Chapter 8

Solutions and Their Properties

Section 8.2 Factors That Affect Solubility and Rate of Dissolving

Solutions for Selected Review Questions

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3. Review Question (page 370)

Vitamin A is soluble in fats but not in water. This vitamin is found in foods such as yellow fruit and green vegetables. People who have little access to meat frequently show signs of vitamin A deficiency even when their diet contains a good supply of the necessary fruit and vegetables. Why do these people show signs of vitamin A deficiency?

Vitamin A is a molecular compound that is not soluble in water but is soluble in fat. In the diet of many North Americans, fat is obtained through eating meats. A vegetarian diet would not include meat. If no other source of fat is included in the diet, there would be no solvent in which the vitamin A could dissolve and this nutrient would not be absorbed into the body cells.

4. Review Question (page 370)

Explain why calcium hydroxide, $Ca(OH)_2(s)$, is insoluble in water, but sodium hydroxide, NaOH(s), is soluble.

$Ca(OH)_2(s)$ is less soluble because the attraction between the oppositely charged Ca^{2+} ions and OH^{-} ions is greater than the attractions between polar water molecules and the ions. The 2+ charge on the calcium ion is the main factor contributing to this strong ion–ion attraction.

On the other hand, in NaOH(s), the attraction between the oppositely charged Na^{+} ions and OH^{-} ions is less than the attraction between polar water molecules and the ions. The charge on the sodium ion is 1+. This will be the main contributing factor to the weaker ion–ion attractions in this compound.

The hydrogen bonding between polar water molecules is less than the attractions between the ions and the water molecules. The water molecules surround the ions, or hydrate the ions, as dissolving occurs.

5. Review Question (page 370)

Is iodine, $I_2(s)$, more likely to dissolve in water or in carbon tetrachloride, $CCl_4(\ell)$? Explain.

Iodine is more likely to dissolve in $CCl_4(\ell)$. $I_2(s)$ and $CCl_4(\ell)$ are both non-polar molecular compounds, whereas water is a polar molecular compound. There are no significant attractions between the non-polar I_2 molecules and polar water molecules that would cause molecules of $I_2(s)$ to separate.

6. Review Question (page 370)

Explain why the solubility of a gas in olive oil is similar to the solubility of the same gas in animal fat. How could this information be useful to a researcher who is evaluating the safety of a new anesthetic gas? Anesthetics are medicines that are given to patients before surgery to keep them from feeling pain during the procedure.

Fats and oils are chemically similar. Physically, the oils have weaker intermolecular forces between molecules and have a lower melting point than fats. The solubility of a gas in an oil would be similar to the solubility in fat if it is soft (i.e., has a lower melting point). This information is valuable to a researcher, because the solubility of a new anesthetic can be tested in the laboratory using oil rather than on a patient.

7. Review Question (page 370)

Food colouring is often added to ice cream, candies, and icing for birthday cakes. Are the molecules in food colouring more likely to be polar or non-polar? Explain your answer.

Food colouring must dissolve completely because there is a homogeneous appearance to the foods. Since the food colouring mixes completely, and since each food contains polar water molecules, the food colouring would be expected to be made up of polar molecules. The polar water molecules would hydrate the molecules in the food colouring.

8. Review Question (page 370)

A scuba diver who is experiencing the "bends" as a result of nitrogen bubbles in the blood may be treated in a recompression chamber. The air pressure in this sealed chamber can be increased to many times the atmospheric pressure. Explain how a recompression chamber can be used to remove the nitrogen bubbles safely.

There is a problem with ascending from an underwater dive too quickly. A scuba diver breathes air at a greater pressure under water than at the surface of the water. More nitrogen is dissolved in the diver's blood. Slow surfacing allows the dissolved nitrogen to come out of the blood solution gradually, preventing the sudden formation of bubbles of gas in the blood that is potentially fatal.

A recompression chamber can be used to simulate the underwater pressure conditions and cause the nitrogen gas to dissolve in the blood. The pressure can then be decreased slowly, similar to ascending from the dive gradually. The nitrogen gas can be safely exhaled in small amounts.

9. Review Question (page 370)

Use the solubility curves in **Figure 8.11** (below) to predict whether each solution of potassium chlorate, $KClO_3(aq)$, is saturated, unsaturated, or supersaturated.

a. 15 g of $KClO_3(aq)$ in 100 g of water at 40°C
b. 10 g of $KClO_3(aq)$ in 50 g of water at 65°C
c. 8 g of $KClO_3$**(**aq) in 50 g of water at 50°C

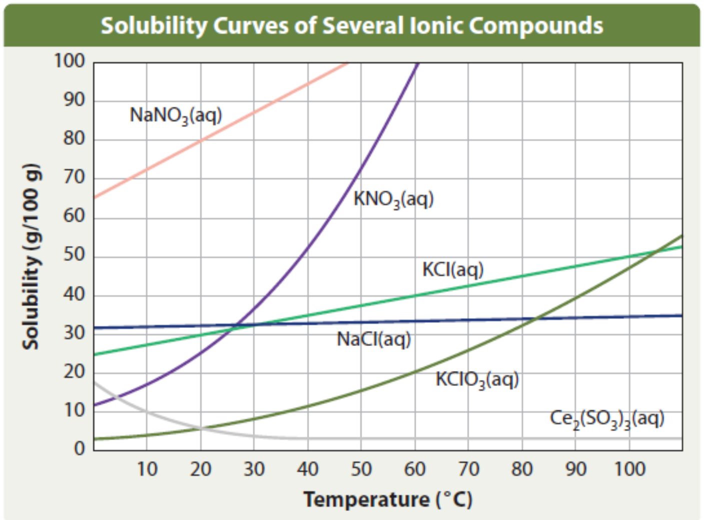

Figure 8.11 The solubility of most ionic substances in water increases with temperature. In this graph, the solubility is given in grams of solute per 100 g of *solvent*. This is different from other expressions of solubility, which are given in grams of solute per 100 mL of *solution*.

a. At 40°C, the solubility of $KClO_3(aq)$ in 100 g of water is 12 g. A solution containing 15 g of $KClO_3(aq)$ in 100 g of water is supersaturated.
b. At 65°C, the solubility of $KClO_3(aq)$ in 100 g of water is 24 g. At 65°C, the solubility of $KClO_3(aq)$ in 50 g of water is 12 g. A solution containing 10 g of $KClO_3(aq)$ in 50 g of water is unsaturated.
c. At 50°C, the solubility of $KClO_3(aq)$ in 100 g of water is 16 g. At 50°C the solubility of $KClO_3(aq)$ in 50 g of water is 8 g. A solution containing 8 g of $KClO_3(aq)$ in 50 g of water is saturated.

11. Review Question (page 370)

Explain why sodium chloride, NaCl(s), is insoluble in benzene, $C_6H_6(\ell)$. In your explanation, refer to the forces of attraction between the various particles.

NaCl(s) is an ionic solid held together by strong electrical attraction between oppositely charged Na^+ ions and Cl^- ions. $C_6H_6(\ell)$ is a non-polar molecular compound in which molecules are weakly attracted to one another. There are no centres of charge in the $C_6H_6(\ell)$ that can attract ions and cause separation of the ions in NaCl(s). Therefore, NaCl(s) does not dissolve in $C_6H_6(\ell)$.

15. Review Question (page 370)

The molecular structure of methanol is shown below. Use this structure to explain why methanol is soluble in both water and gasoline.

```
      H
      |
H – C – O – H
      |
      H
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CH_3OH has a polar –OH group on one side of the molecule that can lead to hydrogen bonding. The CH_3– is non-polar. Methanol is soluble in water because the hydrogen bonding in both water and methanol results in attractions between the polar water molecules and the polar methanol molecules. The non-polar part of methanol will be attracted to, and mix with, non-polar octane, $C_8H_{18}(\ell)$, the main component of gasoline.

16. Review Question (page 370)

Boiling is an effective method for sterilizing water. The water will remain sterile if it is covered while it cools to room temperature. Water that is sterilized in this way is not suitable for filling a fish tank, however. Explain why.

Fish survive by extracting dissolved oxygen from water. The solubility of a gas in a liquid decreases with increasing temperature. Boiling the water will decrease the dissolved oxygen content to zero, and because the water is left covered while it cools, oxygen in the air cannot dissolve in the water. Fish would have no oxygen to breathe in the cooled water and would die.

Section 8.3 Concentrations of Solutions

Solutions for Practice Problems

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1. Practice Problem (page 373)

A pharmacist adds 20.0 mL of distilled water to 30.0 g of a powdered medicine. The volume of the solution formed is 25.0 mL. What is the percent (m/v) concentration of the solution?

What Is Required?

You need to calculate the percent (m/v) concentration of a solution.

What Is Given?

You know the mass of the powdered medicine solute: 30.0 g
You know the volume of the solution: 25.0 mL

Plan Your Strategy

Write the formula for percent (m/v) concentration.
Substitute the given data into the expression to calculate the concentration.

Act on Your Strategy

$$\begin{aligned}\text{percent (m/v)} &= \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\% \\ &= \frac{30.0\text{ g}}{25.0\text{ mL}} \times 100\% \\ &= 1.20 \times 10^2\%\end{aligned}$$

The concentration of the solution is 1.20×10^2% (m/v).

Check Your Solution

Since the mass of solute is greater than the volume of solution, it is reasonable to have a percent (m/v) concentration greater than 100%. The answer correctly shows three significant digits.

2. Practice Problem (page 373)

A solution contains 21.4 g of sodium nitrate, $NaNO_3(s)$, dissolved in 250 mL of solution. Find the percent (m/v) concentration of the solution.

What Is Required?

You need to calculate the percent (m/v) concentration of a solution.

What Is Given?
You know the mass of the sodium nitrate solute: 21.4 g
You know the volume of the solution: 250 mL

Plan Your Strategy
Write the formula for percent (m/v) concentration.
Substitute the given data into the expression to calculate the concentration.

Act on Your Strategy

$$\begin{aligned}\text{percent (m/v)} &= \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\% \\ &= \frac{21.4 \text{ g}}{250 \text{ mL}} \times 100\% \\ &= 8.56\%\end{aligned}$$

The concentration of the solution is 8.56% (m/v).

Check Your Solution
Since the volume of solution is about 11 times greater than the mass of solute, the percent (m/v) concentration is about $\frac{1}{11} \times 100\%$ or about 9% (m/v). This agrees with the calculated value and the answer correctly shows three significant digits.

3. Practice Problem (page 373)
A chemist slowly evaporated 1.80 L of a 1.75% (m/v) solution of calcium nitrate, $Ca(NO_3)_2(aq)$. What mass of solute should the chemist obtain?

What Is Required?
You need to calculate the mass of calcium nitrate.

What Is Given?
You know the concentration of the solution: 1.75% (m/v)
You know the volume of the solution: 1.80 L

Plan Your Strategy
Convert the volume of the solution from litres to millilitres: $1 \text{ L} = 1 \times 10^3 \text{ mL}$
Write the formula for percent (m/v) concentration.
Rearrange the formula to solve for the mass of solute.
Substitute the given data into the expression to calculate the mass of calcium nitrate, *m*.

Act on Your Strategy

Volume conversion:

$$\text{volume of solution} = 1.80\ \cancel{\text{L}} \times 1 \times 10^3\ \text{mL}/\cancel{\text{L}}$$
$$= 1800\ \text{mL}$$

Formula for percent (m/v) concentration:

$$\text{percent (m/v)} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\%$$

Rearranged formula to solve for the mass of solute:

$$\frac{\text{percent (m/v)}}{100\%} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}}$$

$$\text{mass of solute [in grams]} = \frac{\text{percent (m/v)}}{100\%} \times \text{volume of solution [in millilitres]}$$

Substitution to calculate *m*:

$$m = \frac{1.75\ \cancel{\%}\ \frac{\text{g}}{\cancel{\text{mL}}} \times 1800\ \cancel{\text{mL}}}{100\ \cancel{\%}}$$
$$= 31.5\ \text{g}$$

The mass of calcium nitrate that the chemist should obtain is 31.5 g.

Check Your Solution

Use the calculated answer to express the mass as a percentage of the volume:

$$\frac{31.5\ \text{g}}{1800\ \text{mL}} \times 100\% = 1.75\%\ \text{(m/v)}$$

The answer is accurate and correctly shows three significant digits.

4. Practice Problem (page 373)

What mass of potassium permanganate must be dissolved to make 2.0 L of a 4.0% (m/v) solution?

What Is Required?

You need to calculate the mass of potassium permanganate.

What Is Given?

You know the concentration of the solution: 4.0% (m/v)

You know the volume of the solution: 2.0 L

Plan Your Strategy

Convert the volume of the solution from litres to millilitres: 1 L = 1×10^3 mL

Write the formula for percent (m/v) concentration.

Rearrange the formula to solve for the mass of solute.

Substitute the data into the expression to calculate the mass of potassium permanganate, *m*.

Act on Your Strategy

Volume conversion:

$$\begin{aligned}\text{volume of solution} &= 2.0\ \cancel{\text{L}} \times 1 \times 10^3\ \text{mL}/\cancel{\text{L}} \\ &= 2000\ \text{mL}\end{aligned}$$

Formula for percent (m/v) concentration:

$$\text{percent (m/v)} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\%$$

Rearranged formula to solve for the mass of solute:

$$\frac{\text{percent (m/v)}}{100\%} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}}$$

$$\text{mass of solute [in grams]} = \frac{\text{percent (m/v)}}{100\%} \times \text{volume of solution [in millilitres]}$$

Substitution to calculate *m*:

$$\begin{aligned} m &= \frac{4.0\ \cancel{\%}\ \frac{\text{g}}{\cancel{\text{mL}}} \times 2000\ \cancel{\text{mL}}}{100\ \cancel{\%}} \\ &= 80\ \text{g}\end{aligned}$$

The mass of potassium permanganate that must be dissolved is 80 g.

Check Your Solution

Express the mass as a percentage of the volume:

$$\frac{80\ \text{g}}{2000\ \text{mL}} \times 100\% = 4.0\%\ \text{(m/v)}$$

The answer is accurate and correctly shows two significant digits.

5. Practice Problem (page 373)

A chemist measured 25.00 g of water and bubbled hydrogen chloride gas into the water. The resulting solution had a mass of 26.68 g and a volume of 25.2 mL. Determine the percent (m/v) concentration of the solution.

What Is Required?

You need to calculate the percent (m/v) concentration of a solution.

What Is Given?

You know the mass of the hydrogen chloride solution, HCl(aq): 26.68 g
You know the mass of the solvent: 25.00 g
You know the volume of the solution: 25.2 mL

Plan Your Strategy

Calculate the mass of solute by subtracting the mass of solvent from the mass of solution.
Write the formula for percent (m/v) concentration.
Substitute the given data into the expression to calculate the concentration.

Act on Your Strategy

$$\begin{aligned}\text{mass of solute} &= \text{mass of solution} - \text{mass of solvent}\\ &= 26.68\text{ g} - 25.00\text{ g}\\ &= 1.68\text{ g}\end{aligned}$$

$$\begin{aligned}\text{percent (m/v)} &= \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\%\\ &= \frac{1.68\text{ g}}{25.2\text{ mL}} \times 100\%\\ &= 6.67\%\end{aligned}$$

The concentration of the solution is 6.67% (m/v).

Check Your Solution

Estimating, the mass of solute is about $\frac{1}{15}$ the volume of the solution. The concentration in percent (m/v) expressed as a fraction is $\frac{7}{100}$, or about $\frac{1}{15}$. This agrees with the calculated value and the answer correctly shows three significant digits.

6. Practice Problem (page 373)

A student carefully evaporated all the water from an 80.0 mL salt solution. She found that the mass of the residue from the sample was 1.40 g. Calculate the percent (m/v) concentration of the salt solution.

What Is Required?

You need to calculate the percent (m/v) concentration of a salt solution.

What Is Given?

You know the mass of the salt that was dissolved: 1.40 g

You know the volume of the solution: 80.0 mL

Plan Your Strategy

Write the formula for percent (m/v) concentration.

Substitute the given data into the expression to calculate the concentration.

Act on Your Strategy

$$\begin{aligned}\text{percent (m/v)} &= \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\% \\ &= \frac{1.40\text{ g}}{80.0\text{ mL}} \times 100\% \\ &= 1.75\%\end{aligned}$$

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

Check Your Solution

Estimating:

$$\frac{1.5 \times 100}{80} = 1.90$$

This agrees with the calculated value and the answer correctly shows three significant digits.

7. Practice Problem (page 373)

A household bleach has a concentration of 4.60% (m/v) of sodium hypochlorite, NaOCl(aq). What mass of sodium hypochlorite does a 2.84 L container of this bleach contain?

What Is Required?

You need to calculate the mass of sodium hypochlorite.

What Is Given?
You know the concentration of the solution: 4.60% (m/v)
You know the volume of the solution: 2.84 L

Plan Your Strategy
Convert the volume of the solution from litres to millilitres: 1 L = 1 × 10^3 mL
Write the formula for percent (m/v) concentration.
Rearrange the formula to solve for the mass of solute.
Substitute the data into the expression to calculate the mass of sodium hypochlorite, *m*.

Act on Your Strategy
Volume conversion:

$$\begin{aligned}\text{volume of solution} &= 2.84\ \cancel{\text{L}} \times 1 \times 10^3\ \text{mL}/\cancel{\text{L}}\\ &= 2840\ \text{mL}\end{aligned}$$

Formula for percent (m/v) concentration:

$$\text{percent (m/v)} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\%$$

Rearranged formula to solve for the mass of solute:

$$\frac{\text{percent (m/v)}}{100\%} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}}$$

$$\text{mass of solute [in grams]} = \frac{\text{percent (m/v)}}{100\%} \times \text{volume of solution [in millilitres]}$$

Substitution to calculate *m*:

$$\begin{aligned}m &= \frac{4.60\ \cancel{\%}\ \dfrac{\text{g}}{\cancel{\text{mL}}} \times 2840\ \cancel{\text{mL}}}{100\ \cancel{\%}}\\ &= 130.64\ \text{g}\\ &= 131\ \text{g}\end{aligned}$$

The mass of sodium hypochlorite that the container contains is 131 g.

Check Your Solution
Using the calculated answer, express the mass as a percentage of the volume:

$$\frac{131\ \text{g}}{2840\ \text{mL}} \times 100\% = 4.61\%\ \text{(m/v)}$$

The answer is accurate and correctly shows three significant digits.

8. Practice Problem (page 373)

Ringer's solution contains 0.86% (m/v) NaCl(aq), 0.03% (m/v) KCl(aq), and 0.033% (m/v) $CaCl_2$(aq). Calculate the mass of each of these compounds in a 300 mL bag of Ringer's solution.

What Is Required?

You need to calculate the masses of sodium chloride, potassium chloride, and calcium chloride in a solution.

What Is Given?

You know the concentration of each solute in the solution:
0.86% (m/v) NaCl(aq)
0.03% (m/v) KCl(aq)
0.033% (m/v) $CaCl_2$(aq)
You know the volume of the solution: 300 mL

Plan Your Strategy

Write the formula for percent (m/v) concentration.
Rearrange the formula to solve for the mass of each solute.
Substitute the data into the expression to calculate the mass of each solute, *m*.

Act on Your Strategy

Formula for percent (m/v) concentration:

$$\text{percent (m/v)} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\%$$

Rearranged formula to solve for the mass of solute:

$$\frac{\text{percent (m/v)}}{100\%} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}}$$

$$\text{mass of solute [in grams]} = \frac{\text{percent (m/v)}}{100\%} \times \text{volume of solution [in millilitres]}$$

• Substitution to calculate the mass of NaCl(s) solute, m_{NaCl}:

$$\begin{aligned} m_{NaCl} &= \frac{0.86 \cancel{\%} \ \frac{\text{g}}{\cancel{\text{mL}}} \times 300 \ \cancel{\text{mL}}}{100 \cancel{\%}} \\ &= 2.58 \text{ g} \\ &= 2.6 \text{ g} \end{aligned}$$

The mass of sodium chloride is 2.6 g.

• Substitution to calculate the mass of KCl(s) solute, m_{KCl}:

$$m_{KCl} = \frac{0.03\cancel{\%}\,\frac{g}{\cancel{mL}} \times 300\,\cancel{mL}}{100\cancel{\%}}$$
$$= 0.09 \text{ g}$$

The mass of potassium chloride is 0.09 g.

• Substitution to calculate the mass of $CaCl_2$(s) solute, m_{CaCl_2}:

$$m_{CaCl_2} = \frac{0.033\cancel{\%}\,\frac{g}{\cancel{mL}} \times 300\,\cancel{mL}}{100\cancel{\%}}$$
$$= 0.099 \text{ g}$$

The mass of calcium chloride is 0.099 g.

Check Your Solution

Estimating by expressing each mass as a percentage of the volume:

NaCl(aq): $\frac{2.6 \text{ g}}{300 \text{ mL}} \times 100\% = 0.9\% \text{ (m/v)}$

KCl(aq): $\frac{0.09 \text{ g}}{300 \text{ mL}} \times 100\% = 0.03\% \text{ (m/v)}$

$CaCl_2$(aq): $\frac{0.099 \text{ g}}{300 \text{ mL}} \times 100\% = 0.033\% \text{ (m/v)}$

The answers show the correct number of significant digits.

9. Practice Problem (page 373)

What volume of 5.0% (m/v) solution of sodium chloride, NaCl(aq), can be made using 40 g of NaCl(s)?

What Is Required?

You need to calculate the volume of a NaCl(aq) solution.

What Is Given?

You know the concentration of the solution: 5.0% (m/v)

You know the mass of the solute: 40 g

Plan Your Strategy
Write the formula for percent (m/v) concentration.
Rearrange the formula to solve for the volume of solution.
Substitute the data into the expression to calculate the volume of the sodium chloride solution, *V*.

Act on Your Strategy
Formula for percent (m/v) concentration:

$$\text{percent (m/v)} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\%$$

Rearranged formula to solve for the volume of solution:

$$\text{percent (m/v)} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\%$$

$$\text{percent (m/v)} \times \text{volume of solution [in millilitres]} = \text{mass of solute [in grams]} \times 100\%$$

$$\text{volume of solution [in millilitres]} = \frac{\text{mass of solute [in grams]}}{\text{percent (m/v)}} \times 100\%$$

Substitution to calculate the volume of the sodium chloride solution, *v*:

$$\begin{aligned} v &= \frac{40\ \cancel{\text{g}}}{5.0\cancel{\%}\ \frac{\cancel{\text{g}}}{\text{mL}}} \times 100\cancel{\%} \\ &= 800\ \text{mL} \end{aligned}$$

The volume of the solution is 800 ml.

Check Your Solution
Using the calculated value for the volume of solution, express the mass as a percentage of the volume:

$$\frac{40\ \text{g}}{800\ \text{mL}} \times 100\% = 5.0\%\ \text{(m/v)}$$

The answer agrees with the given data and correctly shows two significant digits.

10. Practice Problem (page 373)
How would you prepare 400 mL of a 3.5% (m/v) solution of sodium acetate?

What Is Required?
You need to calculate the mass of sodium acetate and describe how to prepare a solution.

What Is Given?
You know the concentration of the solution: 3.5% (m/v)
You know the volume of the solution: 400 mL

Plan Your Strategy
Write the formula for percent (m/v) concentration.
Rearrange the formula to solve for the mass of solute.
Substitute the data into the expression to calculate the mass of sodium acetate, *m*.
Prepare the solution of sodium acetate.

Act on Your Strategy
Formula for percent (m/v) concentration:

$$\text{percent (m/v)} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}} \times 100\%$$

Rearranged formula to solve for the mass of solute:

$$\frac{\text{percent (m/v)}}{100\%} = \frac{\text{mass of solute [in grams]}}{\text{volume of solution [in millilitres]}}$$

$$\text{mass of solute [in grams]} = \frac{\text{percent (m/v)}}{100\%} \times \text{volume of solution [in millilitres]}$$

Substitution to calculate the mass of sodium acetate, *m*:

$$m = \frac{3.5\,\cancel{\%}\,\dfrac{\text{g}}{\cancel{\text{mL}}} \times 400\,\cancel{\text{mL}}}{100\,\cancel{\%}}$$
$$= 14\text{ g}$$

The mass of sodium acetate is 14 g.

To prepare the solution, measure 14 g of the solute and dissolve in water. Add water to bring the total volume of the solution to 400 mL.

Check Your Solution
Using the calculated value for mass of solute, express the mass as a percentage of the volume: $\frac{14\text{ g}}{400\text{ mL}} \times 100\% = 3.5\%\text{ (m/v)}$
The answer agrees with the given data and correctly shows two significant digits.

Section 8.3 Concentrations of Solutions
Solutions for Practice Problems
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11. Practice Problem (page 375)

Calculate the percent (m/m) concentration of a solution that contains 11 g of pure sodium hydroxide in 75 g of solution.

What Is Required?

You need to determine the percent (m/m) concentration of a solution.

What Is Given?

You know the mass of the sodium hydroxide solute: 11 g
You know the mass of the solution: 75 g

Plan Your Strategy

Write the formula for percent (m/m) concentration.
Substitute the given data into the expression to calculate the concentration.

Act on Your Strategy

$$\begin{aligned}\text{percent (m/m)} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\% \\ &= \frac{11\ \cancel{g}}{75\ \cancel{g}} \times 100\% \\ &= 14.66\% \\ &= 15\%\end{aligned}$$

The concentration of the solution is 15% (m/m).

Check Your Solution

Estimating the answer, the mass of solution is about 7 times the mass of solute. The fraction $\frac{1}{7}$ as a percent is about 15%. The answer seems reasonable and correctly shows two significant digits.

12. Practice Problem (page 375)

A physiotherapist makes a footbath solution by dissolving 120 g of magnesium sulfate (Epsom salts), $MgSO_4(s)$, in 3.00 kg of water. Calculate the percent (m/m) of magnesium sulfate in the solution. (**Hint:** Remember to use the mass of *solution*.)

What Is Required?

You need to determine the percent (m/m) concentration of a magnesium sulfate solution.

What Is Given?

You know the mass of the magnesium sulfate solute: 120 g

You know the mass of the solvent: 3.00 kg

Plan Your Strategy

Convert the mass from kilograms to grams: 1 kg = 1×10^3 g

Determine the mass of solution by adding the mass of solute to the mass of solvent.

Write the formula for percent (m/m) concentration.

Substitute the data into the expression to calculate the concentration.

Act on Your Strategy

Mass conversion:

$$\begin{aligned}\text{mass of solvent} &= 3.00\ \cancel{\text{kg}} \times 1 \times 10^3\ \text{g}/\cancel{\text{kg}} \\ &= 3000\ \text{g}\end{aligned}$$

$$\begin{aligned}\text{mass of solution} &= \text{mass of solvent} + \text{mass of solute} \\ &= 3000\ \text{g} + 120\ \text{g} \\ &= 3120\ \text{g}\end{aligned}$$

Percent (m/m) concentration:

$$\begin{aligned}\text{percent (m/m)} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\% \\ &= \frac{120\ \cancel{\text{g}}}{3120\ \cancel{\text{g}}} \times 100\% \\ &= 3.846\% \\ &= 3.85\%\end{aligned}$$

The concentration of the solution is 3.85% (m/m).

Check Your Solution
Rounding off and estimating, the concentration in percent (m/m) is about 4% and the mass of solution is about 3000 g.
Four percent of 3000 is about 120 g. The estimate is close to the calculated value and seems reasonable. The calculated answer correctly shows three significant digits.

13. Practice Problem (page 375)

How much chromium, nickel, and iron would you need to make a 500 kg batch of 18/8 stainless steel, which is steel made with 18% (m/m) chromium and 8% (m/m) nickel in iron?

What Is Required?
You need to determine the mass of chromium, iron, and nickel needed to make stainless steel.

What Is Given?
You know the mass of the solution: 500 kg
You know the percent (m/m) of the component elements:
18% chromium
8% nickel
74% iron (the difference between the concentration of the solution (100%) and the sum of the concentrations of chromium and nickel)

Plan Your Strategy
Write the formula for percent (m/m) concentration.
Rearrange the formula to solve for the mass of solute.
Substitute the data into the expression and solve for the mass of each solute, *m*.

Act on Your Strategy
Formula for percent (m/m) concentration:

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

Rearranged formula to solve for the mass of solute:

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

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

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

• Substitution to calculate the mass of the chromium solute, m_{Cr}:

$$m_{Cr} = \frac{18\,\cancel{\%} \times 500\text{ kg}}{100\,\cancel{\%}}$$

$$= 90\text{ kg}$$

• Substitution to calculate the mass of the nickel solute, m_{Ni}:

$$m_{\text{Ni}} = \frac{8 \cancel{\%} \times 500 \text{ kg}}{100 \cancel{\%}}$$
$$= 40 \text{ kg}$$

• Substitution to calculate the mass of the iron solute, m_{Fe}:

$$m_{\text{Fe}} = \frac{74 \cancel{\%} \times 500 \text{ kg}}{100 \cancel{\%}}$$
$$= 370 \text{ kg}$$

To make 500 kg of stainless steel, you would need 90 kg of chromium, 40 kg of nickel, and 370 kg of iron.

Check Your Solution
The answers are reasonable. The mass of nickel is a little less than half the mass of chromium and the percent (m/m) nickel (8%) is a little less than half the percent (m/m) of chromium (18%).

14. Practice Problem (page 375)
When evaporated, a sample of a solution of silver nitrate, $AgNO_3$(aq), leaves a residue with a mass of 3.47 g. The original sample had a mass of 43.88 g. Calculate the percent (m/m) concentration of the silver nitrate solution.

What Is Required?
You need to calculate the percent (m/m) concentration of a solution of silver nitrate.

What Is Given?
You know the mass of the $AgNO_3$(s) solute: 3.47 g
You know the mass of the $AgNO_3$(aq) solution: 43.88 g

Plan Your Strategy
Write the formula for percent (m/m) concentration.
Substitute the given data into the expression to calculate the concentration.

Act on Your Strategy

$$\text{percent (m/m)} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$
$$= \frac{3.47 \cancel{\text{g}}}{43.88 \cancel{\text{g}}} \times 100\%$$
$$= 7.907\%$$
$$= 7.91\%$$

The concentration of the silver nitrate solution is 7.91% (m/m).

Check Your Solution
Using rounded-off values, and working backward to estimate the mass of solute:
$8\%\ (\text{m/m}) \times 45\ \text{g AgNO}_3(\text{aq}) = 3.6\ \text{g}$
This estimated answer agrees with the given mass of solute. The calculated answer is reasonable and correctly shows three significant digits.

15. Practice Problem (page 375)
A solution is made by dissolving 12.9 g of carbon tetrachloride, $CCl_4(\ell)$, in 72.5 g of benzene, $C_6H_6(\ell)$. Calculate the percent (m/m) concentration of carbon tetrachloride in the solution.

What Is Required?
You have to calculate the percent (m/m) concentration of a solution of carbon tetrachloride in benzene.

What Is Given?
You know the mass of the $CCl_4(\ell)$ solute: 12.9 g
You know the mass of the solvent, $C_6H_6(\ell)$: 72.5g

Plan Your Strategy
Determine the mass of solution by adding the mass of the solute, $CCl_4(\ell)$, and the mass of the solvent, $C_6H_6(\ell)$.
Write the formula for percent (m/m) concentration.
Substitute the given data into the expression to calculate the concentration.

Act on Your Strategy

$$\begin{aligned}\text{mass of solution} &= \text{mass of solute} + \text{mass of solvent}\\ &= 12.9\ \text{g} + 72.5\ \text{g}\\ &= 85.4\ \text{g}\end{aligned}$$

$$\begin{aligned}\text{percent (m/m)} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%\\ &= \frac{12.9\ \cancel{\text{g}}}{85.4\ \cancel{\text{g}}} \times 100\%\\ &= 15.1\%\end{aligned}$$

The concentration of the solution is 15.1% (m/m).

Check Your Solution
Using rounded-off values, and working backward to estimate the mass of solute $CCl_4(\ell)$:
15% (m/m) × 85 g solution = 12.75 g
This estimated answer agrees with the given mass of solute, $CCl_4(\ell)$. The calculated answer is reasonable and correctly shows three significant digits.

16. Practice Problem (page 375)
Since pure gold is quite soft, gold jewellery is usually made with an alloy. An 18 karat gold alloy contains 75% (m/m) gold. How much of this alloy can a jeweller make with 8.00 g of pure gold?

What Is Required?
You must determine the mass of a solution of gold alloy.

What Is Given?
You know the mass of gold solute: 8.00 g:
You know the percent (m/m) concentration of the solution: 75%

Plan Your Strategy
Write the formula for percent (m/m) concentration.
Rearrange the formula to solve for the mass of solution.
Substitute the data into the expression and calculate the mass of the alloy, *m*.

Act on Your Strategy
Formula for percent (m/m) concentration:

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

Rearranged formula to solve for the mass of solution:

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

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

Substitution to calculate the mass of the gold alloy, *m*:

$$m = \frac{8.00\text{ g} \times 100\cancel{\%}}{75\cancel{\%}}$$

$$= 10.66\text{ g}$$

$$= 11\text{ g}$$

The mass of the gold alloy is 11 g.

Check Your Solution
Using rounded values, and working backward to estimate the mass of solution:

$$\frac{8\ \cancel{g}\ \text{[solute]}}{11\ \cancel{g}\ \text{[solution]}} \times 100\% = 73\%$$

This estimated answer agrees closely with the given percent (m/m) concentration. The calculated answer is reasonable and correctly shows two significant digits.

17. Practice Problem (page 375)
Surgical steel is an iron alloy that is easy to clean and sterilize. It contains 12 to 14% (m/m) chromium. Calculate the minimum mass of chromium in a 40 g instrument made from surgical steel.

What Is Required?
You need to determine the minimum mass of chromium in stainless steel.

What Is Given?
You know the mass of the stainless steel solution: 40 g
You know the minimum percent (m/m) of the chromium solute: 12%

Plan Your Strategy
Write the formula for percent (m/m) concentration.
Rearrange the equation to solve for the mass of solute.
Substitute the given data into the expression to calculate the minimum mass of the chromium solute, *m*.

Act on Your Strategy
Formula for percent (m/m) concentration:

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

Rearranged formula to solve for the mass of solute:

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

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

Substitution to calculate the mass of the chromium solute:

$$\begin{aligned} m &= \frac{12\ \cancel{\%} \times 40\text{ g}}{100\ \cancel{\%}} \\ &= 4.8\text{ g} \end{aligned}$$

The minimum mass of the chromium solute is 4.8 g.

Check Your Solution
Using rounded values, and working backward to estimate the mass of solute:

$$\frac{5\ \cancel{g}\ \text{[solute]}}{40\ \cancel{g}\ \text{[solution]}} \times 100\% = 12.5\%$$

This estimated answer agrees closely with the given percent (m/m) concentration. The calculated answer is reasonable and correctly shows two significant digits.

18. Practice Problem (page 375)
Pure iron is a relatively soft metal. Adding carbon to iron makes a type of steel that is much stronger than pure iron. Calculate the percent (m/m) concentration of carbon in a 5.0 kg steel bar that contains 85 g of carbon.

What Is Required?
You have to calculate the percent (m/m) concentration of a solution of iron alloy.

What Is Given?
You know the mass of the carbon solute: 85 g.
You know the mass of the solution of iron alloy 5.0 kg.

Plan Your Strategy
Convert the mass of the solution from kilograms to grams: 1 kg = 1×10^3 g
Write the formula for percent (m/m) concentration.
Substitute the data into the expression to calculate the concentration of carbon.

Act on Your Strategy

$$\begin{aligned}\text{mass of solution} &= 5.0\ \cancel{kg} \times 1 \times 10^3\ \text{g}/\cancel{kg} \\ &= 5000\ \text{g}\end{aligned}$$

$$\begin{aligned}\text{percent (m/m)} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\% \\ &= \frac{85\ \cancel{g}}{5000\ \cancel{g}} \times 100\% \\ &= 1.7\%\end{aligned}$$

The concentration of the solution of iron alloy is 1.7% (m/m).

Check Your Solution
Using rounded values, and working backward to estimate the mass of solute:

$$2\%(\text{m/m}) \times 5000 \text{ g} = 100 \text{ g}$$

This estimated answer approximates the given mass of solute. The calculated answer is reasonable and correctly shows two significant digits.

19. Practice Problem (page 375)
A technician who was monitoring the health of a lake analyzed a sample of water from the lake. The sample had a mass of 155 g and contained 1.12 mg of dissolved oxygen. Calculate the percent (m/m) concentration of oxygen in the sample.

What Is Required?
You have to calculate the percent (m/m) concentration of dissolved oxygen in lake water.

What Is Given?
You know the mass of oxygen solute: 1.12 mg
You know the mass of solution: 155 g

Plan Your Strategy
Convert the mass of oxygen solute from milligrams to grams:
1 mg = 1×10^{-3} g
Write the formula for percent (m/m) concentration.
Substitute the data into the expression to calculate the concentration of dissolved oxygen.

Act on Your Strategy

$$\begin{aligned}\text{mass of solute} &= 1.12 \cancel{\text{ mg}} \times 1 \times 10^{-3} \text{ g}/\cancel{\text{mg}} \\ &= 1.12 \times 10^{-3} \text{ g}\end{aligned}$$

$$\begin{aligned}\text{percent (m/m)} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\% \\ &= \frac{1.12 \times 10^{-3} \cancel{\text{ g}}}{155 \cancel{\text{ g}}} \times 100\% \\ &= 7.2258 \times 10^{-4}\% \\ &= 7.23 \times 10^{-4}\%\end{aligned}$$

The concentration of oxygen in the lake water is $7.23 \times 10^{-4}\%$ (m/m).

Check Your Solution

Using rounded values, and working backward to estimate the mass of solute:

$$7 \times 10^{-4}\% \text{ (m/m)} \times 1.5 \times 10^{2} \text{ g} = 1 \times 10^{-3} \text{ g or about 1 mg}$$

This estimated answer approximates the given mass of solute. The calculated answer is reasonable and correctly shows three significant digits.

20. Practice Problem (page 375)

A mining company in Sudbury reported mining 6.91×10^5 t of ore, from which it extracted 1.68×10^3 t of nickel, 1.6×10^4 t of copper, and 1.6 t of platinum. What is the percent (m/m) concentration of each metal in the ore?

What Is Required?

You need to calculate the percent (m/m) concentrations of nickel, copper, and platinum in an ore.

What Is Given?

You know the mass of each metal in the ore:

1.68×10^3 t of nickel

1.6×10^4 t of copper

1.6 t of platinum

You know the mass of the ore (solution): 6.91×10^5 t

Plan Your Strategy

Write the formula for percent (m/m) concentration.

Substitute the data into the expression to calculate the concentration of each metal.

Act on Your Strategy

- concentration of nickel

$$\begin{aligned}\text{percent (m/m)} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\% \\ &= \frac{1.68 \times 10^3 \cancel{\text{t}}}{6.91 \times 10^5 \cancel{\text{t}}} \times 100\% \\ &= 0.24312\% \\ &= 0.243\%\end{aligned}$$

The concentration of nickel in the ore is 0.243% (m/m).

• concentration of copper

$$\text{percent (m/m)} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$
$$= \frac{1.6 \times 10^4 \not{t}}{6.91 \times 10^5 \not{t}} \times 100\%$$
$$= 2.315\%$$
$$= 2.3\%$$

The concentration of copper in the ore is 2.3% (m/m).

• concentration of platinum

$$\text{percent (m/m)} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$
$$= \frac{1.6 \not{t}}{6.91 \times 10^5 \not{t}} \times 100\%$$
$$= 2.315 \times 10^{-4}\%$$
$$= 2.3 \times 10^{-4}\%$$

The concentration of nickel in the ore is 2.3×10^{-4}% (m/m).

Check Your Solution
The amounts of each metal differ approximately by a number of powers of ten. The percent (m/m) concentrations differ by the same powers of ten. The calculated answers seem reasonable and are expressed to the correct number of significant digits.

Section 8.3 Concentrations of Solutions

Solutions for Practice Problems

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21. Practice Problem (page 376)
The rubbing alcohol that is sold in pharmacies is usually a 70% (v/v) aqueous solution of isopropyl alcohol. What volume of isopropyl alcohol is present in a 500 mL bottle of this solution?

What Is Required?
You need to determine the volume of isopropyl alcohol (solute) in a bottle of rubbing alcohol.

What Is Given?
You know the volume of the solution: 500 mL
You know the percent (v/v) concentration: 70%

Plan Your Strategy
Write the formula for percent (v/v) concentration.
Rearrange the equation to solve for the volume of solute.
Substitute the data into the expression to calculate the volume of isopropyl alcohol, *V*.

Act on Your Strategy
Formula for percent (v/v) concentration:

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

Rearranged equation to solve for the volume of solute:

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

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

Substitution to calculate the volume of isopropyl alcohol:

$$\begin{aligned} v &= \frac{\text{percent (v/v)} \times \text{volume of solution}}{100\%} \\ &= \frac{70\cancel{\%} \times 500\ \text{mL}}{100\cancel{\%}} \\ &= 3.5 \times 10^2\ \text{mL} \end{aligned}$$

The volume of isopropyl alcohol in the bottle of rubbing alcohol is 3.5×10^2 mL (v/v).

Check Your Solution
The volume of isopropyl alcohol is approximately $\frac{3}{4}$ of the volume of the 500 mL bottle, which is about 70% of the given concentration. The calculated answer correctly shows two significant digits.

22. Practice Problem (page 376)

If 80 mL of ethanol is diluted with water to a final volume of 500 mL, what is the percent (v/v) concentration of ethanol in the solution?

What Is Required?

You need to determine the percent (v/v) concentration of an ethanol solution.

What Is Given?

You know the volume of the solution: 500 mL
You know the volume of ethanol solute: 80 mL

Plan Your Strategy

Write the formula for percent (v/v) concentration.
Substitute the data into the expression to calculate the concentration of ethanol.

Act on Your Strategy

$$\begin{aligned}\text{percent (v/v)} &= \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\% \\ &= \frac{80\ \cancel{\text{mL}}}{500\ \cancel{\text{mL}}} \times 100\% \\ &= 16\%\end{aligned}$$

The concentration of the ethanol is 16% (v/v).

Check Your Solution

Using the answer and the given volume of solution, 16% of 500 is 80 mL. The calculated answer is accurate and correctly shows two significant digits.

23. Practice Problem (page 376)

A particular brand of windshield washer fluid contains 40% (v/v) methanol. How much pure methanol does a 4.0 L container of this fluid contain?

What Is Required?

You need to determine the volume of methanol (solute) in a bottle of windshield washer fluid.

What Is Given?

You know the volume of the solution: 4.0 L
You know the percent (v/v) concentration of the solution: 40%

Plan Your Strategy
Write the formula for percent (v/v) concentration.
Rearrange the formula to solve for the volume of solute.
Substitute the data into the expression to calculate the volume of methanol solute, *V*.

Act on Your Strategy
Formula for percent (v/v) concentration:

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

Rearranged equation to solve for the volume of solute:

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

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

Substitution to calculate the volume of methanol:

$$\begin{aligned} v &= \frac{\text{percent (v/v)} \times \text{volume of solution}}{100\%} \\ &= \frac{40\cancel{\%} \times 4.0\ \text{L}}{100\cancel{\%}} \\ &= 1.6\ \text{L} \end{aligned}$$

The volume of methanol in the windshield washer fluid is 1.6 L.

Check Your Solution
The volume of methanol is less than half the volume of solution, which is approximately 40% of the total volume. The calculated answer seems reasonable and correctly shows two significant digits.

24. Practice Problem (page 376)
A concentrated solution of engine coolant contains 75% (v/v) ethylene glycol in water. The label tells consumers to use a 1:1 mixture of the concentrate with water in their cars. Determine the approximate volume of pure ethylene glycol in an automotive cooling system that contains 6.0 L of the diluted solution.

What Is Required?
You need to determine the volume of ethylene glycol (solute) in the cooling system of an engine.

What Is Given?
You know the volume of the solution: 6.0 L
You know the percent (v/v) concentration of stock solution: 75%
You know the stock solution will be diluted 1:1 with water.

Plan Your Strategy
Determine the percent (v/v) concentration of ethylene glycol in the engine's cooling system.
Write the formula for percent (v/v) concentration.
Rearrange the formula for percent (v/v) to solve for the volume of solute.
Substitute the data into the expression to calculate the volume of ethylene glycol, *V*.

Act on Your Strategy
Since the stock solution of ethylene glycol is diluted 1:1, each volume of ethylene glycol in the cooling system is diluted in an equal volume of water. The percent (v/v) concentration of the coolant solution in the engine therefore is $\frac{1}{2}$ the concentration of the stock solution:

$$\begin{aligned}\frac{1 \text{ volume ethylene glycol}}{1 \text{ volume ethylene glycol } + 1 \text{ volume of } H_2O} \times 75\% &= \frac{1 \text{ volume}}{2 \text{ volumes}} \times 75\% \\ &= 37.5\%\end{aligned}$$

Formula for percent (v/v) concentration:

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

Rearranged equation to solve for the volume of solute:

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

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

Substitution to calculate the volume of ethylene glycol:

$$\begin{aligned}V &= \frac{\text{percent (v/v)} \times \text{volume of solution}}{100\%} \\ &= \frac{37.5\not\% \times 6.0 \text{ L}}{100\not\%} \\ &= 2.25 \text{ L} \\ &= 2.2 \text{ L}\end{aligned}$$

The volume of ethylene glycol in the engine is 2.2 L.

Check Your Solution
Rounding the data and estimating the percent (v/v) concentration:

$$\frac{2\text{ L}}{6\text{ L}} \times 100\% = 33\%$$

This estimate approximates the given concentration. The calculated answer correctly shows two significant digits.

25. Practice Problem (page 376)
Describe how to prepare a 5.00% (v/v) solution with 50.0 mL of pure ethylene glycol.

What Is Required?
You need to determine the volume of an ethylene glycol solution and outline how to prepare this solution.

What Is Given?
You know the percent (v/v) concentration of the solution: 5.00% (v/v)
You know the volume of ethylene glycol solute: 50.0 mL

Plan Your Strategy
Write the formula for percent (v/v) concentration.
Rearrange the expression for the percent (v/v) concentration to solve for the volume of solution.
Substitute the data into the expression to calculate the volume.
Subtract the volume of solute from the volume of the solution to determine the volume of solvent (water) required.

Act on Your Strategy
Formula for percent (v/v) concentration:

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

Rearranged formula to solve for the volume of solution:

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

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

Substitution to calculate the volume:

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

$$= \frac{50.0\ \text{mL} \times 100\not\%}{5.00\not\%}$$

$$= 1000\ \text{mL}$$

Calculation of volume of solvent:

$$\text{volume of solvent} = \text{volume of solution} - \text{volume of solute}$$

$$= 1000.0\ \text{mL} - 50.0\ \text{mL}$$

$$= 950.0\ \text{mL}$$

$$= 9.50 \times 10^2\ \text{mL}$$

To prepare this solution, add 50.0 mL of ethylene glycol to 9.50×10^2 mL of water.

Check Your Solution

Using the calculated volume of solution, 5% of 1000 mL is 50 mL. The calculated answer is reasonable and correctly shows three significant digits.

26. Practice Problem (page 376)

Gasoline sold in Ontario must contain at least 5.0% (v/v) ethanol. How much ethanol is a driver likely to get when buying 30 L of gasoline?

What Is Required?

You need to determine the volume of ethanol (solute) in gasoline.

What Is Given?

You know the volume of the solution: 30 L

You know the percent (v/v) concentration of ethanol: 5.0%

Plan Your Strategy

Write the formula for percent (v/v) concentration.

Rearrange the formula to solve for the volume of solute.

Substitute the data into the expression to calculate the volume of ethanol, *V*.

Act on Your Strategy

Formula for percent (v/v) concentration:

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

Rearranged formula to solve for the volume of solute:

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

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

Substitution to calculate the volume of ethanol, *v*:

$$\begin{aligned} v &= \frac{\text{percent (v/v)} \times \text{volume of solution}}{100\%} \\ &= \frac{5.0\,\cancel{\%} \times 30\ \text{L}}{100\,\cancel{\%}} \\ &= 1.5\ \text{L} \end{aligned}$$

The volume of ethanol in the gasoline is 1.5 L.

Check Your Solution

Using the calculated volume of ethanol and the volume of solution, estimate the percent (v/v):

$$\frac{1.5\ \text{L}}{30\ \text{L}} \times 100\% = 5\%\ \text{(v/v)}$$

The calculated answer is reasonable and correctly shows two significant digits.

27. Practice Problem (page 376)

A vending machine mixes a liquid flavour concentrate with water in a ratio of 1:10 to make coffee. Determine the percent (v/v) concentration of the flavour concentrate in the drink.

What Is Required?

You need to determine the percent (v/v) concentration of a liquid flavour concentrate.

What Is Given?

You know the volume ratio of concentrate to water (solvent): 1:10

Plan Your Strategy

Assume that 1.0 L of concentrate (solute) and 10.0 L of water (solvent) are used to make the solution.

Add the volume of the solute and the volume of the solvent to determine the volume of the solution.

Write the formula for percent (v/v) concentration.

Substitute the data into the expression to calculate the concentration.

Act on Your Strategy

$$\begin{aligned}\text{volume of solution} &= \text{volume of solute} + \text{volume of solvent}\\ &= 1.0\text{ L} + 10.0\text{ L}\\ &= 11.0\text{ L}\end{aligned}$$

$$\begin{aligned}\text{percent (v/v)} &= \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%\\ &= \frac{1.0\ \cancel{\text{L}}}{11.0\ \cancel{\text{L}}} \times 100\%\\ &= 9.09\ \%\\ &= 9.1\ \%\end{aligned}$$

The concentration of the flavour concentrate is 9.1% (v/v).

Check Your Solution

Using the answer and the given volume of solution, 9% of 11 L is about 1 L of solute. The calculated answer is reasonable and correctly shows two significant digits.

28. Practice Problem (page 376)

Your teacher has 4.0 L of a 15% (v/v) solution of sulfuric acid in water. What will be the volume of the solution if it is diluted to 10% (v/v)?

What Is Required?

You need to determine the volume of a diluted solution.

What Is Given?

You know the volume and percent (v/v) concentration of a concentrated sulfuric acid solution:

$V = 4.0$ L

concentration = 15% (v/v)

You know the percent (v/v) concentration of the dilute sulfuric acid solution: 10% (v/v)

Plan Your Strategy

Write the formula for percent (v/v) concentration.

Rearrange the expression to solve for the volume of solute.

Substitute the data for the concentrated solution to calculate the volume of sulfuric acid solute.

The volume of sulfuric acid (solute) is the same in each solution.

Rearrange the expression to solve for the volume of the dilute solution.

Use the calculated volume of solute to determine the volume of dilute solution when the percent (v/v) concentration is 10%.

Act on Your Strategy

Formula for percent (v/v) concentration:

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

Rearranged formula to solve for the volume of solute:

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

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

Substitution to calculate the volume of the sulfuric acid solute:

$$\begin{aligned}\text{volume of solute} &= \frac{\text{percent (v/v)} \times \text{volume of solution}}{100\%} \\ &= \frac{15\cancel{\%} \times 4.0\text{ L}}{100\cancel{\%}} \\ &= 0.6\text{ L}\end{aligned}$$

The volume of the sulfuric acid is 0.60 L.

Rearranged formula to solve for the volume of the diluted solution:

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

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

Substitution to calculate the volume of the diluted solution:

$$\begin{aligned}\text{volume of solution} &= \frac{0.60\text{ L} \times 100\cancel{\%}}{10\cancel{\%}} \\ &= 6.0\text{ L}\end{aligned}$$

The volume of the diluted solution is 6.0 L.

Check Your Solution

Using the calculated answer to check the percent (v/v) concentration:

$$\frac{0.6\text{ L}}{6.0\text{ L}} \times 100\% = 10\%$$

The calculated answer is reasonable and correctly shows two significant digits.

29. Practice Problem (page 376)

Two concentrations of the same cleaning chemical are mixed: 6.0 L of a 75% (v/v) solution and 14.0 L of a 25% (v/v) solution. What is the concentration of the resulting solution?

What Is Required?

You must determine the percent (v/v) concentration of a solution of cleaning chemical.

What Is Given?

You know the volume and concentration (v/v) of two solutions that will be mixed.
Solution A: V = 6.0 L; concentration = 75% (v/v)
Solution B: V = 14.0 L; concentration = 25% (v/v)

Plan Your Strategy

Write the formula for percent (v/v) concentration.
Rearrange the expression for to solve for the volume of solute.
Substitute the data to calculate the volume of solute in solution A. Then calculate the volume of solute in solution B.
Add the volumes of solute for solution A and solution B.
Add the volumes of the two solutions.
Substitute the volumes into the expression for percent (v/v) concentration to calculate the concentration.

Act on Your Strategy

Formula for percent (v/v) concentration:

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

Rearranged formula to solve for the volume of solute:

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

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

Substitution to calculate the volume of solute in Solution A:

$$\begin{aligned}\text{volume of solute} &= \frac{75\cancel{\%} \times 6.0\ \text{L}}{100\cancel{\%}} \\ &= 4.5\ \text{L}\end{aligned}$$

Substitution to calculate the volume of solute in Solution B:

$$\text{volume of solute} = \frac{25\cancel{\%} \times 14.0\ \text{L}}{100\cancel{\%}}$$
$$= 3.5\ \text{L}$$

Calculation of total volume of solute and total volume of solution:

$$\text{total volume of solute} = 4.5\ \text{L} + 3.5\ \text{L}$$
$$= 8.0\ \text{L}$$
$$\text{total volume of solution} = 6.0\ \text{L} + 14.0\ \text{L}$$
$$= 20.0\ \text{L}$$

Substitution to calculate the final concentration:

$$\text{percent (v/v)} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$$
$$= \frac{8.0\ \cancel{\text{L}}}{20.0\ \cancel{\text{L}}} \times 100\%$$
$$= 40\%$$

The final concentration (v/v) after mixing the two solutions is 40%.

Check Your Solution

Solution A contributes a little more than half of the total volume of solute, but solution B contributes more than twice as much to the total volume of the solution. The answer seems reasonable, with the final concentration being between the two given concentrations and closer to the concentration of solution B.

30. Practice Problem (page 376)

You need 125 mL of white vinegar, which has a concentration of 5.0% (v/v) of acetic acid. You are out of white vinegar. However, you do have pickling vinegar with a concentration of 8.5% (v/v) of acetic acid. How much pickling vinegar should you dilute to substitute for the white vinegar?

What Is Required?

You need to determine the volume of pickling vinegar that has the same amount of acetic acid as a given amount of white vinegar.

What Is Given?
You know the volume and concentration of the white vinegar solution:
$V = 125$ mL
concentration = 5.0% (v/v)
You know the concentration of pickling vinegar: 8.5% (v/v)

Plan Your Strategy
Write the formula for percent (v/v) concentration.
Rearrange the formula to solve for the volume of solute.
Substitute the data to calculate the volume of solute in white vinegar.
The volume of acetic acid in white vinegar is equal to the volume of acetic acid in pickling vinegar.
Rearrange the expression for percent (v/v) concentration to calculate the volume of solution of pickling vinegar.

Act on Your Strategy
Formula for percent (v/v) concentration:

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

Rearranged formula to solve for the volume of solute:

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

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

Substitution to calculate the volume of solute in white vinegar:

$$\text{volume of solute} = \frac{5\cancel{\%} \times 125 \text{ mL}}{100\cancel{\%}}$$
$$= 6.25 \text{ mL}$$

The volume of the solute is 6.25 mL. Therefore, the volume of acetic acid in pickling vinegar is 6.25 mL.

Rearranged formula to solve for volume of solution:

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

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

Substitution to calculate the volume of solute in white vinegar:

$$\text{volume of solution} = \frac{6.25 \text{ mL} \times 100\cancel{\%}}{8.5\cancel{\%}}$$
$$= 73.529 \text{ mL}$$
$$= 74 \text{ mL}$$

The volume of pickling vinegar needed is 74 mL.

Check Your Solution
A smaller volume of pickling vinegar should be required since the pickling vinegar has a higher percent (v/v) concentration of acetic acid. The volume of pickling vinegar may be estimated:

$$125 \text{ mL} \times \frac{5.0}{8.5} = 71 \text{ mL}$$

The calculated answer seems reasonable and correctly shows two significant digits.

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31. Practice Problem (page 378)
A sample of lake water has a mass of 310 g and contains 2.24 mg of dissolved oxygen. Calculate the oxygen concentration in parts per million.

What Is Required?
You need to calculate the concentration of dissolved oxygen in parts per million.

What Is Given?
You know the mass of dissolved oxygen (solute): 2.24 mg
You know the mass of water (solution): 310 g

Plan Your Strategy
Convert the mass of dissolved oxygen from milligrams to grams so that you can cancel the units:1 mg = 1×10^{-3} g
Write the formula for ppm.
Substitute the data into the expression to calculate the concentration of dissolved oxygen.

Act on Your Strategy

Mass conversion:

$$\text{mass of solute} = 2.24\ \cancel{\text{mg}} \times 1 \times 10^{-3}\ \text{g}/\cancel{\text{mg}}$$
$$= 2.24 \times 10^{-3}\ \text{g}$$

$$\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^{6}$$
$$= \frac{2.24 \times 10^{-3}\ \cancel{\text{g}}}{310\ \cancel{\text{g}}} \times 10^{6}$$
$$= 7.2258$$
$$= 7.22$$

The concentration of dissolved oxygen is 7.22 ppm.

Check Your Solution

Using rounded numbers, to estimate the answer:

$$\frac{2 \times 10^{-3} \times 10^{6}}{3 \times 10^{2}} = 7$$

The estimated answer is close to the calculated answer. The calculated answer correctly shows three significant digits and seems reasonable.

32. Practice Problem (page 378)

The agricultural use of the pesticide DDT has been banned in Canada since 1969 because of its effect on wildlife. In 1967, the average concentration of DDT in trout taken from Lake Simcoe, in Ontario, was 16 ppm. Today, the average concentration is less than 1 ppm. What mass of DDT is present in a 2.2 kg smallmouth bass contaminated with 16 ppm of DDT?

What Is Required?

You need to determine the mass of DDT in a smallmouth bass.

What Is Given?

You know the mass of the smallmouth bass (solution): 2.2 kg
You know the concentration of DDT: 16 ppm

Plan Your Strategy

Convert the mass of the solution from kilograms to grams: 1 kg = 1×10^{3} g
Write the formula for ppm concentration.
Rearrange the equation to solve for the mass of solute.
Substitute the given data into the expression to calculate the mass of the DDT.

Act on Your Strategy
Mass conversion:

$$\text{mass of solution} = 2.2\ \cancel{\text{kg}} \times 1 \times 10^3\ \text{g}/\cancel{\text{kg}}$$
$$= 2.2 \times 10^3\ \text{g}$$

Formula for ppm:

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

Rearranged formula to solve for the mass of solute:

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

Substitution to solve for the mass of DDT:

$$\text{mass of DDT} = \frac{16 \times 2.2 \times 10^3\ \text{g}}{10^6}$$
$$= 0.03520\ \text{g}$$
$$= 0.035\ \text{g}$$

The mass of DDT present is 0.035 g.

Check Your Solution
Using rounded numbers and the calculated value of the mass of solute, estimate the concentration in parts per million:

$$\text{ppm} = \frac{0.035}{2 \times 10^3} \times 10^6$$
$$= 18$$

The estimated answer is close to the given concentration. The calculated answer seems reasonable and is correctly expressed to two significant digits.

33. Practice Problem (page 378)
Dry air contains about 0.000 07% (m/m) helium. Express this concentration in parts per million.

What Is Required?
You need to express a concentration in ppm.

What Is Given?
You know the percent (m/m) concentration: 0.000 07% (m/m)

Plan Your Strategy

Write the formula for percent (m/m) concentration.

Rearrange the expression for percent (m/m) concentration to solve for $\frac{\text{mass of solute}}{\text{mass of solution}}$.

Write the formula for ppm.

Substitute the given data into the formula to calculate the concentration in ppm.

Act on Your Strategy

Formula for percent (m/m) concentration:

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

Rearranged formula to solve for $\frac{\text{mass of solute}}{\text{mass of solution}}$:

$$\text{percent (m/m)} \times \frac{1}{100\%} = \frac{\text{mass of solute}}{\text{mass of solution}} \times \cancel{100\%} \times \frac{1}{\cancel{100\%}}$$

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

Formula for ppm:

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

Substitution to calculate the concentration in ppm:

$$\begin{aligned}
\text{ppm} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6 \\
&= \frac{\text{percent (m/m)}}{100\%} \times 10^6 \\
&= \frac{0.000\ 07\cancel{\%}}{100\cancel{\%}} \times 10^6 \\
&= \frac{0.000\ 07}{10^2} \times 10^6 \\
&= 0.000\ 07 \times 10^4 \\
&= 7 \times 10^{-1}
\end{aligned}$$

The concentration of helium expressed in ppm is 7×10^{-1}.

Check Your Solution
The expressions for ppm and concentration (m/m) differ by a factor of 10^4. The calculated value for ppm and the given percent (m/m) differ by a factor of 10^4. The answer seems to be accurate and correctly shows one significant digit.

34. Practice Problem (page 378)
A fungus that grows on peanuts produces aflatoxin, a potentially deadly toxin. A quality control inspector tests a 100 g sample from a shipment of peanuts to check that it contains no more than 25 ppb of aflatoxin. What mass of aflatoxin would the sample contain if the concentration is 25 ppb?

What Is Required?
You need to calculate the mass of aflatoxin in a sample of peanuts.

What Is Given?
You know the concentration: 25 ppb
You know the mass of the sample: 100 g

Plan Your Strategy
Write the formula for ppb.
Rearrange the expression to solve for the mass of solute.
Substitute the given data into the formula to calculate the mass of aflatoxin.

Act on Your Strategy
Formula for ppb:

$$\text{ppb} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^9$$

Rearranged formula to solve for the mass of solute:

$$\text{ppb} \times \text{mass of solution} = \text{mass of solute} \times 10^9$$

$$\text{mass of solute} = \frac{\text{ppb} \times \text{mass of solution}}{10^9}$$

Substitution to calculate the mass of the aflatoxin:

$$\begin{aligned}\text{mass of solute} &= \frac{\text{ppb} \times \text{mass of solution}}{10^9} \\ &= \frac{25 \times 100 \text{ g}}{10^9} \\ &= 2.5 \times 10^{-6} \text{ g}\end{aligned}$$

The mass of aflatoxin in the peanut sample is 2.5×10^{-6} g.

Check Your Solution
Use the calculated answer for mass of solute to calculate the concentration in ppb:

$$\text{ppb} = \frac{2.5 \times 10^{-6}\ \cancel{\text{g}}}{100\ \cancel{\text{g}}} \times 10^{9}$$
$$= 25$$

The calculated concentration in ppb agrees with the given value. The answer is accurate and correctly shows two significant digits.

35. Practice Problem (page 378)
A sample of water contains one atom of lead for every million water molecules. Calculate the concentration of lead, in parts per million, in this sample.

What Is Required?
You need to express the concentration of lead in ppm.

What Is Given?
You know that there is one atom of lead in one million molecules of water.

Plan Your Strategy
Use the periodic table to find the atomic molar mass of Pb(s).
Determine the molar mass of $H_2O(\ell)$.
Use the Avogadro constant: $N_A = 6.02 \times 10^{23}$
Calculate the amount in moles of Pb(s) and of $H_2O(\ell)$ using the relationship $n = \frac{N}{N_A}$.
Calculate the masses of the Pb(s) and the $H_2O(\ell)$ using the relationship $m = n \times M$.
Write the formula for ppm concentration.
Substitute the calculated data into the expression to calculate the concentration.

Act on Your Strategy
Molar mass, *M*, of Pb(s):
207.2 g/mol (from the periodic table)

Molar mass, *M*, of $H_2O(\ell)$:

$$\begin{aligned} M_{H_2O} &= 2M_H + 1M_O \\ &= 2(1.01\text{ g/mol}) + 1(16.00\text{ g/mol}) \\ &= 18.02\text{ g/mol} \end{aligned}$$

Amount in moles, n, of the Pb atoms:

$$n_{Pb} = \frac{N}{N_A}$$
$$= \frac{1 \cancel{\text{ atom}}}{6.02 \times 10^{23} \cancel{\text{ atoms}}\text{/mol}}$$
$$= 1.6611 \times 10^{-24} \text{ mol}$$

Amount in moles, n, of $H_2O(\ell)$:

$$n_{H_2O} = \frac{N}{N_A}$$
$$= \frac{1 \times 10^6 \cancel{\text{ molecules}}}{6.02 \times 10^{23} \cancel{\text{ molecules}}\text{/mol}}$$
$$= 1.6611 \times 10^{-18} \text{ mol}$$

Mass, m, of the Pb(s):

$$m_{Pb} = n \times M$$
$$= 1.6611 \times 10^{-24} \cancel{\text{ mol}} \times 207.2 \text{ g/}\cancel{\text{mol}}$$
$$= 3.4417 \times 10^{-22} \text{ g}$$

Mass, m, of the $H_2O(\ell)$:

$$m_{H_2O} = n \times M$$
$$= 1.6611 \times 10^{-24} \cancel{\text{ mol}} \times 18.02 \text{ g/}\cancel{\text{mol}}$$
$$= 2.993 \times 10^{-17} \text{ g}$$

$$\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$$
$$= \frac{3.4417 \times 10^{-22} \cancel{\text{ g}}}{2.993 \times 10^{-17} \cancel{\text{ g}}} \times 10^6$$
$$= 11.499$$
$$= 11$$
$$= 1 \times 10^1$$

The concentration of lead in the water is 1×10^1 ppm.

Check Your Solution
The answer appears to be reasonable. The units divided correctly. The answer has one significant digit, the same number of significant digits given in the number of atoms of lead.

36. Practice Problem (page 378)
The concentration of chlorine in swimming pools is generally kept in the range from 1.4 to 4.0 mg/L. A pool contains 3.0 ppm of chlorine. Is this concentration within the acceptable range? Show your work, and explain your reasoning. (**Hint:** 1 L of water has a mass of 1 kg.)

What Is Required?
You need to calculate the concentration of chlorine in water and determine if it is in the acceptable range.

What Is Given?
You know the chlorine concentration in the water: 3.0 ppm
You know the acceptable range of chlorine concentration: 1.4 to 4.0 mg/L
You know the mass of 1 L of water: 1 kg

Plan Your Strategy
Convert the mass of 1 L of water from kilograms to milligrams: 1 kg = 10^6 mg
Convert mg/L to ppm.

Act on Your Strategy
Mass conversion:

$$\begin{aligned}\text{mass of 1 L of water} &= 1\ \cancel{\text{kg}} \times 1 \times 10^6\ \text{mg}/\cancel{\text{kg}} \\ &= 10^6\ \text{mg}\end{aligned}$$

1 L of water has a mass of 1 kg or 10^6 mg.

Conversion from mg/L to ppm:

$$\begin{aligned}1\ \text{ppm} &= \frac{1\ \text{mg}}{10^6\ \text{mg}} \\ &= \frac{1\ \text{mg}}{1\ \text{kg}} \\ &= \frac{1\ \text{mg}}{1\ \text{L}}\end{aligned}$$

$$3.0\ \text{ppm} = \frac{3.0\ \text{mg}}{1\ \text{L}}$$

The 3.0 ppm concentration of chlorine is equivalent to 3.0 mg/L. This is within the acceptable limits.

Check Your Solution
The units are divided correctly. The answer appears reasonable and shows the correct number of significant digits.

37. Practice Problem (page 378)
Water supplies that contain more than 500 ppm of dissolved calcium carbonate, $CaCO_3(aq)$, are considered unacceptable for most domestic purposes. What is the maximum mass of calcium carbonate that would be acceptable in a 250 mL sample of tap water?

What Is Required?
You need to determine the maximum mass of calcium carbonate acceptable in a sample.

What Is Given?
You know the concentration of $CaCO_3(aq)$ in the tap water: 500 ppm
You know the volume of the water sample: 250 mL

Plan Your Strategy
Determine the mass of the water using a density of 1 g/mL.
Write the formula for ppm.
Rearrange the expression to solve for the mass of solute.
Substitute the given data to calculate the mass of calcium carbonate.

Act on Your Strategy
Mass of water:

$$\begin{aligned}\text{mass} &= \text{volume} \times \text{density}\\ &= 250\ \cancel{\text{mL}} \times 1\ \text{g}/\cancel{\text{ml}}\\ &= 250\ \text{g}\end{aligned}$$

Formula for ppm:

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

Rearranged formula to solve for the mass of solute:

$$\text{ppm} \times \text{mass of solution} = \text{mass of solute} \times 10^6$$

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

Substitution to calculate the mass of the $CaCO_3$(aq):

$$\text{mass of } CaCO_3(aq) = \frac{\text{ppm} \times \text{mass of solution}}{10^6}$$
$$= \frac{500 \times 250 \text{ g}}{10^6}$$
$$= 0.125 \text{ g}$$

The maximum mass of calcium carbonate that would be acceptable in the water is 0.125 g.

Check Your Solution
Use the calculated value for the mass of solute to estimate the concentration in ppm:

$$\text{ppm} = \frac{0.125 \cancel{\text{g}}}{250 \cancel{\text{g}}} \times 10^6$$
$$= 500$$

The estimated answer agrees with the given data. The calculated answer is accurate and correctly shows three significant digits.

38. Practice Problem (page 378)
Since 1991, house paint produced in Canada must contain less than 600 ppm of lead. What is the maximum mass of lead permitted in a can that contains 7.0 kg of paint?

What Is Required?
You need to determine the maximum mass of lead that is acceptable in a paint sample.

What Is Given?
You know the maximum acceptable concentration of lead in paint: 600 ppm
You know the mass of the paint (solution): 7.0 kg

Plan Your Strategy
Convert the mass of the paint from kilograms to grams: 1 kg = 1×10^3 g
Write the formula for ppm.
Rearrange the formula to solve for the mass of solute.
Substitute the given data into the expression to calculate the maximum acceptable mass of lead.

Act on Your Strategy

Mass conversion:

$$\text{mass of solution} = 7.0\ \cancel{\text{kg}} \times 1 \times 10^3\ \text{g}/\cancel{\text{kg}} = 7000\ \text{g}$$

Formula for ppm:

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

Rearranged formula to solve for the mass of solute:

$$\text{ppm} \times \text{mass of solution} = \text{mass of solute} \times 10^6$$

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

Substitution to calculate the mass of lead:

$$\begin{aligned}\text{mass of lead} &= \frac{\text{ppm} \times \text{mass of solution}}{10^6}\\ &= \frac{600 \times 7000\ \text{g}}{10^6}\\ &= 4.2\ \text{g}\end{aligned}$$

The maximum mass of lead that would be permitted in the paint is 4.2 g.

Check Your Solution

Check the answer using a rounded calculated value for the mass of solute to estimate the concentration in ppm:

$$\begin{aligned}\text{ppm} &= \frac{4\ \cancel{\text{g}}}{7000\ \cancel{\text{g}}} \times 10^6\\ &= 5.7 \times 10^2\end{aligned}$$

The estimated answer agrees closely with the given data. The calculated answer is reasonable and correctly shows two significant digits.

39. Practice Problem (page 378)

Cadmium is a highly toxic metal. The average level of cadmium in the blood of Canadians is about 0.35 ppb. At this level, what mass of cadmium would be present in 1.5 kg of blood?

What Is Required?

You need to determine the average mass of cadmium that is in the blood.

What Is Given?

You know the average concentration of cadmium in the blood: 0.35 ppb

You know the mass of the blood (solution): 1.5 kg

Plan Your Strategy

Convert the mass of the solution from kilograms to grams: 1 kg = 1×10^3 g

Write the formula for ppb.

Rearrange the expression to solve for the mass of solute.

Substitute the given data into the expression to calculate the mass of cadmium.

Act on Your Strategy

Mass conversion:

$$\begin{aligned}\text{mass of solution} &= 1.5\ \cancel{\text{kg}} \times 1 \times 10^3\ \text{g}/\cancel{\text{kg}} \\ &= 1500\ \text{g}\end{aligned}$$

Formula for ppb:

$$\text{ppb} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^9$$

Rearranged formula to solve for the mass of solute:

$$\text{ppb} \times \text{mass of solution} = \text{mass of solute} \times 10^9$$

$$\text{mass of solute} = \frac{\text{ppb} \times \text{mass of solution}}{10^9}$$

Substitution to calculate the mass of cadmium:

$$\begin{aligned}\text{mass of cadmium} &= \frac{\text{ppb} \times \text{mass of solution}}{10^9} \\ &= \frac{0.35 \times 1500\ \text{g}}{10^9} \\ &= 5.25 \times 10^{-7}\ \text{g} \\ &= 5.2 \times 10^{-7}\ \text{g}\end{aligned}$$

The average mass of cadmium in the blood is 5.2×10^{-7} g.

Check Your Solution

The answer is a very small value but seems reasonable. Check the answer using a rounded calculated value for the mass of solute to estimate the concentration in ppm:

$$\begin{aligned}\text{ppb} &= \frac{5 \times 10^{-7}\ \cancel{\text{g}}}{1500\ \cancel{\text{g}}} \times 10^9 \\ &= 0.33\end{aligned}$$

The estimated answer agrees closely with the given data. The calculated answer is reasonable and correctly shows two significant digits.

40. Practice Problem (page 378)

Determine the concentration, in parts per million, of a solution that contains 0.1 g of solute per litre.

What Is Required?

You need to determine the concentration of a solution in ppm.

What Is Given?

You know the mass of the solute: 0.1 g
You know the volume of solution: 1 L
You know the density of water: 1 kg/L

Plan Your Strategy

Convert volume of water to mass of water (in grams): 1 kg = 1×10^3 g
Write the formula for ppm.
Substitute the given data into the expression to calculate the concentration.

Act on Your Strategy

Mass of water (in grams):

$$\begin{aligned}\text{mass} &= \text{volume} \times \text{density} \\ &= 1\ \cancel{\text{L}} \times 1\ \cancel{\text{kg}}/\cancel{\text{L}} \times 1 \times 10^3\ \text{g}/\cancel{\text{kg}} \\ &= 1000\ \text{g}\end{aligned}$$

$$\begin{aligned}\text{ppm} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6 \\ &= \frac{0.1\ \cancel{\text{g}}}{1\ 000\ \cancel{\text{g}}} \times 10^6 \\ &= 1 \times 10^2\end{aligned}$$

The concentration of the solution is 1×10^2 ppm.

Check Your Solution

The answer seems reasonable and the units are divided correctly. The calculated answer correctly shows one significant digit.

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41. Practice Problem (page 381)

Determine the molar concentration of each saline solution.

a. 0.60 mol NaCl(s) dissolved in 0.40 L of solution

b. 0.90 g NaCl(s) dissolved in 100 mL of solution

What Is Required?

You need to determine the molar concentration of two NaCl(aq) solutions.

What Is Given?

You know the following information:

a. NaCl(aq): n = 0.60 mol; V = 0.40 L of solution

b. NaCl(aq): m = 0.90 g; V = 100 mL of solution

Plan Your Strategy

a. 0.60 mol NaCl(aq)

Write the formula for molar concentration.

Substitute the given data into the formula to calculate the concentration.

b. 0.90 g NaCl(aq)

Determine the molar mass of NaCl(aq).

Determine the amount in moles of NaCl(aq) using the relationship $n = \frac{m}{M}$.

Convert the volume of the solution from millilitres to litres: 1 mL = 1×10^{-3} L

Write the formula for molar concentration.

Substitute the given data into the formula to calculate the concentration.

Act on Your Strategy

a. 0.60 mol NaCl(aq)

Molar concentration, c:

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

$$= \frac{0.60 \text{ mol}}{0.40 \text{ L}}$$

$$= 1.5 \text{ mol/L}$$

The molar concentration is 1.5 mol/L.

b. 0.90 g NaCl(aq)
Molar mass, *M*, of NaCl(aq):

$$\begin{aligned} M_{NaCl} &= 1M_{Na} + 1M_{Cl} \\ &= 1(22.99 \text{ g/mol}) + 1(35.45 \text{ g/mol}) \\ &= 58.44 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of the NaCl(aq):

$$\begin{aligned} n_{NaCl} &= \frac{m}{M} \\ &= \frac{0.90 \text{ }\cancel{\text{g}}}{58.44 \text{ }\cancel{\text{g}}\text{/mol}} \\ &= 0.01540 \text{ mol} \end{aligned}$$

Volume (in litres) of the solution, *V*:

$$\begin{aligned} V &= 100 \text{ }\cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L/}\cancel{\text{mL}} \\ &= 0.100 \text{ L} \end{aligned}$$

Molar concentration, *c*:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0.01540 \text{ mol}}{0.100 \text{ L}} \\ &= 0.154 \text{ mol/L} \end{aligned}$$

The molar concentration is 0.154 mol/L.

Check Your Solution
The concentrations seem reasonable, and have the correct units and number of significant digits.

42. Practice Problem (page 381)
What volume of 0.25 mol/L solution can be made using 14 g of sodium hydroxide?

What Is Required?
You need to determine the volume of sodium hydroxide, NaOH(aq).

What Is Given?
You know the molar concentration of the NaOH(aq): 0.25 mol/L
You know the mass of the NaOH(s): 14 g

Plan Your Strategy
Determine the molar mass of NaOH(s).

Calculate the amount in moles of solute using the relationship $n = \frac{m}{M}$.

Write the formula for molar concentration
Rearrange the formula to solve for the mass of solute.
Substitute the data into the formula to calculate the volume of the NaOH(aq) solution.

Act on Your Strategy
Molar mass, *M*, of NaOH(s):

$$\begin{aligned} M_{\text{NaOH}} &= 1M_{\text{Na}} + 1M_{\text{O}} + 1M_{\text{H}} \\ &= 1(22.99 \text{ g/mol}) + 1(16.00 \text{ g/mol}) + 1(1.01 \text{ g/mol}) \\ &= 40.00 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of the NaOH(aq):

$$\begin{aligned} n_{\text{NaOH}} &= \frac{m}{M} \\ &= \frac{14 \cancel{\text{g}}}{40.00 \cancel{\text{g}}\text{/mol}} \\ &= 0.350 \text{ mol} \end{aligned}$$

Formula for molar concentration:

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

Rearranged formula to solve for the volume of solute:

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

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

$$\cancel{c}V \times \frac{1}{\cancel{c}} = n \times \frac{1}{c}$$

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

Substitution to calculate the volume, *V*:

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

$$= \frac{0.350\ \cancel{\text{mol}}}{0.25\ \cancel{\text{mol}}/\text{L}}$$

$$= 1.4\ \text{L}$$

The volume of sodium hydroxide solution is 1.4 L.

Check Your Solution
The correct units have been used and the number of significant digits agrees with the given data.
The calculated answer seems reasonable.

43. Practice Problem (page 381)
Calculate the molar concentration of each solution.
a. 14 g of copper(II) sulfate, $CuSO_4(s)$, dissolved in 70 mL of solution
b. 5.07 g of sucrose, $C_{12}H_{22}O_{11}(s)$, dissolved in 23.6 mL of solution
c. 1.1 g of calcium nitrate, $Ca(NO_3)_2(s)$, dissolved in 70 mL of solution

What Is Required?
You need to determine the molar concentrations of three solutions.

What Is Given?
You know the masses and volumes of the three solutions:
a. $CuSO_4(s)$: $m = 14$ g; $V = 70$ mL
b. $C_{12}H_{22}O_{11}(s)$: $m = 5.07$ g; $V = 23.6$ mL
c. $Ca(NO_3)_2(s)$: $m = 1.1$ g; $V = 70$ mL

Plan Your Strategy
Determine the molar mass of each solute.

Calculate the amount in moles of each solute using the relationship $n = \frac{m}{M}$.

Convert the volume of each solution from millilitres to litres:
1 mL = 1×10^{-3} L
Calculate the molar concentration of each solution using the relationship

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

Act on Your Strategy

a. copper(II) sulfate

Molar mass, *M*, of $CuSO_4$(s):

$$\begin{aligned} M_{CuSO_4} &= 1M_{Cu} + 1M_S + 4M_O \\ &= 1(63.55 \text{ g/mol}) + 1(32.07 \text{ g/mol}) + 4(16.00 \text{ g/mol}) \\ &= 159.62 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of the $CuSO_4$(s):

$$\begin{aligned} n_{CuSO_4} &= \frac{m}{M} \\ &= \frac{14 \not{g}}{159.62 \not{g}\text{/mol}} \\ &= 0.087708 \text{ mol} \end{aligned}$$

Volume, *V*, of the $CuSO_4$(aq):

$$\begin{aligned} V &= 70 \not{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\not{\text{mL}} \\ &= 0.070 \text{ L} \end{aligned}$$

Molar concentration, *c*:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0.087708 \text{ mol}}{0.070 \text{ L}} \\ &= 1.253 \text{ mol/L} \\ &= 1.2 \text{ mol/L} \end{aligned}$$

The molar concentration of copper(II) sulfate is 1.2 mol/L.

b. sucrose

Molar mass, *M*, of $C_{12}H_{22}O_{11}$(s):

$$\begin{aligned} M_{C_{12}H_{22}O_{11}} &= 12M_C + 22M_H + 11M_O \\ &= 12(12.01 \text{ g/mol}) + 22(1.01 \text{ g/mol}) + 11(16.00 \text{ g/mol}) \\ &= 342.34 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of the $C_{12}H_{22}O_{11}$(s):

$$\begin{aligned} n_{C_{12}H_{22}O_{11}} &= \frac{m}{M} \\ &= \frac{5.07\ \cancel{g}}{342.34\ \cancel{g}/\text{mol}} \\ &= 0.014809\ \text{mol} \end{aligned}$$

Volume, *V*, of $C_{12}H_{22}O_{11}$(aq):

$$\begin{aligned} V &= 23.6\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.0236\ \text{L} \end{aligned}$$

Molar concentration, *c*:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0.014809\ \text{mol}}{0.0236\ \text{L}} \\ &= 0.6275\ \text{mol/L} \\ &= 0.628\ \text{mol/L} \end{aligned}$$

The molar concentration of sucrose is 0.628 mol/L.

c. calcium nitrate

Molar mass, *M*, of $Ca(NO_3)_2$(s):

$$\begin{aligned} M_{Ca(NO_3)_2} &= 1M_{Ca} + 2M_N + 6M_O \\ &= 1(40.08\ \text{g/mol}) + 2(14.01\ \text{g/mol}) + 6(16.00\ \text{g/mol}) \\ &= 164.1\ \text{g/mol} \end{aligned}$$

Amount in moles, *n*, of the $Ca(NO_3)_2$(s):

$$\begin{aligned} n_{Ca(NO_3)_2} &= \frac{m}{M} \\ &= \frac{1.1\ \cancel{g}}{164.1\ \cancel{g}/\text{mol}} \\ &= 0.006703\ \text{mol} \end{aligned}$$

Volume, *V*, of $Ca(NO_3)_2$(aq):

$$\begin{aligned} V &= 70\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.0700\ \text{L} \end{aligned}$$

Molar concentration, c:

$$c = \frac{n}{V}$$
$$= \frac{0.006703 \text{ mol}}{0.0700 \text{ L}}$$
$$= 0.095757 \text{ mol/L}$$
$$= 0.096 \text{ mol/L}$$

The molar concentration of calcium nitrate is 0.096 mol/L.

Check Your Solution
The correct units have been used and the number of significant digits in each case agrees with the given data. The calculated answers seem reasonable.

44. Practice Problem (page 381)
At 20°C, a saturated solution of calcium sulfate, $CaSO_4(aq)$, has a concentration of 0.0153 mol/L. A student takes 65 mL of this solution and evaporates it. What mass of solute should be left in the evaporating dish?

What Is Required?
You need to determine the mass of solute.

What Is Given?
You know the molar concentration of a solution of $CaSO_4(aq)$: 0.0153 mol/L
You know the volume of the solution: 65 mL

Plan Your Strategy
Convert the volume of the solution, V, from millilitres to litres: 1 mL = 1×10^{-3} L
Write the formula for molar concentration.
Rearrange the expression to solve for the amount in moles.
Substitute the data into the equation to calculate the amount in moles of $CaSO_4(aq)$.
Determine the molar mass of $CaSO_4(s)$.
Determine the mass of the $CaSO_4(s)$ using the relationship $m = n \times M$.

Act on Your Strategy
Volume conversion:

$$V = 65 \cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\cancel{\text{mL}}$$
$$= 0.065 \text{ L}$$

Formula for molar concentration:

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

Rearranged formula to solve for the amount in moles:

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

$$n = c \times V$$

Substitution to calculate the amount in moles, *n*, of $CaSO_4$(aq):

$$\begin{aligned} n_{CaSO_4} &= c \times V \\ &= 0.0153 \text{ mol}/\cancel{L} \times 0.065 \cancel{L} \\ &= 9.945 \times 10^{-4} \text{ mol} \end{aligned}$$

Molar mass, *M*, of $CaSO_4$(s):

$$\begin{aligned} M_{CaSO_4} &= 1M_{Ca} + 1M_S + 4M_O \\ &= 1(40.08 \text{ g/mol}) + 1(32.07 \text{ g/mol}) + 4(16.00 \text{ g/mol}) \\ &= 136.15 \text{ g/mol} \end{aligned}$$

Mass, *m*, of $CaSO_4$(s):

$$\begin{aligned} m_{CaSO_4} &= n \times M \\ &= 9.945 \times 10^{-4} \cancel{\text{mol}} \times 136.15 \text{ g}/\cancel{\text{mol}} \\ &= 0.13540 \text{ g} \\ &= 0.14 \text{ g} \end{aligned}$$

The mass of calcium sulfate that remains after evaporation is 0.14 g.

Check Your Solution

The mass would be expected to be small since the volume of solution and the concentration are both low numbers. The units have cancelled correctly and the answer correctly shows two significant digits.

45. Practice Problem (page 381)

Find the mass of solute in each aqueous solution.

a. 28 mL of 0.045 mol/L calcium hydroxide, $Ca(OH)_2(aq)$

b. 50 mL of 4.0 mol/L acetic acid, $CH_3COOH(aq)$

c. 5.31 L of 0.675 mol/L ammonium phosphate, $(NH_4)_3PO_4(aq)$

What Is Required?

You need to determine the mass of solute in each solution.

What Is Given?

You know the volume and molar concentration of each solution:

a. $Ca(OH)_2(aq)$: $V = 28$ mL; $c = 0.045$ mol/L

b. $CH_3COOH(aq)$: $V = 50$ mL; $c = 4.0$ mol/L

c. $(NH_4)_3PO_4(aq)$: $V = 5.31$ L; $c = 0.675$ mol/L

Plan Your Strategy

Where necessary, convert each volume of solution from millilitres to litres: 1 mL = 1×10^{-3} L

Write the formula for molar concentration.

Rearrange the expression to solve for the amount in moles.

Substitute data into the formula to calculate the amount in moles, n, of each solute.

Determine the molar mass of each solute.

Determine the mass of each solute using the relationship $m = n \times M$.

Act on Your Strategy

a. calcium hydroxide

Volume conversion:

$$\begin{aligned}\text{volume of } Ca(OH)_2\text{(aq) solution} &= 28\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.028\ \text{L}\end{aligned}$$

Formula for molar concentration:

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

Rearranged formula to solve for the amount in moles:

$$\begin{aligned}c \times V &= \frac{n}{\cancel{V}} \times \cancel{V} \\ n &= c \times V\end{aligned}$$

Substitution to calculate the amount in moles, *n*, of $Ca(OH)_2$(aq):

$$\begin{aligned} n_{\mathrm{Ca(OH)_2}} &= c \times V \\ &= 0.045\ \mathrm{mol/\cancel{L}} \times 0.028\ \cancel{\mathrm{L}} \\ &= 1.260 \times 10^{-3}\ \mathrm{mol} \end{aligned}$$

Molar mass, *M*, of $Ca(OH)_2$(s):

$$\begin{aligned} M_{\mathrm{Ca(OH)_2}} &= 1M_{\mathrm{Ca}} + 2M_{\mathrm{O}} + 2M_{\mathrm{H}} \\ &= 1(40.08\ \mathrm{g/mol}) + 2(16.00\ \mathrm{g/mol}) + 2(1.01\ \mathrm{g/mol}) \\ &= 74.1\ \mathrm{g/mol} \end{aligned}$$

Mass, *m*, of $Ca(OH)_2$(s):

$$\begin{aligned} m_{\mathrm{Ca(OH)_2}} &= n \times M \\ &= 1.260 \times 10^{-3}\ \cancel{\mathrm{mol}} \times 74.1\ \mathrm{g/\cancel{mol}} \\ &= 0.09336\ \mathrm{g} \\ &= 0.093\ \mathrm{g} \end{aligned}$$

The mass of the calcium hydroxide is 0.093 g.

b. acetic acid

Volume conversion:

$$\begin{aligned} \text{volume of } \mathrm{CH_3COOH(aq)} \text{ solution} &= 50\ \cancel{\mathrm{mL}} \times 1 \times 10^{-3}\ \mathrm{L/\cancel{mL}} \\ &= 0.050\ \mathrm{L} \end{aligned}$$

Formula for molar concentration:

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

Rearranged formula to solve for the amount in moles:

$$\begin{aligned} c \times V &= \frac{n}{\cancel{V}} \times \cancel{V} \\ n &= c \times V \end{aligned}$$

Substitution to calculate the amount in moles, *n*, of CH_3COOH(aq):

$$\begin{aligned} n_{\mathrm{CH_3COOH}} &= c \times V \\ &= 4.0\ \mathrm{mol/\cancel{L}} \times 0.050\ \cancel{\mathrm{L}} \\ &= 0.20\ \mathrm{mol} \end{aligned}$$

Molar mass, *M*, of CH_3COOH (s):

$$M_{CH_3COOH} = 2M_C + 2M_O + 4M_H$$
$$= 2(12.01\ g/mol) + 2(16.00\ g/mol) + 2(1.01\ g/mol)$$
$$= 60.06\ g/mol$$

Mass, *m*, of CH_3COOH(s):

$$m_{CH_3COOH} = n \times M$$
$$= 0.20\ \cancel{mol} \times 60.06\ g/\cancel{mol}$$
$$= 12.012\ g$$
$$= 12\ g$$

The mass of acetic acid is 12 g.

c. ammonium phosphate
volume of $(NH_4)_3PO_4$(aq) = 5.31 L

Formula for molar concentration:

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

Rearranged formula to solve for the amount in moles:

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

Substitution to calculate the amount in moles, *n*, of $(NH_4)_3PO_4$(aq):

$$n_{(NH_4)_3PO_4} = c \times V$$
$$= 0.675\ mol/\cancel{L} \times 5.31\ \cancel{L}$$
$$= 3.584\ mol$$

Molar mass, *M*, of $(NH_4)_3PO_4$(s):

$$M_{(NH_4)_3PO_4} = 3M_N + 12M_H + 1M_P + 4M_O$$
$$= 3(14.01\ g/mol) + 12(1.01\ g/mol) + 1(30.97\ g/mol) + 4(16.00\ g/mol)$$
$$= 149.12\ g/mol$$

Mass, *m*, of $(NH_4)_3PO_4(s)$:

$$
\begin{aligned}
m_{(NH_4)_3PO_4} &= n \times M \\
&= 0.675\ \cancel{\text{mol}} \times 149.12\ \text{g}/\cancel{\text{mol}} \\
&= 100.656\ \text{g} \\
&= 101\ \text{g}
\end{aligned}
$$

The mass of ammonium phosphate is 101 g.

Check Your Solution

The masses seem reasonable and the units have cancelled correctly. The answers show the correct number of significant digits.

46. Practice Problem (page 381)

Calculate the molar concentrations of the ions in each solution.

a. 18 g of sodium sulfate, $Na_2SO_4(s)$, dissolved in 210 mL of solution
b. 15 g of ammonium phosphate, $(NH_4)_3PO_4(s)$, dissolved in 98 mL of solution
c. 20 mg of calcium phosphate, $Ca_3(PO_4)_2(s)$, dissolved in 1.7 L of solution

What Is Required?

You need to determine the molar concentrations of the ions in three solutions.

What Is Given?

You know the masses and volumes of the three solutions:

a. $Na_2SO_4(s)$: $m = 18$ g; $V = 210$ mL
b. $(NH_4)_3PO_4(s)$: $m = 15$ g; $V = 98$ mL
c. $Ca_3(PO_4)_2(s)$: $m = 20$ mg; $V = 1.7$ L

Plan Your Strategy

Where necessary, convert the mass of solute from milligrams to grams: 1 mg = 1×10^{-3} g
Where necessary, convert the volume of solution from millilitres to litres: 1 mL = 1×10^{-3} L
Determine the molar mass of each solute.
Determine the mass of each solute using the relationship $n = \dfrac{m}{M}$.
Calculate the molar concentration using the relationship $c = \dfrac{n}{V}$.
Write the dissociation equation for each compound and use the mole ratio in this balanced equation to calculate the concentration of each ion.

Act on Your Strategy

a. sodium sulfate

Volume conversion:

$$\text{volume of } Na_2SO_4(aq) \text{ solution} = 210\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}}$$
$$= 0.210\ \text{L}$$

Molar mass, *M*, of $Na_2SO_4(s)$:

$$M_{Na_2SO_4} = 2M_{Na} + 1M_S + 4M_O$$
$$= 2(22.99\ \text{g/mol}) + 1(32.07\ \text{g/mol}) + 4(16.00\ \text{g/mol})$$
$$= 142.05\ \text{g/mol}$$

Amount in moles, *n*, of $Na_2SO_4(s)$;

$$n_{Na_2SO_4} = \frac{m}{M}$$
$$= \frac{18\ \cancel{\text{g}}}{142.05\ \cancel{\text{g}}/\text{mol}}$$
$$= 0.1267\ \text{mol}$$

Molar concentration, *c*, of $Na_2SO_4(aq)$:

$$c = \frac{n}{V}$$
$$= \frac{0.1267\ \text{mol}}{0.210\ \text{L}}$$
$$= 0.6034\ \text{mol/L}$$

The molar concentration of $Na_2SO_4(aq)$ is 0.6034 mol/L.

Dissociation equation: $Na_2SO_4(s) \rightarrow 2Na^+(aq) + SO_4^{2-}$

Mole ratio: 1 mole 2 moles 1 mole

Molar concentration of Na^+(aq):

$$\frac{2 \text{ mol Na}^+\text{(aq)}}{1 \text{ mol Na}_2\text{SO}_4\text{(aq)}} = \frac{c}{0.6034 \text{ mol/L Na}_2\text{SO}_4\text{(aq)}}$$

$$2 \text{ mol Na}^+\left(\text{aq}\right) \times 0.6034 \text{ mol/L Na}_2\text{SO}_4\left(\text{aq}\right) = 1 \text{ mol Na}_2\text{SO}_4\left(\text{aq}\right) \times c$$

$$c = \frac{2 \cancel{\text{mol}} \text{ Na}^+\left(\text{aq}\right) \times 0.6034 \text{ mol/L } \cancel{\text{Na}_2\text{SO}_4\left(\text{aq}\right)}}{1 \cancel{\text{mol}} \cancel{\text{Na}_2\text{SO}_4\left(\text{aq}\right)}}$$

$$= 1.206 \text{ mol/L Na}^+\left(\text{aq}\right)$$

$$= 1.2 \text{ mol/L Na}^+\left(\text{aq}\right)$$

The molar concentration of Na^+(aq) is 1.2 mol/L.

Molar concentration of SO_4^{2-}(aq):

$$\frac{1 \text{ mol SO}_4^{2-}\text{(aq)}}{1 \text{ mol Na}_2\text{SO}_4\text{(aq)}} = \frac{c}{0.6034 \text{ mol/L Na}_2\text{SO}_4\text{(aq)}}$$

$$1 \text{ mol SO}_4^{2-}\left(\text{aq}\right) \times 0.6034 \text{ mol/L Na}_2\text{SO}_4\left(\text{aq}\right) = 1 \text{ mol Na}_2\text{SO}_4\left(\text{aq}\right) \times c$$

$$c = \frac{1 \cancel{\text{mol}} \text{ SO}_4^{2-}\left(\text{aq}\right) \times 0.6034 \text{ mol/L } \cancel{\text{Na}_2\text{SO}_4\left(\text{aq}\right)}}{1 \text{ mol } \cancel{\text{Na}_2\text{SO}_4\left(\text{aq}\right)}}$$

$$= 0.6034 \text{ mol/L SO}_4^{2-}\left(\text{aq}\right)$$

$$= 0.60 \text{ mol/L SO}_4^{2-}\left(\text{aq}\right)$$

The molar concentration of SO_4^{2-}(aq) is 0.60 mol/L.

b. ammonium phosphate

Volume conversion:

$$\text{volume of } (\text{NH}_4)_3\text{PO}_4\left(\text{aq}\right) \text{solution} = 98 \cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\cancel{\text{mL}}$$

$$= 0.098 \text{ L}$$

Molar mass, M, of $(NH_4)_3PO_4$(s):

$$M_{(\text{NH}_4)_3\text{PO}_4} = 3M_\text{N} + 12M_\text{H} + 1M_\text{P} + 4M_\text{O}$$

$$= 3(14.01 \text{ g/mol}) + 12(1.01 \text{ g/mol}) + 1(30.97 \text{ g/mol}) + 4(16.00 \text{ g/mol})$$

$$= 149.12 \text{ g/mol}$$

Amount in moles, n, of $(NH_4)_3PO_4$(s);

$$n_{(NH_4)_3PO_4} = \frac{m}{M}$$
$$= \frac{15\ \cancel{g}}{149.12\ \cancel{g}/\text{mol}}$$
$$= 0.10059\ \text{mol}$$

Molar concentration, c, of $(NH_4)_3PO_4$(aq):

$$c = \frac{n}{V}$$
$$= \frac{0.10059\ \text{mol}}{0.098\ \text{L}}$$
$$= 1.026\ \text{mol/L}$$

The molar concentration of $(NH_4)_3PO_4$(aq) is 1.026 mol/L.

Dissociation equation: $(NH_4)_3PO_4(s) \rightarrow 3NH_4^{+}(aq) + PO_4^{3-}$
Mole ratio: 1 mole 3 moles 1 mole

Molar concentration of NH_4^{+}(aq):

$$\frac{3\ \text{mol}\ NH_4^{+}(aq)}{1\ \text{mol}(NH_4)_3PO_4(aq)} = \frac{c}{1.026\ \text{mol/L}\ (NH_4)_3PO_4(aq)}$$

$$3\ \text{mol}\ NH_4^{+}(aq) \times 1.026\ \text{mol/L}\left(NH_4^{+}\right)_3 PO_4(aq) = 1\ \text{mol}\ \left(NH_4^{+}\right)_3 PO_4(aq) \times c$$

$$c = \frac{3\ \cancel{\text{mol}}\ NH_4^{+}(aq) \times 1.026\ \text{mol/L}\ \cancel{(NH_4)_3PO_4(aq)}}{1\ \cancel{\text{mol}\ (NH_4)_3PO_4(aq)}}$$
$$= 3.079\ \text{mol/L}\ NH_4^{+}(aq)$$
$$= 3.1\ \text{mol/L}\ NH_4^{+}(aq)$$

The molar concentration of NH_4^{+}(aq) is 3.1 mol/L.

Molar concentration of PO_4^{3-}(aq):

$$\frac{1\text{ mol }PO_4^{3-}(aq)}{1\text{ mol}(NH_4)_3PO_4(aq)} = \frac{c}{1.026\text{ mol/L }(NH_4)_3PO_4(aq)}$$

$$1\text{ mol }PO_4^{3-}(aq) \times 1.026\text{ mol/L}\left(NH_4^+\right)_3PO_4(aq) = 1\text{ mol }\left(NH_4^+\right)_3PO_4(aq) \times c$$

$$c = \frac{1\text{ mol }PO_4^{3-}(aq) \times 1.026\text{ mol/L }(NH_4)_3PO_4(aq)}{1\text{ mol }(NH_4)_3PO_4(aq)}$$

$$= 1.026\text{ mol/L }PO_4^{3-}(aq)$$

$$= 1.0\text{ mol/L }PO_4^{3-}(aq)$$

The molar concentration of PO_4^{3-}(aq) is 1.0 mol/L.

c. calcium phosphate
volume of $Ca_3(PO_4)_2$(aq) solution = 1.7 L

Mass conversion:

$$\text{mass of }Ca_3(PO_4)_2(s) = 20\text{ mg} \times 1 \times 10^{-3}\text{ g/mg}$$

$$= 0.020\text{ g}$$

Molar mass, *M*, of $Ca_3(PO_4)_2$(s):

$$M_{Ca_3(PO_4)_2} = 3M_{Ca} + 2M_P + 8M_O$$

$$= 3(40.08\text{ g/mol}) + 2(30.97\text{ g/mol}) + 8(16.00\text{ g/mol})$$

$$= 310.18\text{ g/mol}$$

Amount in moles, *n*, of $Ca_3(PO_4)_2$(s):

$$n_{Ca_3(PO_4)_2} = \frac{m}{M}$$

$$= \frac{0.020\text{ g}}{310.18\text{ g/mol}}$$

$$= 6.4478 \times 10^{-5}\text{ mol}$$

Molar concentration, c, of $Ca_3(PO_4)_2(aq)$:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{6.4478 \times 10^{-5}\ \text{mol}}{1.7\ \text{L}} \\ &= 3.7928 \times 10^{-5}\ \text{mol/L} \end{aligned}$$

The molar concentration of $Ca_3(PO_4)_2(aq)$ is 3.7928×10^{-5} mol/L.

Dissociation equation: $Ca_3(PO_4)_2(s) \rightarrow 3Ca^{2+}(aq) + 2PO_4^{3-}(aq)$
Mole ratio: 1 mole 3 moles 2 moles

Molar concentration of $Ca^{2+}(aq)$:

$$\frac{3\ \text{mol}\ Ca^{2+}(aq)}{1\ \text{mol}\ Ca_3(PO_4)_2(aq)} = \frac{c}{3.7928 \times 10^{-5}\ \text{mol/L}\ Ca_3(PO_4)_2(aq)}$$

$$3\ \text{mol}\ Ca^{2+}(aq) \times 3.7928 \times 10^{-5}\ \text{mol/L}\ Ca_3(PO_4)_2(aq) = 1\ \text{mol}\ Ca_3(PO_4)_2(aq) \times c$$

$$\begin{aligned} c &= \frac{3\ \cancel{\text{mol}}\ Ca^{2+}(aq) \times 3.7928\times10^{-5}\ \text{mol/L}\ \cancel{Ca_3(PO_4)_2(aq)}}{1\ \cancel{\text{mol}\ Ca_3(PO_4)_2(aq)}} \\ &= 1.137 \times 10^{-4}\ \text{mol/L}\ Ca^{2+}(aq) \\ &= 1.1 \times 10^{-4}\ \text{mol/L}\ Ca^{2+}(aq) \end{aligned}$$

The molar concentration of $Ca^{2+}(aq)$ is 1.1×10^{-4} mol/L.

Molar concentration of $PO_4^{3-}(aq)$:

$$\frac{2\ \text{mol}\ PO_4^{3-}(aq)}{1\ \text{mol}\ Ca_3(PO_4)_2(aq)} = \frac{c}{3.7928 \times 10^{-5}\ \text{mol/L}\ Ca_3(PO_4)_2(aq)}$$

$$2\ \text{mol}\ PO_4^{3-}(aq) \times 3.7928 \times 10^{-5}\ \text{mol/L}\ Ca_3(PO_4)_3(aq) = 1\ \text{mol}\ Ca_3(PO_4)_3(aq) \times c$$

$$\begin{aligned} c &= \frac{2\ \cancel{\text{mol}}\ PO_4^{3-}(aq) \times 3.7928 \times 10^{-5}\ \text{mol/L}\ \cancel{Ca_3(PO_4)_2(aq)}}{1\ \cancel{\text{mol}\ Ca_3(PO_4)_2(aq)}} \\ &= 7.5856 \times 10^{-5}\ \text{mol/L}\ PO_4^{3-}(aq) \\ &= 7.6 \times 10^{-5}\ \text{mol/L}\ PO_4^{3-}(aq) \end{aligned}$$

The molar concentration of $PO_4^{3-}(aq)$ is 7.6×10^{-5} mol/L.

Check Your Solution
The concentrations seem reasonable and they are in the correct mole ratio. The units have cancelled correctly. The answers show the correct number of significant digits.

47. Practice Problem (page 381)

A student dissolves 28.46 g of silver nitrate, $AgNO_3(s)$, in water to make 580 mL of solution.
Find the molar concentration of the solution.

What Is Required?

You need to determine the molar concentration of a silver nitrate solution.

What Is Given?

You know the mass and volume of the solution:
$m = 28.46$ g
$V = 580$ mL

Plan Your Strategy

Determine the molar mass of $AgNO_3(s)$.

Calculate the amount in moles of the $AgNO_3(s)$ using the relationship $n = \frac{m}{M}$.

Convert the volume of the solution from millilitres to litres: 1 mL = 1×10^{-3} L

Calculate the molar concentration of solution using the relationship $c = \frac{n}{V}$.

Act on Your Strategy

Molar mass, M, of $AgNO_3(s)$:

$$\begin{aligned} M_{AgNO_3} &= 1M_{Ag} + 1M_{N} + 3M_{O} \\ &= 1(107.87 \text{ g/mol}) + 1(14.01 \text{ g/mol}) + 3(16.00 \text{ g/mol}) \\ &= 169.88 \text{ g/mol} \end{aligned}$$

Amount in moles, n, of $AgNO_3(s)$:

$$\begin{aligned} n_{AgNO_3} &= \frac{m}{M} \\ &= \frac{28.46 \text{ g}}{169.88 \text{ g/mol}} \\ &= 0.16753 \text{ mol} \end{aligned}$$

Volume conversion:

$$\begin{aligned} \text{volume of } AgNO_3(aq) &= 580 \text{ mL} \times 1 \times 10^{-3} \text{ L/mL} \\ &= 0.580 \text{ L} \end{aligned}$$

Molar concentration, c, of the solution:

$$\begin{aligned}c &= \frac{n}{V}\\ &= \frac{0.16753 \text{ mol}}{0.580 \text{ L}}\\ &= 0.28884 \text{ mol/L}\\ &= 0.289 \text{ mol/L}\end{aligned}$$

The molar concentration of the silver nitrate solution is 0.289 mol/L.

Check Your Solution
The concentration seems reasonable and the units have cancelled correctly.
The answer correctly shows three significant digits.

48. Practice Problem (page 381)
Formalin is an aqueous solution that is made by dissolving formaldehyde gas, HCHO(g), in water. A saturated formalin solution has a concentration of about 37% (m/v). This concentration is used to preserve biological specimens. Calculate the molar concentration of 37% (m/v) formalin.

What Is Required?
You need to determine the molar concentration of a solution of formalin.

What Is Given?
You know the percent (m/v) concentration of the formalin: 37%.
You know that 37% (m/v) means 37 g of solute in 100 mL of solution.

Plan Your Strategy
Determine the molar mass of HCHO(g).

Calculate the amount in moles of the HCHO(g) using the relationship $n = \frac{m}{M}$.

Convert the volume of the solution from millilitres to litres: 1 mL = 1×10^{-3} L

Calculate the molar concentration of solution using the relationship $c = \frac{n}{V}$.

Act on Your Strategy
Molar mass, M, of HCHO(g):

$$\begin{aligned}M_{\text{HCHO}} &= 1M_{\text{C}} + 2M_{\text{H}} + 1M_{\text{O}}\\ &= 1(12.01 \text{ g/mol}) + 2(1.01 \text{ g/mol}) + 1(16.00 \text{ g/mol})\\ &= 30.03 \text{ g/mol}\end{aligned}$$

Amount in moles, *n*, of HCHO(g):

$$n_{\text{HCHO}} = \frac{m}{M}$$
$$= \frac{37\ \text{g}}{30.03\ \text{g/mol}}$$
$$= 1.2321\ \text{mol}$$

Volume conversion:

$$\text{volume of the solution} = 100\ \text{mL} \times 1 \times 10^{-3}\ \text{L/mL}$$
$$= 0.100\ \text{L}$$

Molar concentration, *c*, of the HCHO(aq) solution:

$$c = \frac{n}{V}$$
$$= \frac{1.2321\ \text{mol}}{0.100\ \text{L}}$$
$$= 12.321\ \text{mol/L}$$
$$= 12\ \text{mol/L}$$

The molar concentration of the formalin solution is 12 mol/L.

Check Your Solution

The 37 g of solute in 100 mL of solution is a little more than 1 mol of HCHO in 0.10 L. The answer of 12 mol/L is reasonable and correctly shows two significant digits.

49. Practice Problem (page 381)

What volume of a 0.555 mol/L aqueous solution contains 12.8 g of sodium carbonate, Na_2CO_3(aq)?

What Is Required?

You need to determine the volume of Na_2CO_3(aq).

What Is Given?

You know the molar concentration of Na_2CO_3(aq): 0.555 mol/L
You know the mass of Na_2CO_3(s): 12.8 g

Plan Your Strategy
Determine the molar mass of Na_2CO_3(s).

Calculate the amount in moles of the Na_2CO_3(s) using the relationship $n = \frac{m}{M}$.

Write the formula for molar concentration.
Rearrange the formula to solve for the volume of solution.
Substitute the calculated data into the equation to determine the volume of the solution.

Act on Your Strategy
Molar mass, *M*, of Na_2CO_3(s):

$$\begin{aligned} M_{\text{Na}_2\text{CO}_3} &= 2M_{\text{Na}} + 1M_{\text{C}} + 3M_{\text{O}} \\ &= 2(22.9 \text{ g/mol}) + 1(12.01 \text{ g/mol}) + 3(16.00 \text{ g/mol}) \\ &= 105.99 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of Na_2CO_3(s):

$$\begin{aligned} n_{\text{Na}_2\text{CO}_3} &= \frac{m}{M} \\ &= \frac{12.8 \text{ } \cancel{\text{g}}}{105.99 \text{ } \cancel{\text{g}}\text{/mol}} \\ &= 0.12076 \text{ mol} \end{aligned}$$

Formula for molar concentration:

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

Rearranged formula to solve for the volume of solute:

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

$$V\cancel{c} \times \frac{1}{\cancel{c}} = n \times \frac{1}{c}$$

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

Substitution of calculated data to determine the volume, *V*, of the solution:

$$V = \frac{n}{c}$$
$$= \frac{0.12076\ \cancel{\text{mol}}}{0.555\ \cancel{\text{mol}}/\text{L}}$$
$$= 0.21758\ \text{L}$$
$$= 0.218\ \text{L}$$

The volume of the sodium carbonate solution is 0.218 L.

Check Your Solution
The correct units have been used and the answer correctly shows three significant digits. The calculated answer seems reasonable.

50. Practice Problem (page 381)
Zinc oxide, ZnO(s), has a solubility of 0.16 mg/100 mL in water at 30°C. Find the molar concentration of a saturated solution of zinc oxide at 30°C.

What Is Required?
You need to determine the molar concentration of a zinc oxide solution.

What Is Given?
You know the solubility of the zinc oxide: 0.16 mg/100 mL of solution

Plan Your Strategy
Convert the solubility from mg/100 mL to g/L:
1 mg = 1 × 10^{-3} g
1 mL = 1 × 10^{-3} L
Determine the molar mass of ZnO(s).

Calculate the amount in moles of the ZnO(s) using the relationship $n = \frac{m}{M}$.

Calculate the molar concentration of the solution using the relationship $c = \frac{n}{V}$.

Act on Your Strategy
Solubility conversion:

$$\frac{0.16\ \cancel{\text{mg}} \times 1 \times 10^{-3}\ (\text{g}/\cancel{\text{mg}})}{100\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ (\text{L}/\cancel{\text{mL}})} = 0.0016\ \text{g/L}$$

Molar mass, *M*, of ZnO(s):

$$M_{ZnO} = 1M_{Zn} + 1M_{O}$$
$$= 1(65.38 \text{ g/mol}) + 1(16.00 \text{ g/mol})$$
$$= 81.38 \text{ g/mol}$$

Amount in moles, *n*, of ZnO(s):

$$n_{ZnO} = \frac{m}{M}$$
$$= \frac{0.0016 \not{\text{g}}}{81.38 \not{\text{g}}\text{/mol}}$$
$$= 1.966 \times 10^{-5} \text{ mol}$$
$$= 2.0 \times 10^{-5} \text{ mol}$$

Molar concentration, *c*, of the solution:

$$c = \frac{n}{V}$$
$$= \frac{2.0 \times 10^{-5} \text{ mol}}{1 \text{ L}}$$
$$= 2.0 \times 10^{-5} \text{ mol/L}$$

The molar concentration of the zinc oxide solution is 2.0×10^{-5} mol/L.

Check Your Solution

The concentration would be expected to be low given the low solubility. The answer seems reasonable and the units have cancelled correctly. The answer correctly shows two significant digits.

Section 8.3 Concentrations of Solutions

Solutions for Selected Review Questions

Student Edition page 382

3. Review Question (page 382)

A 50 g sample of seawater is found to contain 0.02 g of sodium chloride.
a. State the concentration of sodium as a mass percent.
b. Express the concentration of sodium in parts per million.

a.
$$\text{percent (m/m)} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$
$$= \frac{0.02\ \cancel{g}\ [\text{NaCl}]}{50\ \cancel{g}\ [\text{seawater}]} \times 100\%$$
$$= 0.04\%$$

b.
$$\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$$
$$= \frac{0.02\ \cancel{g}\ [\text{NaCl}]}{50\ \cancel{g}\ [\text{seawater}]} \times 10^6$$
$$= 400$$

4. Review Question (page 382)

Calcium carbonate, $CaCO_3(aq)$, may be naturally present in household water supplies. Suppose that a toilet tank holds 6.0 L of water, and the water contains 90 ppm of calcium carbonate. What mass of calcium carbonate is in the water in the tank?

What Is Required?
You need to determine the mass of calcium carbonate in the water.

What Is Given?
You know the volume of water: 6.0 L
You know the mass of 1 L of water: 1 kg
You know the concentration of calcium carbonate in the water: 90 ppm

Plan Your Strategy
Determine the mass (in grams) of 6.0 L of water.
Write the formula for ppm.
Rearrange the equation to solve for the mass of solute.
Substitute the data into the equation to calculate the mass of solute.

Act on Your Strategy

$$\text{mass of water (in grams)} = 6.0\ \cancel{\text{L}} \times \frac{1\ \cancel{\text{kg}}}{1\ \cancel{\text{L}}} \times 1 \times 10^{3}\ \text{g}/\cancel{\text{kg}}$$
$$= 6000\ \text{g}$$

Formula for ppm:

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

Rearranged formula for the mass of solute:

$$\text{ppm} \times \text{mass of solution} = \cancel{\text{mass of solution}} \times \frac{\text{mass of solute}}{\cancel{\text{mass of solution}}} \times 10^{6}$$

$$\text{ppm} \times \text{mass of solution} = \text{mass of solute} \times 10^{6}$$

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

Substitution to solve for mass of solute:

$$\text{mass of solute} = \frac{\text{ppm} \times \text{mass of solution}}{10^{6}}$$
$$= \frac{90 \times 6.0 \times 10^{3}\ \text{g}}{10^{6}}$$
$$= 0.54\ \text{g}$$

The mass of calcium carbonate in the water is 0.54 g.

Check Your Solution

The amount of dissolved calcium carbonate is expected to be small if the concentration is measured in ppm. The answer is a small value and seems reasonable. The answer correctly shows two significant digits.

5. Review Question (page 382)

Aldrin and dieldrin are pesticides that used to be allowed for the control of soil insects. In Ontario, the maximum allowable total concentration of aldrin plus dieldrin in drinking water is 0.7 ppb. If a 250 mL sample of drinking water is found to contain 0.0001 mg of aldrin and dieldrin, does the concentration exceed the standard? Explain.

What Is Required?

You need to determine if the concentration of pesticide exceeds the allowable standard.

What Is Given?

You know the volume of the sample of water: 250 mL

You know the mass of dissolved pesticide: 1×10^{-4} mg

You know the maximum allowable concentration of pesticide in the water: 0.7 ppb

You know the mass of 1 mL of water: 1 g

Plan Your Strategy

Determine the mass of the sample of water.

Convert the mass of pesticide (solute) to grams: 1 mg = 1×10^{-3} g

Substitute the data into the expression for ppb.

Act on Your Strategy

$$\begin{aligned}\text{mass of water (solution)} &= 250\ \cancel{\text{mL}} \times 1\ \text{g}/\cancel{\text{mL}} \\ &= 250\ \text{g}\end{aligned}$$

$$\begin{aligned}\text{mass of solute} &= 1 \times 10^{-4}\ \cancel{\text{mg}} \times 1 \times 10^{-3}\ \text{g}/\cancel{\text{mg}} \\ &= 1 \times 10^{-7}\ \text{g}\end{aligned}$$

$$\begin{aligned}\text{ppb} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^{9} \\ &= \frac{1 \times 10^{-7}\ \cancel{\text{g}}}{250\ \cancel{\text{g}}} \times 10^{9} \\ &= 0.4\ \text{ppb}\end{aligned}$$

The concentration of pesticide in the water is 0.4 ppb. This is below the acceptable level of 0.7 ppb.

Check Your Solution

The units are correct and the calculated value is in the range expected for the small mass given in the data. The answer seems reasonable and correctly shows one significant digit.

6. Review Question (page 382)

A researcher distilled an 85.1 mL sample of a solution of liquid hydrocarbons. The distillation process separated out 20.3 mL of hexane. Find the percent (v/v) concentration of hexane in the solution.

$$\begin{aligned}\text{percent (v/v)} &= \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\% \\ &= \frac{20.3\ \cancel{\text{mL}}}{85.1\ \cancel{\text{mL}}} \times 100\% \\ &= 23.85\% \\ &= 23.9\%\end{aligned}$$

The concentration of hexane in the solution is 23.9% (v/v).

7. Review Question (page 282)

Phosphoric acid, $H_3PO_4(aq)$, can be used to remove rust. Find the molar concentration of an 85% (m/v) solution of phosphoric acid in water.

What Is Required?

You need to change the concentration from percent (m/v) to mol/L.

What Is Given?

You know the concentration in percent (m/v): 85%
You know the mass of 1 mL of water: 1 g

Plan Your Strategy

Express the concentration in grams of solute in 100 mL of solution.
Convert the volume of 100 mL of solution to litres: 1 mL = 1 × 10^{-3} L
Determine the molar mass of $H_3PO_4(s)$.

Calculate the amount in moles, n, of $H_3PO_4(s)$ using the relationship $n = \frac{m}{M}$.

Calculate the molar concentration, c, of $H_3PO_4(aq)$ using the expression $c = \frac{n}{V}$.

Act on Your Strategy

concentration of solution = 85 g $H_3PO_4(s)$/100 mL $H_3PO_4(aq)$

Volume conversion:

$$\begin{aligned}\text{volume of solution} &= 100\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.100\ \text{L}\end{aligned}$$

Molar mass, *M*, of H_3PO_4(s):

$$
\begin{aligned}
M_{H_3PO_4} &= 3M_H + 1M_P + 4M_O \\
&= 3(1.01\ \text{g/mol}) + 1(30.97\ \text{g/mol}) + 4(16.00\ \text{g/mol}) \\
&= 98.00\ \text{g/mol}
\end{aligned}
$$

Amount in moles, *n*, of H_3PO_4(s):

$$
\begin{aligned}
n_{H_3PO_4} &= \frac{m}{M} \\
&= \frac{85\ \cancel{\text{g}}}{98.00\ \cancel{\text{g}}/\text{mol}} \\
&= 0.86734\ \text{mol}
\end{aligned}
$$

Molar concentration, *c*, of the H_3PO_4(aq):

$$
\begin{aligned}
c &= \frac{n}{V} \\
&= \frac{0.86734\ \text{mol}}{0.100\ \text{L}} \\
&= 8.6734\ \text{mol/L} \\
&= 8.7\ \text{mol/L}
\end{aligned}
$$

The molar concentration of the phosphoric acid solution is 8.7 mol/L.

Check Your Solution

Estimating, the percent (m/v) is 85 g/0.100 L, which is close to 1 mol per 0.100 L or 10 mol/L. This estimate is close to the calculated molar concentration. The answer seems reasonable and correctly shows two significant digits.

9. Review Question (page 382)

Since the Industrial Revolution, the atmospheric concentration of carbon dioxide has increased from 280 parts per million to 380 parts per million. The mass of Earth's atmosphere is estimated to be 5.3×10^{18} kg. What mass of carbon dioxide has been added to Earth's atmosphere?

$$\text{ppm} = \frac{\text{mass of solute } [CO_2]}{\text{mass of solution [Earth's atmosphere]}} \times 10^6$$

$$\text{ppm} \times \text{mass of solution} = \cancel{\text{mass of solution}} \times \frac{\text{mass of solute}}{\cancel{\text{mass of solution}}} \times 10^6$$

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

change in concentration of $CO_2(g)$ = 380 ppm – 280 ppm
= 100 ppm

$$\text{increase in mass of } CO_2(g) = \frac{\text{ppm} \times \text{mass of solution}}{10^6} = \frac{100 \times 5.3 \times 10^{18}\ \text{kg}}{10^6} = 5.3 \times 10^{14}\ \text{kg}$$

The increase in mass of $CO_2(g)$ is 5.3×10^{14} kg.

11. Review Question (page 382)

The Canadian Ambient Air Quality Objective for ground-level ozone is 82 ppb. What is the maximum mass of ozone, $O_3(g)$, allowed per cubic metre of air? The density of air is 1.2 kg/m^3.

Volume of 1 kg of air:
Let *x* be the volume of 1 kg of air.

$$\frac{1\ \text{m}^3}{1.2\ \text{kg}} = \frac{x}{1\ \text{kg}}$$

$$x = \frac{1\ \text{m}^3 \times 1\ \cancel{\text{kg}}}{1.2\ \cancel{\text{kg}}} = 0.833\ \text{m}^3$$

The volume of 1 kg of air is 0.833 m^3.

Maximum mass of ozone:

$$\begin{aligned}82\text{ ppb} &= \frac{82\ \mu\text{g [ozone]}}{1\text{ kg [air]}}\\ &= \frac{82\ \mu\text{g}}{0.833\text{ m}^3}\\ &= 98\ \mu\text{g/m}^3\end{aligned}$$

The maximum acceptable mass of ozone in the air is 98 μg/m^3.

12. Review Question (page 382)

One teaspoon of table salt is added to the water in a swimming pool. The swimming pool is 10 m long, 5.0 m wide, and 2.0 m deep. One teaspoon of table salt has a mass of 4.5 g. Calculate the concentration (in parts per billion) of table salt in the water. Assume 10 m has two significant digits.

What Is Required?

You need to determine the salt concentration is a swimming pool.

What Is Given?

You know the dimensions of the pool and the mass of salt in the pool.

Plan Your Strategy

Use the dimensions of the pool to calculate the volume of water.
Use the density of water of 1 kg/m^3 to determine the mass of water in the pool.
Express the mass of water in the pool in grams: 1 kg = 1×10^3 g
Write the formula for ppb.
Substitute the data in the expression to calculate the salt concentration.

Act on Your Strategy

$$\begin{aligned}\text{volume of swimming pool} &= \text{length} \times \text{width} \times \text{depth}\\ &= 10\text{ m} \times 5.0\text{ m} \times 2.0\text{ m}\\ &= 1.0 \times 10^2\text{ m}^3\end{aligned}$$

1 m^3 of water has a mass of 10^3 kg.
Therefore, 1.0×10^2 m^3 of water has a mass of $1.0 \times 10^2 \times 10^3$ kg.

$$\begin{aligned}\text{mass of water in swimming pool} &= 1.0 \times 10^5\ \cancel{\text{kg}} \times 1 \times 10^3\text{ g/}\cancel{\text{kg}}\\ &= 1.0 \times 10^8\text{ g}\end{aligned}$$

$$\text{ppb} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^9$$
$$= \frac{4.5 \cancel{\text{g}} \text{[salt]}}{1.0 \times 10^8 \cancel{\text{g}} \text{[water]}} \times 10^9$$
$$= 4.5 \times 10^1 \text{ ppb}$$
$$= 45 \text{ ppb}$$

The salt concentration in the swimming pool is 45 ppb.

Check Your Solution
The units are correct. Concentration in ppb is a small unit of concentration and the answer is expected to be large. The answer correctly shows two significant digits.

13. Review Question (page 382)
The concentration of dissolved iron(II) ions, Fe^{2+}(aq), in a sample of ground water is 7.2×10^{-5} mol/L. Is this concentration an acceptable level if the recommended maximum level is 300 ppb? Show your work, and explain your reasoning.

What Is Required?
You need to determine if the Fe^{2+}(aq) concentration is within an acceptable level.

What Is Given?
You know the Fe^{2+}(aq) concentration: 7.2×10^{-5} mol/L
You know the maximum acceptable level of Fe^{2+}(aq): 300 ppb

Plan Your Strategy
Use the molar mass for iron (from the periodic table) and the relationship $m = n \times M$ to calculate the concentration of Fe^{2+}(aq) in g/L.
For dilute solutions, the density is 1 g/mL. The mass of 1 L of solution is 1000 g.
Write the equation for ppb.
Substitute the mass of solute, Fe^{2+}(aq), in grams and the mass of solution in grams into the expression for ppb and solve.
Compare the calculated concentration in ppb with the maximum accepted level for Fe^{2+}(aq).

Act on Your Strategy

$M_{Fe^{2+}} = 55.85 \text{ g/mol}$

Mass, *m*, of Fe^{2+}(aq) in 1 L of solution:

$$\begin{aligned} m_{Fe^{2+}} &= n \times M \\ &= 7.2 \times 10^{-5} \cancel{\text{mol}} \times 55.85 \text{ g/} \cancel{\text{mol}} \\ &= 4.0212 \times 10^{-3} \text{ g} \end{aligned}$$

mass of solution = 1000 g

Formula for ppb:

$$\text{ppb} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^9$$

Substitution to solve for ppb:

$$\begin{aligned} \text{ppb} &= \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^9 \\ &= \frac{4.0212 \times 10^{-3} \cancel{\text{g}} \ [Fe^{2+}]}{1.0 \times 10^3 \cancel{\text{g}} \ [\text{solution}]} \times 10^9 \\ &= 4.0212 \times 10^3 \\ &= 4.0212 \times 10^3 \\ &= 4.0 \times 10^3 \end{aligned}$$

This concentration of 4.0×10^3 ppb for Fe^{2+}(aq) exceeds the acceptable level of 300 ppb.

Check Your Solution

The units are correct and the answer correctly shows two significant digits. The answer seems reasonable.

14. Review Question (page 382)

A pharmacist dilutes a 10% (m/v) saline solution until the final volume is four times the initial volume. Find the molar concentration of sodium chloride in the diluted solution.

What Is Required?

You need to determine the molar concentration of the diluted solution.

What Is Given?
You know the initial concentration of the salt solution: 10% (m/v)
You know that the salt solution is diluted to 4 times the original volume.

Plan Your Strategy
Use the dilution equation to calculate the final concentration of the diluted solution in percent (m/v).
Determine the molar mass of NaCl(aq).
Calculate the amount in moles of NaCl(aq) using the relationship $n = \frac{m}{M}$.
Calculate the molar concentration of NaCl(aq) using the expression $c = \frac{n}{V}$.

Act on Your Strategy
Calculation of c_2:

$$c_1V_1 = c_2V_2$$

$$10\% \text{ (m/v)} \times V_1 = c_2 \times 4V_1$$

$$c_2 = \frac{10\% \text{ (m/v)} \times \cancel{V_1}}{4\cancel{V_1}}$$

$$= 2.5\% \text{ (m/v)}$$

The dilute salt solution has 2.5 g of NaCl(s) in 100 mL of solution.
The density of dilute solutions is 1 g/mL.
The volume of the dilute solution is 100 mL.

$$\text{volume of dilute solution} = 100 \ \cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\cancel{\text{mL}}$$

$$= 0.100 \text{ L}$$

Molar mass, M, of NaCl(s):

$$M_{\text{NaCl}} = 1M_{\text{Na}} + 1M_{\text{Cl}}$$

$$= 1(22.99 \text{ g/mol}) + 1(35.45 \text{ g/mol})$$

$$= 58.44 \text{ g/mol}$$

Amount in moles, *n*, of the NaCl(s):

$$n_{\text{NaCl}} = \frac{m}{M}$$
$$= \frac{2.5\ \cancel{g}}{58.44\ \cancel{g}/\text{mol}}$$
$$= 4.2778 \times 10^{-2}\ \text{mol}$$

Molar concentration, *c*, of the NaCl(aq):

$$c = \frac{n}{V}$$
$$= \frac{4.2778 \times 10^{-2}\ \text{mol}}{0.100\ \text{L}}$$
$$= 0.42778\ \text{mol/L}$$
$$= 0.43\ \text{mol/L}$$

The molar concentration of the saline solution is 0.43 mol/L.

Check Your Solution

The units are correct and the answer correctly shows two significant digits. The dilution of the original concentrated solution is correct and the change to mol/L seems reasonable.

Section 8.4 Preparing Solutions in the Laboratory

Solutions for Practice Problems

Student Edition page 386

51. Practice Problem (page 386)

Suppose that you are given a stock solution of 1.50 mol/L ammonium sulfate, $(NH_4)_2SO_4(aq)$.

What volume of the stock solution do you need to use to prepare each of the following solutions?

a. 50.0 mL of 1.00 mol/L $(NH_4)_2SO_4(aq)$

b. 2×10^2 mL of 0.800 mol/L $(NH_4)_2SO_4(aq)$

c. 250 mL of 0.300 mol/L $NH_4^+(aq)$

What Is Required?

You need to calculate the initial volume, V_1, of $(NH_4)_2SO_4(aq)$ stock solution needed to prepare each given dilute solution.

What Is Given?
You know the concentration of the stock solution: c_1 = 1.50 mol/L
You know the final volume and concentration of each dilute solution.
a. $(NH_4)_2SO_4$(aq): V_2 = 50.0 mL; c_2 = 1.00 mol/L
b. $(NH_4)_2SO_4$(aq): V_2 = 200 mL; c_2 = 0.800 mol/L
c. NH_4^+(aq): V_2 = 250 mL; c_2 = 0.300 mol/L

Plan Your Strategy
Convert the volume of each solution from millilitres to litres:
1 mL = 1×10^{-3} L
Write the dilution equation.
Rearrange the equation to solve for V_1.
Substitute the data into the equation to calculate V_1.
For part **c**, write the balanced equation for the dissociation of $(NH_4)_2SO_4$(s) and use the mole ratio from this equation to determine the concentration of $(NH_4)_2SO_4$ needed to obtain the required amount of NH_4^+(aq).

Act on Your Strategy
a. 50.0 mL of 1.00 mol/L ammonium sulfate
Volume conversion:

$$V_2 = 50.0 \cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\cancel{\text{mL}}$$
$$= 0.050 \text{ L}$$

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged formula to solve for V_1:

$$c_1V_1 = c_2V_2$$
$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$
$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to solve for V_1:

$$V_1 = \frac{c_2V_2}{c_1}$$
$$= \frac{1.00 \cancel{\text{mol/L}} \times 0.050 \text{ L}}{1.50 \cancel{\text{mol/L}}}$$
$$= 0.0333 \text{ L}$$

The initial volume of $(NH_4)_2SO_4$(aq) stock solution required is 0.0333 L.

b. 2×10^2 mL of 0.800 mol/L ammonium sulfate
Volume conversion:

$$V_2 = 2\times10^2 \ \cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\cancel{\text{mL}}$$
$$= 0.200 \text{ L}$$

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged formula to solve for V_1:

$$c_1V_1 = c_2V_2$$
$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$
$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to solve for V_1:

$$V_1 = \frac{c_2V_2}{c_1}$$
$$= \frac{0.800\ \cancel{\text{mol/L}} \times 0.200 \text{ L}}{1.50\ \cancel{\text{mol/L}}}$$
$$= 0.10666 \text{ L}$$
$$= 0.107 \text{ L}$$

Volume conversion:

$$V_1 = 0.107\ \cancel{\text{L}} \times 1 \times 10^3 \text{ mL}/\cancel{\text{L}}$$
$$= 107 \text{ mL}$$

The initial volume of $(NH_4)_2SO_4$(aq) stock solution required is 107 mL.

c. 250 mL of 0.300 mol/L ammonium ions
Dissociation equation: $(NH_4)_2SO_4(s) \rightarrow 2NH_4^+(aq) + SO_4^{2-}(aq)$
Mole ratio: 1 mole 2 moles 1 mole

Molar concentration of $(NH_4)_2SO_4(aq)$:

$$\frac{2 \text{ mol } NH_4^+}{1 \text{ mol } (NH_4)_2SO_4} = \frac{0.300 \text{ mol/L } NH_4^+}{c}$$

$$c \times 2 \text{ mol } NH_4^+(aq) = 1 \text{ mol } (NH_4)_2SO_4(aq) \times 0.300 \text{ mol/L } NH_4^+(aq)$$

$$c = \frac{1 \cancel{\text{mol}} (NH_4)_2SO_4(aq) \times 0.300 \text{ mol/L } \cancel{NH_4^+(aq)}}{2 \text{ mol } \cancel{NH_4^+(aq)}}$$

$$= 0.150 \text{ mol/L } (NH_4)_2SO_4(aq)$$

The molar concentration of $(NH_4)_2SO_4(aq)$ is 0.150 mol/L.

Volume conversion:

$$V_2 = 250 \cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\cancel{\text{mL}}$$

$$= 0.250 \text{ L}$$

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for V_1:

$$c_1V_1 = c_2V_2$$

$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$

$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to solve for V_1:

$$V_1 = \frac{c_2V_2}{c_1}$$

$$= \frac{0.150 \cancel{\text{mol/L}} \times 0.250 \text{ L}}{1.50 \cancel{\text{mol/L}}}$$

$$= 0.0250 \text{ L}$$

The initial volume of $(NH_4)_2SO_4(aq)$ stock solution required is 0.0250 L.

Check Your Solution
The units and number of significant digits are correct. The initial volume of concentrated solution is always less than the final volume of dilute solution. The answers seem reasonable.

52. Practice Problem (page 386)
What is the concentration of the solution that is obtained by diluting 60.0 mL of 0.580 mol/L potassium hydroxide to each of the following volumes?
a. 350 mL
b. 180 mL
c. 3.00 L

What Is Required?
You need to calculate the final concentration, c_2, of the resulting solutions obtained when a solution of potassium hydroxide is diluted.

What Is Given?
You know the initial concentration and initial volume of the potassium hydroxide solution:
c_1 = 60.0 mL
V_1 = 0.580 mol/L
You know the final volume of each dilute solution:
a. V_2 = 350 mL
b. V_2 = 180 mL
c. V_2 = 3.00 L

Plan Your Strategy
Where necessary, convert the volume of the solution from millilitres to litres: 1 mL = 1 × 10^{-3} L
Write the dilution equation.
Rearrange the equation to solve for c_2.
Substitute the data into the equation to calculate c_2.

Act on Your Strategy
a. 350 mL of potassium hydroxide
Volume conversion:

$$V_1 = 350\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}}$$
$$= 0.350\ \text{L}$$

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for c_2:

$$c_1V_1 = c_2V_2$$

$$\frac{c_1V_1}{V_2} = \frac{c_2\cancel{V_2}}{\cancel{V_2}}$$

$$c_2 = \frac{c_1V_1}{V_2}$$

Substitution to solve for c_2:

$$\begin{aligned} c_2 &= \frac{c_1V_1}{V_2} \\ &= \frac{0.580\ \text{mol/L} \times 0.0600\ \cancel{\text{L}}}{0.350\ \cancel{\text{L}}} \\ &= 0.099428\ \text{mol/L} \\ &= 0.0994\ \text{mol/L} \end{aligned}$$

The final concentration of the potassium hydroxide solution is 0.0994 mol/L.

b. 180 mL of potassium hydroxide
Volume conversion:

$$\begin{aligned} V_1 &= 180\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.180\ \text{L} \end{aligned}$$

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for c_2:

$$c_1V_1 = c_2V_2$$

$$\frac{c_1V_1}{V_2} = \frac{c_2\cancel{V_2}}{\cancel{V_2}}$$

$$c_2 = \frac{c_1V_1}{V_2}$$

Substitution to solve for c_2:

$$
\begin{aligned}
c_2 &= \frac{c_1V_1}{V_2} \\
&= \frac{0.580\ \text{mol/L} \times 0.0600\ \cancel{\text{L}}}{0.180\ \cancel{\text{L}}} \\
&= 0.19333\ \text{mol/L} \\
&= 0.193\ \text{mol/L}
\end{aligned}
$$

The final concentration of the potassium hydroxide solution is 0.193 mol/L.

c. 3.00 L of potassium hydroxide
Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for c_2:

$$
\begin{aligned}
c_1V_1 &= c_2V_2 \\
\frac{c_1V_1}{V_2} &= \frac{c_2\cancel{V_2}}{\cancel{V_2}} \\
c_2 &= \frac{c_1V_1}{V_2}
\end{aligned}
$$

Substitution to solve for c_2:

$$
\begin{aligned}
c_2 &= \frac{c_1V_1}{V_2} \\
&= \frac{0.580\ \text{mol/L} \times 0.0600\ \cancel{\text{L}}}{3.00\ \cancel{\text{L}}} \\
&= 0.0116\ \text{mol/L}
\end{aligned}
$$

The final concentration of the potassium hydroxide solution is 0.0116 mol/L.

Check Your Solution
The units and number of significant digits are correct. Comparing answers: V_2 for part **b** is about $\frac{1}{2}$ V_2 for part **a**, and c_2 for part **b** is about 2 times that for part **a**. Similarly, V_2 for part **c** is about 9 times V_2 for part **a**, and c_2 for part **c** is about $\frac{1}{9}$ times that for part **a**. The answers seem reasonable.

53. Practice Problem (page 386)

What volume of a 1.60 mol/L stock solution of calcium chloride, $CaCl_2(aq)$, would you use to make 0.500 L of a 0.300 mol/L solution?

What Is Required?

You need to calculate the initial volume, V_1, of $CaCl_2(aq)$ stock solution needed to prepare a dilute solution.

What Is Given?

You know the initial concentration of the stock solution: $c_1 = 1.60$ mol/L

You know the final volume and concentration of the dilute solution:

$V_2 = 0.500$ L

$c_2 = 0.300$ mol/L

Plan Your Strategy

Write the dilution equation.

Rearrange the equation to solve for V_1.

Substitute the data into the equation to calculate V_1.

Act on Your Strategy

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for V_1:

$$c_1V_1 = c_2V_2$$

$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$

$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to solve for V_1:

$$\begin{aligned} V_1 &= \frac{c_2V_2}{c_1} \\ &= \frac{0.300\ \cancel{\text{mol/L}} \times 0.500\ \text{L}}{1.60\ \cancel{\text{mol/L}}} \\ &= 0.09375\ \text{L} \\ &= 0.0938\ \text{L} \end{aligned}$$

The initial volume of calcium chloride stock solution required is 0.0938 L.

Check Your Solution
The final volume, V_2, is about 5 times the initial volume, V_1. The final concentration, c_2, is about $\frac{1}{5}$ the initial concentration, c_1. The answer seems reasonable and correctly shows three significant digits.

54. Practice Problem (page 386)
Water is added to 100 mL of 0.15 mol/L sodium nitrate, $NaNO_3(aq)$, to make 700 mL of diluted solution. Calculate the molar concentration of the diluted solution.

What Is Required?
You need to calculate the final concentration, c_2, of a solution of sodium nitrate.

What Is Given?
You know the initial concentration and the initial volume of the sodium nitrate solution:
$V_1 = 100$ mL
$c_1 = 0.15$ mol/L
You know the final volume:
$V_2 = 700$ mL

Plan Your Strategy
Convert the volumes from millilitres to litres: 1 mL = 1×10^{-3} L
Write the dilution equation.
Rearrange the equation to solve for c_2.
Substitute the data into the equation to calculate c_2.

Act on Your Strategy
Volume conversion:

$$V_1 = 100\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}}$$
$$= 0.100\ \text{L}$$
$$V_2 = 700\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}}$$
$$= 0.700\ \text{L}$$

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for c_2:

$$c_1V_1 = c_2V_2$$

$$\frac{c_1V_1}{V_2} = \frac{c_2\cancel{V_2}}{\cancel{V_2}}$$

$$c_2 = \frac{c_1V_1}{V_2}$$

Substitution to solve for c_2:

$$\begin{aligned} c_2 &= \frac{c_1V_1}{V_2} \\ &= \frac{0.15 \text{ mol/L} \times 0.100 \cancel{\text{L}}}{0.700 \cancel{\text{L}}} \\ &= 0.021428 \text{ mol/L} \\ &= 0.021 \text{ mol/L} \end{aligned}$$

The final concentration of the sodium nitrate solution is 0.021 mol/L.

Check Your Solution

The final volume, V_2, is 7 times the initial volume, V_1. The final concentration, c_2, is about $\frac{1}{7}$ the initial concentration, c_1.

The answer seems reasonable and correctly shows two significant digits.

55. Practice Problem (page 386)

A solution is made by diluting 25 mL of 0.34 mol/L calcium nitrate, $Ca(NO_3)_2(aq)$, solution to 100 mL. Calculate the following concentrations for the solution:

a. the concentration of calcium nitrate

b. the concentration of nitrate ions

a. concentration of calcium nitrate

What Is Required?

You need to determine the final concentration, c_2, of a solution of calcium nitrate.

What Is Given?

You know the initial concentration and the initial volume of the $Ca(NO_3)_2(aq)$:

V_1 = 25 mL

c_1 = 0.34 mol/L

You know the final volume:
V_2 = 100 mL

Plan Your Strategy
Convert the volumes from millilitres to litres: 1 mL = 1 × 10^{-3} L
Write the dilution equation.
Rearrange the equation to solve for c_2.
Substitute the data into the equation to calculate c_2.

Act on Your Strategy
Volume conversion:

$$\begin{aligned} V_1 &= 25\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.025\ \text{L} \\ V_2 &= 100\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.100\ \text{L} \end{aligned}$$

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for c_2:

$$c_1V_1 = c_2V_2$$

$$\frac{c_1V_1}{V_2} = \frac{c_2\cancel{V_2}}{\cancel{V_2}}$$

$$c_2 = \frac{c_1V_1}{V_2}$$

Substitution to solve for c_2:

$$\begin{aligned} c_2 &= \frac{c_1V_1}{V_2} \\ &= \frac{0.34\ \text{mol/L} \times 0.025\ \cancel{\text{L}}}{0.100\ \cancel{\text{L}}} \\ &= 0.085\ \text{mol/L} \end{aligned}$$

The final concentration of the calcium nitrate solution is 0.085 mol/L.

b. concentration of nitrate ions
What Is Required?
You need to determine the molar concentration of NO_3^-(aq).

What Is Given?
You know the concentration of the $Ca(NO_3)_2(aq)$: $c = 0.085$ mol/L

Plan Your Strategy
Write the balanced equation for the dissociation of the $Ca(NO_3)_2(aq)$.
Use the mole ratio from this equation to determine the concentration of NO_3^- (aq).

Act on Your Strategy
Dissociation equation: $Ca(NO_3)_2(aq) \rightarrow Ca^{2+}(aq) + 2NO_3^-(aq)$
Mole ratio: 1 mole 1 mole 2 moles

Molar concentration, c, of the nitrate ion:

$$\frac{2 \text{ mol } NO_3^-(aq)}{1 \text{ mol } Ca(NO_3)_2(aq)} = \frac{c}{0.085 \text{ mol/L } Ca(NO_3)_2(aq)}$$

$$2 \text{ mol } NO_3^-(aq) \times 0.085 \text{ mol/L } Ca(NO_3)_2(aq) = 1 \text{ mol } Ca(NO_3)_2(aq) \times c$$

$$c = \frac{2 \cancel{\text{mol}} NO_3^-(aq) \times 0.085 \text{ mol/L } \cancel{Ca(NO_3)_2(aq)}}{1 \text{ mol } \cancel{Ca(NO_3)_2(aq)}}$$

$$= 0.17 \text{ mol/L } NO_3^-(aq)$$

The molar concentration of the nitrate ion, $NO_3^-(aq)$, is 0.17 mol/L.

Check Your Solution
The final volume, V_2, is 4 times the initial volume, V_1. The final concentration, c_2, is about $\frac{1}{4}$ the initial concentration, c_1. The $NO_3^-(aq)$ concentration is double the concentration of $Ca(NO_3)_2(aq)$, which is consistent with the mole ratio shown in the chemical formula. The answers are reasonable and correctly show two significant digits.

56. Practice Problem (page 386)
A laboratory stockroom has a stock solution of 90% (m/v) sulfuric acid, $H_2SO_4(aq)$. If a technician dilutes 50 mL of the stock solution to a final volume of 300 mL, what will be the new mass/volume percent concentration? **Hint:** The dilution formula can be used for concentration expressed in any units, provided that the units remain the same.

What Is Required?
You need to determine the percent (m/v) concentration, c_2, of a solution prepared by dilution.

What Is Given?
You know the percent (m/v) concentration of a concentrated stock solution of sulfuric acid: c_1 = 90%
You know the initial volume of the concentrated stock solution: V_1 = 50 mL
You know the final volume of the diluted sulfuric acid solution: V_2 = 300 mL

Plan Your Strategy
Write the dilution equation.
Rearrange the equation to solve for the final concentration, c_2.
Substitute the data into this expression to calculate c_2.

Act on Your Strategy
Dilution equation:
$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for c_2:
$$c_1V_1 = c_2V_2$$
$$\frac{c_1V_1}{V_2} = \frac{c_2\cancel{V_2}}{\cancel{V_2}}$$
$$c_2 = \frac{c_1V_1}{V_2}$$

Substitution to solve for c_2:
$$\begin{aligned} c_2 &= \frac{c_1V_1}{V_2} \\ &= \frac{90\%\ (\text{m/v}) \times 50\ \cancel{\text{mL}}}{300\ \cancel{\text{mL}}} \\ &= 15\%\ (\text{m/v}) \end{aligned}$$

The concentration of the diluted solution of sulfuric acid is 15% (m/v).

Check Your Solution
The concentration should change in the same proportion as the change in volume. The answer is reasonable and correctly shows two significant digits.

57. Practice Problem (page 386)

What volume of 1.25 mol/L potassium iodide solution can you make with 125 mL of 3.00 mol/L potassium iodide solution?

What Is Required?

You need to calculate the final volume, V_2, of a diluted potassium iodide solution, KI(aq).

What Is Given?

You know the final concentration of the potassium iodide solution:
$c_2 = 1.25$ mol/L
You know the initial volume and concentration of the concentrated potassium iodide solution:
$V_1 = 125$ mL
$c_1 = 3.00$ mol/L

Plan Your Strategy

Convert the volume of solution from millilitres to litres: 1 mL = 1×10^{-3} L
Write the dilution equation.
Rearrange the equation to solve for the final volume, V_2, of KI(aq).
Substitute the data into the equation to calculate V_2.

Act on Your Strategy

Volume conversion:

$$\begin{aligned} V_1 &= 125 \cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\cancel{\text{mL}} \\ &= 0.125 \text{ L} \end{aligned}$$

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for V_2:

$$c_1V_1 = c_2V_2$$

$$\frac{c_1V_1}{c_2} = \frac{\cancel{c_2}V_2}{\cancel{c_2}}$$

$$V_2 = \frac{c_1V_1}{c_2}$$

Substitution to solve for V_2:

$$V_2 = \frac{c_1V_1}{c_2}$$

$$= \frac{3.00\ \cancel{\text{mol/L}} \times 0.125\ \text{L}}{1.25\ \cancel{\text{mol/L}}}$$

$$= 0.300\ \text{L}$$

The final volume of potassium iodide solution that you can make is 0.300 L.

Check Your Solution

The final volume, V_2, is about 2.5 times the initial volume, V_1. The final concentration, c_2, is about 0.4 times the initial concentration, c_1. The answer seems reasonable and correctly shows three significant digits.

58. Practice Problem (page 386)

Hydrochloric acid is available as a stock solution with a concentration of 10 mol/L. If you need 1.0 L of 5.0 mol/L hydrochloric acid, what volume of stock solution should you measure out? Approximately how much distilled water will you need to make the dilution?

What Is Required?

You need to calculate the initial volume, V_1, of hydrochloric acid, $HCl(aq)$, stock solution required to prepare a dilute solution.

What Is Given?

You know the initial concentration of the hydrochloric acid stock solution:
$c_1 = 10$ mol/L
You know the final volume and concentration of the dilute solution:
$V_2 = 1.0$ L
$c_2 = 5.0$ mol/L

Plan Your Strategy

Write the dilution equation.
Rearrange the equation to solve for V_1.
Substitute the numbers and units for the known variables in the formula and solve for V_1.
Calculate the volume of distilled water required by subtracting the initial volume from the final volume.

Act on Your Strategy

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for V_1:

$$c_1V_1 = c_2V_2$$

$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$

$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to solve for V_1:

$$\begin{aligned} V_1 &= \frac{c_2V_2}{c_1} \\ &= \frac{5.0\ \cancel{\text{mol/L}} \times 1.0\ \text{L}}{10\ \cancel{\text{mol/L}}} \\ &= 0.50\ \text{L} \end{aligned}$$

The initial volume of hydrochloric acid stock solution required is 0.50 L.

$$\begin{aligned} \text{Amount of distilled water required} &= V_2 - V_1 \\ &= 1.0\ \text{L} - 0.50\ \text{L} \\ &= 0.50\ \text{L} \end{aligned}$$

To prepare the dilute HCl solution, add 0.50 L of acid slowly to 0.50 L of water.

Check Your Solution

The final concentration, c_2, is $\frac{1}{2}$ the initial concentration, c_1. The final volume, V_2, is 2 times the initial volume, V_1. The answer seems reasonable and correctly shows two significant digits.

59. Practice Problem (page 386)

Write a procedure you could use to make each aqueous solution using a solid solute.

a. 0.05 L of 0.25 mol/L silver nitrate, $AgNO_3(aq)$
b. 125 mL of 0.350 mol/L potassium carbonate, $K_2CO_3(aq)$
c. 4.00×10^2 mL of 0.200 mol/L potassium permanganate, $KMnO_4(aq)$

What Is Required?
You need to outline how to prepare aqueous solutions starting with solute in the solid state.

What Is Given?
You know the volume and molar concentration of the three solutions:
a. $AgNO_3(aq)$: $V = 50$ mL; $c = 0.25$ mol/L
b. $K_2CO_3(aq)$: $V = 125$ mL; $c = 0.350$ mol/L
c. $KMnO_4(aq)$: $V = 400$ mL; $c = 0.200$ mol/L

Plan Your Strategy
Step 1
Determine the mass of solute required to prepare each solution.
Convert the volume of each solution from millilitres to litres:
1 mL = 1×10^{-3} L
Calculate the amount in moles of each solute using the relationship $n = c \times V$.
Use the periodic table to find the atomic molar masses of the elements in each solute.
Multiply the atomic molar masses by the number of atoms of each element in the compound.
Add these values to calculate the molar mass of each solute.
Calculate the mass of each solute using the relationship $m = n \times M$.

Step 2
Prepare each solution.

Act on Your Strategy
Step 1:
a. silver nitrate, $AgNO_3(aq)$
Amount in moles, *n*, of solute:

$$\begin{aligned} n &= c \times V \\ &= 0.25\ \text{mol}/\cancel{\text{L}} \times 0.050\ \cancel{\text{L}} \\ &= 1.25 \times 10^{-2}\ \text{mol} \end{aligned}$$

Molar mass, *M*, of $AgNO_3(s)$:

$$M_{AgNO_3} = 1M_{Ag} + 1M_{N} + 3M_{O}$$
$$= 1(107.87\text{ g/mol}) + 1(14.01\text{ g/mol}) + 3(16.00\text{ g/mol})$$
$$= 169.88\text{ g/mol}$$

Mass, *m*, of $AgNO_3(s)$:

$$m_{AgNO_3} = n \times M$$
$$= 1.25 \times 10^{-2}\ \cancel{\text{mol}} \times 169.88\text{ g/}\cancel{\text{mol}}$$
$$= 2.1235\text{ g}$$
$$= 2.1\text{ g}$$

The mass of silver nitrate needed to prepare the solution is 2.1 g.

b. potassium carbonate, $K_2CO_3(s)$
Volume conversion :

$$\text{volume of solution} = 125\ \cancel{\text{mL}} \times 1 \times 10^{-3}\text{ L/}\cancel{\text{mL}}$$
$$= 0.125\text{ L}$$

Amount in moles, *n*, of solute:

$$n = c \times V$$
$$= 0.350\text{ mol/}\cancel{\text{L}} \times 0.125\ \cancel{\text{L}}$$
$$= 4.375 \times 10^{-2}\text{ mol}$$

Molar mass, *M*, of $K_2CO_3(s)$:

$$M_{K_2CO_3} = 2M_{K} + 1M_{C} + 3M_{O}$$
$$= 2(39.10\text{ g/mol}) + 1(12.01\text{ g/mol}) + 3(16.00\text{ g/mol})$$
$$= 138.21\text{ g/mol}$$

Mass, *m*, of $K_2CO_3(s)$:

$$m_{K_2CO_3} = n \times M$$
$$= 4.375 \times 10^{-2}\ \cancel{\text{mol}} \times 138.21\text{ g/}\cancel{\text{mol}}$$
$$= 6.0466\text{ g}$$
$$= 6.05\text{ g}$$

The mass of potassium carbonate needed to prepare the solution is 6.05 g.

c. potassium permanganate, $KMnO_4$
Volume conversion:

$$\text{volume of solution} = 4.00 \times 10^{2}\ \text{mL} \times 1 \times 10^{-3}\ \text{L/mL}$$
$$= 4.00 \times 10^{-1}\ \text{L}$$

Amount in moles, *n*, of solute:

$$n = c \times V$$
$$= 0.200\ \text{mol/L} \times 4.00 \times 10^{-1}\ \text{L}$$
$$= 8.00 \times 10^{-2}\ \text{mol}$$

Molar mass, *M*, of $KMnO_4(s)$:

$$M_{KMnO_4} = 1M_K + 1M_{Mn} + 4M_O$$
$$= 1(39.10\ \text{g/mol}) + 1(54.94\ \text{g/mol}) + 4(16.00\ \text{g/mol})$$
$$= 158.04\ \text{g/mol}$$

Mass, *m*, of $KMnO_4(s)$:

$$m_{KMnO_4} = n \times M$$
$$= 8.00 \times 10^{-2}\ \text{mol} \times 158.04\ \text{g/mol}$$
$$= 12.643\ \text{g}$$
$$= 12.6\ \text{g}$$

The mass of potassium permanganate needed to prepare the solution is 12.6 g.

Step 2:
The mass of each solute must be weighed using a balance. The solute can be weighed either onto paper or into a glass container in which the solution will be mixed. In either case, the mass of the paper or container by itself must first be determined.
Add the mass of solute that has been calculated to sufficient water to reach the total volume of solution that has been given. For dilute solutions such as those that are listed, the volume of water is very nearly the volume of the solution. However, the solute does take up a small amount of volume. For accurate work, the solution should be prepared in a volumetric flask.

Check Your Solution
The units are correct and the calculated masses of solute seem reasonable. The number of significant digits in the answers agrees with what is given in the question.

60. Practice Problem (page 386)

Outline a procedure for making each aqueous solution by diluting a stock solution.

a. 0.50 L of 1.0 mol/L sodium hydroxide, $NaOH(aq)$, using 17 mol/L sodium hydroxide

b. 150 mL of 0.300 mol/L ammonia, $NH_3(aq)$, using 6.0 mol/L ammonia

c. 1.75 L of 0.0675 mol/L ammonium bromide, $NH_4Br(aq)$, using 0.125 mol/L ammonium bromide

What Is Required?

You need to outline how to prepare aqueous solutions by diluting a concentrated solution.

What Is Given?

You know the final volume and molar concentration of the three solutions that are to be prepared. You know the initial concentration of the concentrated solution.

a. $NaOH(aq)$: $V_2 = 0.50$ L; $c_2 = 1.0$ mol/L; $c_1 = 17$ mol/L

b. $NH_3(aq)$: $V_2 = 150$ mL; $c_2 = 0.300$ mol/L; $c_1 = 6.0$ mol/L

c. $NH_4Br(aq)$: $V_2 = 1.75$ L; $c_2 = 0.0675$ mol/L; $c_1 = 0.125$ mol/L

Plan Your Strategy

Step 1

Calculate the amount (volume) of concentrated solution and the amount (volume) of water to be added.

Where necessary, convert the volume of solution from millilitres to litres: $1\text{ mL} = 1 \times 10^{-3}\text{ L}$

Write the dilution equation.

Rearrange the equation to solve for the initial volume, V_1, of concentrated solution.

Substitute the given data into the equation to calculate V_1.

Convert the calculated volumes from litres to millilitres for easier measurement: $1\text{ L} = 1 \times 10^{3}\text{ mL}$

Determine the volume of water to add to the calculated volume, V_1, of concentrated solution: $\text{volume of water} = V_2 - V_1$

Step 2

Dilute each concentrated solution.

Use either a graduated cylinder or graduated pipette to measure the volume of concentrated solution and water to be use in each dilution.

Act on Your Strategy

Step 1:

a. NaOH(aq)

Dilution equation:

$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for V_1:

$$c_1V_1 = c_2V_2$$

$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$

$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to solve for V_1:

$$\begin{aligned} V_1 &= \frac{c_2V_2}{c_1} \\ &= \frac{1.0 \cancel{\text{ mol/L}} \times 0.50 \text{ L}}{17 \cancel{\text{ mol/L}}} \\ &= 2.9411 \times 10^{-2} \text{ L} \\ &= 2.9411 \times 10^{-2} \cancel{\text{L}} \times 1 \times 10^{3} \text{ mL/}\cancel{\text{L}} \\ &= 29.411 \text{ mL} \end{aligned}$$

For dilution:

$$\begin{aligned} \text{volume of water} &= V_2 - V_1 \\ &= 500 \text{ mL} - 29.411 \text{ mL} \\ &= 471 \text{ mL} \end{aligned}$$

Step 2:

Use either a graduated cylinder or graduated pipette to measure the volume of concentrated solution and water to be used in the dilution.

To prepare the dilute solution, add 29 mL of concentrated NaOH(aq) solution to 471 mL of water.

b. NH_3(aq)

Step 1:

Volume conversion:

$$\begin{aligned} V_2 &= 150 \cancel{\text{ mL}} \times 1 \times 10^{-3} \text{ L/}\cancel{\text{mL}} \\ &= 0.150 \text{ L} \end{aligned}$$

Dilution equation:
$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for V_1:
$$c_1V_1 = c_2V_2$$
$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$
$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to solve for V_1:
$$\begin{aligned} V_1 &= \frac{c_2V_2}{c_1} \\ &= \frac{0.300\ \cancel{\text{mol/L}} \times 0.150\ \text{L}}{6\ \cancel{\text{mol/L}}} \\ &= 7.50 \times 10^{-3}\ \text{L} \\ &= 7.50 \times 10^{-3}\ \cancel{\text{L}} \times 1 \times 10^{3}\ \text{mL}/\cancel{\text{L}} \\ &= 7.50\ \text{mL} \end{aligned}$$

For dilution:
$$\begin{aligned} \text{volume of water} &= V_2 - V_1 \\ &= 150\ \text{mL} - 7.50\ \text{mL} \\ &= 142.50\ \text{mL} \\ &= 142\ \text{mL} \end{aligned}$$

Step 2:
Use either a graduated cylinder or graduated pipette to measure the volume of concentrated solution and water to be used in the dilution.
To prepare the dilute solution, add 8 mL of concentrated NH_3(aq) solution to 142 mL of water.

c. NH_4Br(aq)
Step 1:
Dilution equation:
$$c_1V_1 = c_2V_2$$

Rearranged equation to solve for V_1:

$$c_1V_1 = c_2V_2$$

$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$

$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to solve for V_1:

$$\begin{aligned} V_1 &= \frac{c_2V_2}{c_1} \\ &= \frac{0.0675\ \cancel{\text{mol/L}} \times 1.75\ \text{L}}{0.125\ \cancel{\text{mol/L}}} \\ &= 9.45 \times 10^{-1}\ \text{L} \\ &= 9.45 \times 10^{-1}\ \cancel{\text{L}} \times 1 \times 10^{3}\ \text{mL}/\cancel{\text{L}} \\ &= 945\ \text{mL} \end{aligned}$$

For dilution:

$$\begin{aligned} \text{volume of water} &= V_2 - V_1 \\ &= 1750\ \text{mL} - 945\ \text{mL} \\ &= 805\ \text{mL} \end{aligned}$$

Step 2:
Use either a graduated cylinder or graduated pipette to measure the volume of concentrated solution and water to be used in the dilution.
To prepare the dilute solution, add 945 mL of concentrated $NH_4Br(aq)$ solution to 805 mL of water.

Check Your Solution
The units and number of significant digits are correct. In each case, the volume of concentrated solution is less than the volume of dilute solution. The answers are reasonable.

Section 8.4 Preparing Solutions in the Laboratory

Solutions for Selected Review Questions

Student Edition page 390

3. Review Question (page 390)

A solution is prepared by dissolving 25.4 g of copper(II) sulfate in a 1 L volumetric flask. Determine the molar concentration of this solution.

Molar mass, *M*, of $CuSO_4$(s):

$$\begin{aligned} M_{CuSO_4} &= 1M_{Cu} + 1M_S + 4M_O \\ &= 1(63.55 \text{ g/mol}) + 1(32.07 \text{ g/mol}) + 4(16.00 \text{ g/mol}) \\ &= 159.62 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of the $CuSO_4$(s):

$$\begin{aligned} n_{CuSO_4} &= \frac{m}{M} \\ &= \frac{25.4 \not{g}}{159.62 \not{g}/\text{mol}} \\ &= 0.1591 \text{ mol} \end{aligned}$$

Molar concentration, *c*, of the $CuSO_4$(aq):

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0.1591 \text{ mol}}{1 \text{ L}} \\ &= 0.1591 \text{ mol/L} \\ &= 0.159 \text{ mol/L} \end{aligned}$$

The molar concentration of the copper(II) sulfate solution is 0.159 mol/L.

5. Review Question (page 390)

What volume of 0.250 mol/L solution could you make with 55.9 g of potassium chloride, KCl(s)?

What Is Required?

You need to calculate the volume of a potassium iodide solution.

What Is Given?

You know the concentration of the KCl(aq) solution: 0.250 mol/L

You know the mass of KCl(s): 55.9 g

Plan Your Strategy

Determine the molar mass of KCl(s).

Calculate the amount in moles of KCl(s) using the relationship $n = \frac{m}{M}$.

Write the formula for molar concentration.

Rearrange the equation to solve for the volume of solution.

Substitute the calculated amounts to determine the volume of the solution.

Act on Your Strategy

Molar mass, *M*, of KCl(s):

$$\begin{aligned} M_{\text{KCl}} &= 1M_{\text{K}} + 1M_{\text{Cl}} \\ &= 1(39.1\text{ g/mol}) + 1(34.45\text{ g/mol}) \\ &= 74.55\text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of KCl(s):

$$\begin{aligned} n_{\text{KCl}} &= \frac{m}{M} \\ &= \frac{55.9\ \cancel{\text{g}}}{74.55\ \cancel{\text{g}}\text{/mol}} \\ &= 0.74983\text{ mol} \end{aligned}$$

Formula for molar concentration:

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

Rearranged formula to solve for volume of solution:

$$\begin{aligned} V \times c &= \cancel{V} \times \frac{n}{\cancel{V}} \\ \frac{V\cancel{c}}{\cancel{c}} &= \frac{n}{c} \\ V &= \frac{n}{c} \end{aligned}$$

Substitution of calculated data to determine the volume, V, of KCl(aq):

$$V = \frac{n}{c}$$
$$= \frac{0.74983 \text{ mol}}{0.250 \text{ mol/L}}$$
$$= 2.999 \text{ L}$$
$$= 3.00 \text{ L}$$

The volume of KCl(aq) solution is 3.00 L.

Check Your Solution
The correct units have been used and the answer correctly shows three significant digits. The calculated answer seems reasonable.

6. Review Question (page 390)
Distilled water and 6.00 mol/L hydrochloric acid solution are mixed to produce 750 mL of a solution with a concentration of 2.00 mol/L. What volume of the hydrochloric acid solution is needed? Estimate the volume of water added.

What Is Required?
You need to calculate the initial volume, V_1, of HCl(aq) stock solution needed to prepare a dilute solution.

What Is Given?
You know the initial concentration of the HCl(aq) stock solution:
$c_1 = 6.00$ mol/L
You know the final volume and concentration of the dilute solution:
$V_2 = 750$ mL
$c_2 = 2.00$ mol/L

Plan Your Strategy
Use the dilution equation: $c_1V_1 = c_2V_2$
Convert the volume of dilute HCl(aq), V_2, from millilitres to litres: 1 mL = 1×10^{-3} L
Rearrange the equation to isolate the variable V_1.
Substitute the data into the equation to calculate V_1.

Act on Your Strategy
Volume conversion:

$$V_2 = 750 \text{ mL} \times 1 \times 10^{-3} \text{ L/mL}$$
$$= 0.750 \text{ L}$$

Isolation of the variable V_1:

$$c_1V_1 = c_2V_2$$

$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$

$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to calculate V_1:

$$\begin{aligned} V_1 &= \frac{c_2V_2}{c_1} \\ &= \frac{2.00\ \cancel{\text{mol/L}} \times 0.750\ \text{L}}{6.00\ \cancel{\text{mol/L}}} \\ &= 0.250\ \text{L} \end{aligned}$$

The initial volume of hydrochloric acid stock solution required is 0.250 L.
To prepare this dilute HCl solution, 0.500 L of water is needed.

Check Your Solution

The final concentration, c_2, is $\frac{1}{3}$ the initial concentration, c_1. The final volume, V_2, is 3 times the initial volume, V_1. The answer seems reasonable and correctly shows three significant digits.

7. Review Question (page 390)

What mass of sodium acetate, $NaCH_3COO(s)$, is needed to make 40.0 mL of a solution with a concentration of 1.25 mol/L?

What Is Required?

You need to find the mass of solute needed to prepare a sodium acetate solution.

What Is Given?

You know the molar concentration of the solution of $NaCH_3COO(aq)$:
1.25 mol/L
You know the volume of the solution: 40.0 mL

Plan Your Strategy
Convert the volume of the solution from millilitres to litres: 1 mL = 1×10^{-3} L
Write the formula for molar concentration.
Rearrange the expression to solve for the amount in moles.
Substitute the given data to calculate the amount in moles of $NaCH_3COO(s)$.
Determine the molar mass of the $NaCH_3COO(s)$.
Calculate the mass of the $NaCH_3COO(s)$ using the relationship $m = n \times M$.

Act on Your Strategy
Volume conversion:

$$\begin{aligned}\text{volume of solution} &= 40.0\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.0400\ \text{L}\end{aligned}$$

Formula for molar concentration:

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

Rearranged formula to solve for moles:

$$\begin{aligned}V \times c &= \cancel{V} \times \frac{n}{\cancel{V}} \\ n &= c \times V\end{aligned}$$

Amount in moles, *n*, of $NaCH_3COO(s)$:

$$\begin{aligned}n_{\text{NaCH}_3\text{COO}} &= c \times V \\ &= 1.25\ \text{mol}/\cancel{\text{L}} \times 0.0400\ \cancel{\text{L}} \\ &= 5.000 \times 10^{-2}\ \text{mol}\end{aligned}$$

Molar mass, *M*, of $NaCH_3COO(s)$:

$$\begin{aligned}M_{\text{NaCH}_3\text{COO}} &= 1M_{\text{Na}} + 2M_{\text{C}} + 3M_{\text{H}} + 2M_{\text{O}} \\ &= 1(22.99\ \text{g/mol}) + 2(12.01\ \text{g/mol}) + 3(1.01\ \text{g/mol}) + 2(16.00\ \text{g/mol}) \\ &= 82.04\ \text{g/mol}\end{aligned}$$

Mass, *m*, of the $NaCH_3COO(s)$:

$$\begin{aligned}m_{\text{NaCH}_3\text{COO}} &= n \times M \\ &= 5.000 \times 10^{-2}\ \cancel{\text{mol}} \times 82.04\ \text{g}/\cancel{\text{mol}} \\ &= 4.102\ \text{g} \\ &= 4.10\ \text{g}\end{aligned}$$

The mass of sodium acetate required to prepare the solution is 4.10 g.

Check Your Solution
The mass seems reasonable. The units have cancelled correctly and the answer correctly shows three significant digits.

8. Review Question (page 390)
A chemical company accidentally released 475 L of a 5.50 mol/L solution of a toxic compound into a nearby stream. The stream flows into a small pond. What volume of water would the pond have to contain to dilute the compound to a safe concentration of 0.35 µmol/L? (1 µmol = 10^{-6} mol)

What Is Required?
You need to calculate the volume of pond water, V_2, needed to dilute a toxic compound.

What Is Given?
You know the initial volume and concentration of the toxic substance:
$V_1 = 475$ L
$c_1 = 5.50$ mol/L
You know the final concentration of the toxin:
$c_2 = 0.35$ µmol/L

Plan Your Strategy
Use the dilution equation: $c_1V_1 = c_2V_2$
Convert the final concentration, c_2, to mol/L.
Rearrange the equation to isolate the variable, V_2, the volume of pond water.
Substitute the data into the equation to calculate V_2.

Act on Your Strategy
Concentration conversion:

$$\text{final concentration of toxin}, c_2 = 0.35\ \cancel{\mu\text{mol/L}} \times \frac{1 \times 10^{-6}\ \text{mol/L}}{1\ \cancel{\mu\text{mol/L}}}$$

$$= 3.5 \times 10^{-7}\ \text{mol/L}$$

Isolation of the variable V_2:

$$c_1V_1 = c_2V_2$$

$$\frac{c_1V_1}{c_2} = \frac{\cancel{c_2}V_2}{\cancel{c_2}}$$

$$V_2 = \frac{c_1V_1}{c_2}$$

Substitution to calculate V_2:

$$\begin{aligned} V_2 &= \frac{c_1V_1}{c_2} \\ &= \frac{5.50\ \cancel{\text{mol/L}} \times 475\ \text{L}}{3.5 \times 10^{-7}\ \cancel{\text{mol/L}}} \\ &= 7.464 \times 10^{9}\ \text{L} \\ &= 7.5 \times 10^{9}\ \text{L} \end{aligned}$$

The volume of pond water required to dilute the toxin is 7.5×10^9 L.

Check Your Solution

The final volume, V_2, is very large, as would be expected to dilute to such a low final concentration. The answer seems reasonable and correctly shows two significant digits.

11. Review Question (page 390)

A stock solution of 16 mol/L nitric acid, HNO_3(aq), is available. Describe a safe procedure for using this stock solution to make 2.0 L of 4.0 mol/L aqueous nitric acid solution.

c_1 = 16 mol/L
V_1 = ?
c_2 = 4.0 mol/L
V_2 = 2.0 L

Use the dilution equation: $c_1V_1 = c_2V_2$
Rearrange the equation to isolate the variable V_1.
Substitute the given data to solve for V_1.

Isolation of the variable V_1:

$$c_1V_1 = c_2V_2$$

$$\frac{\cancel{c_1}V_1}{\cancel{c_1}} = \frac{c_2V_2}{c_1}$$

$$V_1 = \frac{c_2V_2}{c_1}$$

Substitution to calculate V_1:

$$\begin{aligned} V_1 &= \frac{c_2V_2}{c_1} \\ &= \frac{4.00\ \cancel{\text{mol/L}} \times 2.0\ \text{L}}{16\ \cancel{\text{mol/L}}} \\ &= 0.50\ \text{L} \end{aligned}$$

Procedure:
Add 0.50 L of 16 mol/L HNO_3(aq) slowly, with stirring, to 1.5 L of water to prepare 2.0 L of the dilute solution.

12. Review Question (page 390)

Hydrogen peroxide solution, H_2O_2(aq), is available with a concentration of 1.667 mol/L. When diluted to a concentration of 0.25 mol/L, the solution is used as a disinfectant. What volume of water should be added to 100 mL of the concentrated hydrogen peroxide solution to prepare the disinfectant?

What Is Required?

You need to calculate the volume of water that must be added to a concentrated solution of H_2O_2(aq).

What Is Given?

You know the initial volume and concentration of the H_2O_2(aq):
V_1 = 100 mL
c_1 = 1.667 mol/L
You know the final concentration of the H_2O_2(aq):
c_2 = 0.25 mol/L

Plan Your Strategy

Use the dilution equation: $c_1V_1 = c_2V_2$

Convert the initial volume of $H_2O_2(aq)$ from millilitres to litres:
1 mL = 1 × 10^{-3} L

Rearrange the equation to isolate the variable V_2, the final volume of $H_2O_2(aq)$.
Substitute the data into the equation to calculate V_2.
Subtract the initial volume of concentrated $H_2O_2(aq)$ from the final volume of dilute $H_2O_2(aq)$ to determine the volume of water that must be used in this dilution.

Act on Your Strategy

Volume conversion:

$$\text{volume of concentrated } H_2O_2(\text{aq}) = 100\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} = 0.100\ \text{L}$$

Isolation of the variable V_2:

$$c_1V_1 = c_2V_2$$

$$\frac{c_1V_1}{c_2} = \frac{\cancel{c_2}V_2}{\cancel{c_2}}$$

$$V_2 = \frac{c_1V_1}{c_2}$$

Substitution to calculate V_2:

$$\begin{aligned} V_2 &= \frac{c_1V_1}{c_2} \\ &= \frac{1.667\ \cancel{\text{mol/L}} \times 0.100\ \text{L}}{0.25\ \cancel{\text{mol/L}}} \\ &= 0.6668\ \text{L} \\ &= 0.67\ \text{L} \end{aligned}$$

The volume of concentrated $H_2O_2(aq)$ solution required is 0.67 L or 670 mL. Therefore, 570 mL of water must be added to the 100 mL of concentrated $H_2O_2(aq)$ solution.

Check Your Solution

Since the concentration is diluted to about $\frac{1}{7}$ of the original concentration, the volume of the dilute solution should be about 7 times greater than that of the concentrated solution. This estimate is in agreement with the calculate value. The answer seems reasonable and correctly shows two significant digits.

14. Review Question (page 390)

Potassium hydrogen phthalate (KHP) is a solid that is used to make a standard solution, which reacts with bases. Outline a procedure for making 250.0 mL of a 0.1000 mol/L aqueous solution of KHP. The molar mass of KHP is 204.2 g/mol.

What Is Required?

You need to outline how to prepare an aqueous solution of KHP.

What Is Given?

You know the volume and the concentration of the KHP solution:
$V = 250.0$ mL
$c = 0.1000$ mol/L
You know the molar mass of KHP:
$M = 204.2$ g/mol

Plan Your Strategy

Convert the volume of KHP solution, V, from millilitres to litres: 1 mL = 1×10^{-3} L
Calculate the amount in moles of KHP using $n = c \times V$.
Calculate the mass of KHP using $m = n \times M$.
Describe how to prepare the required amount of solution.

Act on Your Strategy

Volume conversion:

$$V = 250.0\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}}$$
$$= 0.2500\ \text{L}$$

Amount in moles, n, of KHP:

$$n_{\text{KHP}} = c \times V$$
$$= 0.1000\ \text{mol}/\cancel{\text{L}} \times 0.2500\ \cancel{\text{L}}$$
$$= 0.02500\ \text{mol}$$

Mass, *m*, of KHP:

$$m_{\text{KHP}} = n \times M$$
$$= 0.02500\ \cancel{\text{mol}} \times 204.2\ \text{g}/\cancel{\text{mol}}$$
$$= 5.105\ \text{g}$$

Procedure:
Use a balance that can determine mass to one thousandth of a gram to weigh 5.105 g of KHP.
Carefully add this amount of KHP to a 250.0 mL volumetric flask. Half fill the flask with distilled water. Gently swirl the flask to dissolve the KHP. Add water up to the line indicating a volume of 250.0 mL.

Check Your Solution
The mass of KHP seems reasonable and is correctly recorded to four significant digits.