish as a solute in a solution.

Rearrange the formula: $\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$ to calculate the mass of solute

Act on Your Strategy

2.5 kg = 2500 g

$\text{mass of DDT} = \frac{\text{ppm} \times \text{mass of fish}}{10^6} = \frac{16 \text{ ppm} \times 2\,500 \text{ g}}{10^6} = 0.040 \text{ g}$

Check Your Solution

The final has the correct unit and number of significant figures. Estimating with power of ten notation gives this approximate answer. This answer seems reasonable.

17. Problem

The concentration of chlorine in a swimming pool is generally kept in the range of 1.4 to 4.0 mg/L. The water in a certain pool has 3.0 mg/L of chlorine. Express this value as parts per million. (**Hint:** 1 L of water has a mass of 1000 g)

What Is Required?

Determine the concentration of chlorine in the water as ppm.

What Is Given?

The mass of water and the concentration in mg/L are given.

Plan Your Strategy

Use the formula: $\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$

Act on Your Strategy

$3.0 \text{ mg/L} \times \frac{1 \text{ g}}{1\,000 \text{ mg}} = 0.0030 \text{ g}$ 1L of water has a mass of 1000 g

$\text{ppm} = \frac{0.0030 \text{ g}}{1\,000 \text{ g}} \times 10^6 = 3.0 \text{ ppm}$

Check Your Solution

The final answer has the correct unit and number of significant figures. Estimating with power of ten notation gives this answer. The answer is reasonable.

18. Problem

Water supplies with dissolved calcium carbonate greater than 500 mg/L are considered unacceptable for most domestic purposes. Express this concentration in parts per million.

What Is Required?

Find the concentration of dissolved calcium carbonate in ppm.

What Is Given?

The concentration in mg/L is given.

Plan Your Strategy

Use the formula: $\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$

Act on Your Strategy

$500 \text{ mg} \times \frac{1 \text{ g}}{1\,000 \text{ mg}} = 0.500 \text{ g}$ 1 L of water has a mass of 1 000 g

$\text{ppm} = \frac{0.500 \text{ g}}{1\,000 \text{ g}} \times 10^6 = 500 \text{ ppm}$

Check Your Solution

The final answer has the correct unit and number of significant figures. Estimating with power of ten notation gives this answer. The answer is reasonable.

19. Problem

What is the molar concentration of each solution?

(a) 0.50 mol of NaCl dissolved in 0.30 L of solution

(b) 0.289 mol of iron(III) chloride, $FeCl_3$, dissolved in 120 mL of solution

(c) 0.0877 mol of copper(II) sulfate, $CuSO_4$, dissolved in 70 mL of solution

(d) 4.63 g of sugar, $C_{12}H_{22}O_{11}$, dissolved in 16.8 mL of solution

(e) 1.2 g of $NaNO_3$ dissolved in 80 mL of solution

What Is Required?

For each of (a), (b), (c), (d), and (e) find the concentration in mol/L.

What Is Given?

For (a), (b), and (c) the number of moles of solute and the total volume of solution are given. For (d) and (e) the mass of solute and the total volume of solution are given.

Plan Your Strategy

If necessary, convert the volume of solution from mL to L.

For (a), (b), and (c) use the formula: $\text{concentration} = \frac{\text{amount of solute (mol)}}{\text{volume of solution (L)}}$

For (d) and (e) find the number of moles of solute and use the above formula.

Act on Your Strategy

(a) $C = \frac{n}{V} = \frac{0.50 \text{ mol}}{0.30 \text{ L}} = 1.7 \text{ mol/L NaCl}$

(b) 120mL = 0.120L

$C = \frac{n}{V} = \frac{0.289 \text{ mol}}{0.120 \text{ L}} = 2.41 \text{ mol/L } FeCl_3$

(c) 70 mL = 0.070 L

$C = \frac{n}{V} = \frac{0.0877 \text{ mol}}{0.070 \text{ L}} = 1.2 \text{ mol/L } CuSO_4$

(d) molar mass of $C_{12}H_{22}O_{11}$ = 342 g/mol 16.8 mL = 0.0168 L

$4.63 \text{ g } C_{12}H_{22}O_{11} \times \frac{1 \text{ mol}}{342 \text{ g}} = 0.0135 \text{ mol } C_{12}H_{22}O_{11}$

$C = \frac{n}{V} = \frac{0.0135 \text{ mol}}{0.0168 \text{ L}} = 0.806 \text{ mol/L sucrose}$

(e) molar mass of $NaNO_3$ = 85 g/mol 80 mL = 0.080 L

$1.2\text{g } NaNO_3 \times \frac{1 \text{ mol}}{85 \text{ g}} = 0.014 \text{ mol } NaNO_3$

$C = \frac{n}{V} = \frac{0.014 \text{ mol}}{0.080 \text{ L}} = 0.18 \text{ mol/L } NaNO_3$

Check Your Solution

The answers all have the correct unit and number of significant figures and seem to be reasonable.

20. Problem

What mass of solute is present in each aqueous solution?

(a) 1.00 mL of 0.045 mol/L calcium hydroxide, $Ca(OH)_2$, solution
(b) 500 mL of 0.100 mol/L silver nitrate, $AgNO_3$, solution
(c) 2.5 L of 1.00 mol/L potassium chromate, K_2CrO_4, solution
(d) 40 mL of 6.0 mol/L sulfuric acid, H_2SO_4, solution
(e) 4.24 L of 0.775 mol/L ammonium nitrate, NH_4NO_3, solution

What Is Required?
Find the mass of solute present in each solution.

What Is Given?
In each case a concentration in mol/L and a volume are given.

Plan a Strategy
Where necessary, convert the volume of solution given in mL to L. Rearrange the formula, $C = \frac{n}{V}$ to find the moles of solute and change this to grams.

Act on Your Strategy
(a) $n = C \times V = 0.045 \text{ mol/L} \times 1.00 \text{ L} = 0.045 \text{ mol}$
molar mass of $Ca(OH)_2 = 74 \text{ g/mol}$
$0.045 \text{ mol } Ca(OH)_2 \times \frac{74 \text{ g}}{1 \text{ mol}} = 3.3 \text{ g } Ca(OH)_2$

(b) 500 mL = 0.500 L
$n = C \times V = 0.100 \text{ mol/L} \times 0.500 \text{ L} = 0.0500 \text{ mol}$
molar mass of $AgNO_3 = 170 \text{ g/mol}$
$0.0500 \text{mol} \times \frac{170 \text{ g}}{\text{mol}} = 8.50 \text{ g } AgNO_3$

(c) $n = C \times V = 1.00 \text{ mol/L} \times 2.5 \text{ L} = 2.5 \text{ mol}$
molar mass of $K_2CrO_4 = 194.2 \text{ g/mol}$
$2.5 \text{ mol } K_2CrO_4 \times \frac{194.2 \text{ g}}{\text{mol}} = 4.9 \times 10^2 \text{ g } K_2CrO_4$

(d) 40.0 mL = 0.0400 L
$n = C \times V = 6.0 \text{ mol/L} \times 0.0400 \text{ L} = 0.24 \text{ mol } H_2SO_4$
molar mass of $H_2SO_4 = 98 \text{ g/mol}$
$0.24 \text{ mol } H_2SO_4 \times \frac{98 \text{ g}}{\text{mol}} = 24 \text{ g } H_2SO_4$

(e) $n = C \times V = 0.775 \text{ mol/L} \times 4.24 \text{ L} = 3.29 \text{ mol } NH_4NO_3$
molar mass of $NH_4NO_3 = 80.0 \text{ g/mol}$
$3.29 \text{ mol } NH_4NO_3 \times \frac{80.0 \text{ g}}{\text{mol}} = 263 \text{ g } NH_4NO_3$

Check Your Solution
In each case the final answer has the correct unit and number of significant figures. These answers are reasonable.

21. Problem
A student dissolves 30.46 g of silver nitrate, $AgNO_3$, in water to make 500 mL of solution. What is the molar concentration of the solution?

What Is Required?
Find the concentration of the solution in mol/L

What Is Given?
You know the mass of silver nitrate, its formula and the volume of solution.

Plan Your Strategy
Convert the mass of $AgNO_3$ to moles, the volume of solution from mL to L and use the formula $C = \frac{n}{V}$ to calculate the concentration in mol/L.

Act on Your Strategy

molar mass of $AgNO_3$ = 169.9 g/mol

$30.46 \text{ g } AgNO_3 \times \frac{1 \text{ mol}}{169.9 \text{ g}} = 0.1793 \text{ mol } AgNO_3$

$C = \frac{n}{V} = \frac{0.1793 \text{ mol}}{0.500 \text{ L}} = 0.359 \text{ mol/L } AgNO_3$

Check Your Solution

The final answer has the correct unit and number of significant figures. This answer is reasonable.

22. Problem

What volume of 0.25 mol/L solution can be made using 14 g of sodium hydroxide, NaOH ?

What Is Required?

Find the volume of NaOH solution.

What Is Given?

You know the concentration of the solution and the mass and the formula of the solute.

Plan Your Strategy

Convert the mass of NaOH to moles and rearrange the formula $C = \frac{n}{V}$ to calculate the volume.

Act on Your Strategy

molar mass of NaOH = 40 g/mol

$14 \text{ g NaOH} \times \frac{1 \text{ mol}}{40 \text{ g}} = 0.35 \text{ mol NaOH}$

$V = \frac{n}{C} = \frac{0.35 \text{ mol}}{0.25 \text{ mol/L}} = 1.4 \text{ L}$

Check Your Solution

The final answer has the correct unit and number of significant figures and seems reasonable.

23. Problem

A 100 mL bottle of skin lotion contains a number of solutes. One of these solutes is zinc oxide, ZnO. The concentration of zinc oxide in the skin lotion is 0.915 mol/L. What mass of zinc oxide is present in the bottle?

What Is Required?

Find the mass of solute in the bottle of lotion.

What Is Given?

You know the concentration and formula of the zinc oxide and the volume of the solution.

Plan Your Strategy

Convert the volume of the solution from mL to L and rearrange the formula $C = \frac{n}{V}$ to find the moles of solute. Convert the moles of solute to grams using the molar mass.

Act on Your Strategy

100 mL = 0.100 L

$n = C \times V = 0.915 \text{ mol/L} \times 0.100 \text{ L} = 0.0915 \text{ mol ZnO}$

molar mass of ZnO = 81.4 g/mol

$0.0915 \text{ mol ZnO} \times \frac{81.4 \text{ g}}{\text{mol}} = 7.45 \text{ g ZnO}$

Check Your Solution
The final answer has the correct unit and number of significant figures and seems reasonable.

24. Problem
Formalin is an aqueous solution of formaldehyde, HCHO, used to preserve biological specimens. What mass of formaldehyde is needed to prepare 1.5 L of formalin with a concentration of 10 mol/L?

What Is Required?
Find a mass of solute in the formaldehyde solution.

What Is Given?
You know the concentration and volume of the formalin solution.

Plan Your Strategy
Rearrange the equation $C = \frac{n}{V}$ to find the moles of solute. Use the molar mass of formaldehyde to convert this number of moles to grams.

Act on Your Strategy
$n = C \times V = 10 \text{ mol/L} \times 1.5 \text{ L} = 15 \text{ mol HCHO}$
molar mass of HCHO = 30 g/mol
$15 \text{ mol HCHO} \times 30 \text{ g/mol} = 4.5 \times 10^2 \text{ g HCHO}$

Check Your Solution
The final answer has the correct unit and number of significant figures and seems reasonable.

25. Problem
Suppose that you are given a solution of 1.25 mol/L sodium chloride in water, $NaCl_{(aq)}$. What volume must you dilute to prepare the following solutions?
(a) 50 mL of 1.00 mol/L $NaCl_{(aq)}$
(b) 200 mL of 0.800 mol/L $NaCl_{(aq)}$
(c) 250 mL of 0.300 mol/L $NaCl_{(aq)}$)

What Is Required?
Find the volume of the concentrated solution that must be used to prepare the given volume of dilute solution.

What Is Given?
In each case you know the volume in mL of dilute solution to prepare and the concentrations of the concentrated and the dilute solutions.

Plan Your Strategy
Convert the volume of the dilute solution from mL to L.
The moles of solute in the final dilute solution = moles of solute taken from the concentrated solution.
apply the relationship:

$$n \text{ (NaCl) in concentrated solution} = n \text{ (NaCl) in dilute solution}$$
$$(C \times V)_{\text{concentrated}} = (C \times V)_{\text{dilute}}$$

Act on Your Strategy
(a) $(C \times V)_{\text{concentrated}} = (C \times V)_{\text{dilute}}$
$1.25 \text{ mol/L} \times V = 1.00 \text{ mol/L} \times 0.050 \text{ L}$
$V = 0.040 \text{ L or } 40 \text{ mL}$
(b) $(C \times V)_{\text{concentrated}} = (C \times V)_{\text{dilute}}$
$1.25 \text{ mol/L} \times V = 0.800 \text{ mol/L} \times 0.200 \text{ L}$
$V = 0.128 \text{ L or } 128 \text{ mL}$

(c) $(C \times V)_{concentrated} = (C \times V)_{dilute}$
$1.25 \text{ mol/L} \times V = 0.300 \text{ mol/L} \times 0.250 \text{ L}$
$V = 0.0600 \text{ L or } 60.0 \text{ mL}$

Check Your Solution
In each case the unit and number of significant figures is correct. The volume of concentrated solution needed is always smaller than the volume of the dilute solution, which is reasonable.

26. Problem
What concentration of solution is obtained by diluting 50.0 mL of 0.720 mol/L aqueous sodium nitrate, $NaNO_3$ to each volume?
(a) 120 mL **(b)** 400 mL **(c)** 5.00 L

What Is Required?
Find the final concentration of a solution after diluting.

What Is Given?
In each case, you know the volume and the concentration of the concentrated solution as well as the final volume of dilute solution.

Plan Your Strategy
Convert the volume of concentrated solution from mL to L.
Apply the relationship developed in question 25.
$$(C \times V)_{concentrated} = (C \times V)_{dilute}$$

Act on Your Strategy
(a) $(C \times V)_{concentrated} = (C \times V)_{dilute}$
$0.720 \text{ mol/L} \times 0.0500 \text{ L} = C \times 0.120 \text{ L}$
$C = 0.300 \text{ mol/L}$
(b) $(C \times V)_{concentrated} = (C \times V)_{dilute}$
$0.720 \text{ mol/L} \times 0.0500 \text{ L} = C \times 0.400 \text{ L}$
$C = 0.0900 \text{ mol/L}$
(c) $(C \times V)_{concentrated} = (C \times V)_{dilute}$
$0.720 \text{ mol/L} \times 0.0500 \text{ L} = C \times 5.00 \text{ L}$
$C = 7.20 \times 10^{-3} \text{ mol/L}$

Check Your Solution
In each case, the final answer has the correct unit and number of significant figures. The concentration of the diluted solution in each case is less than the concentration of the concentrated solution, which is reasonable.

27. Problem
A solution is prepared by adding 600 mL of distilled water to 100 mL of 0.15 mol/L ammonium nitrate, NH_4NO_3. Calculate the molar concentration of the solution. Assume that the volume quantities can be added together.

What Is Required?
Find the final concentration after diluting a solution.

What Is Given?
You know the initial volume and concentration of the starting (concentrated) solution. Also the volume of water that is added is given so you can determine the final volume of the diluted solution.

Plan Your Strategy

Add the volume of water to the initial volume of the concentrated solution. Apply the previously developed relationship, $(C \times V)_{concentrated} = (C \times V)_{dilute}$ and solve for the final concentration.

Act on Your Strategy

final volume of solution = 600 ml water + 100 mL of solution = 700 mL = 0.700 L

$(C \times V)_{concentrated} = (C \times V)_{dilute}$

$0.15 \text{ mol/L} \times 0.100 \text{ L} = C \times 0.700 \text{ L}$

$C = 0.021 \text{ mol/L}$

Check Your Solution

The final answer has the correct unit and number of significant figures. The final concentration is less than the initial concentration, which is reasonable.