Chapter Checklist

Have you mastered the concepts, applications, and skills associated with the following items? Check them off when you are confident in your understanding.

Knowledge

explain the nature of solutions and the dissolving process (5.1, 5.2)	
illustrate how dissolving substances in water is often a prerequisite for chemical change (5.1, 5.2)	
differentiate between electrolytes and nonelectrolytes (5.1, 5.2)	
explain dissolving as an endothermic or an exothermic process with regard to breaking and forming of bonds (5.2)	
express concentration in various ways (5.3)	
perform calculations involving concentration, chemical amount, volume and/or mass (5.3)	
use dissociation equations to calculate ion concentration (5.3)	
describe the procedures and calculations required for preparing solutions from a pure solid and by dilution (5.4)	
define solubility and identify the factors that affect it (5.5)	
explain a saturated solution in terms of equilibrium (5.5)	

STS

illustrate how science and technology are developed to meet societal needs and expand human capabilities (5.1)	
describe interactions of science, technology and society (5.3, 5.5)	
relate scientific and technological work to personal and social values such as honesty, perseverance, tolerance, open-mindedness, critical-mindedness, creativity and curiosity (5.1, 5.3, 5.4, 5.5)	
illustrate how science and technology have both intended and unintended consequences (5.3, 5.5)	
evaluate technologies from a variety of perspectives (5.4, 5.5)	

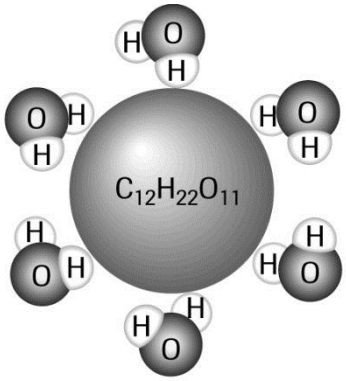
Key Terms

5.1	solution		5.3	concentration	
	solute			amount concentration	
	solvent		5.4	standard solution	
	electrolyte			stock solution	
	nonelectrolyte		5.5	saturated solution	
5.2	dissociation			solubility	
	ionization			dynamic equilibrium	

Key Skills

design laboratory procedures involving concentrations *(Inv.5.4)*	
use volumetric glassware to prepare solutions *(Inv. 5.2 and 5.3)*	

Dissolving, Dissociation, and Ionization



$C_{12}H_{22}O_{11}(s) \longrightarrow C_{12}H_{22}O_{11}(aq)$

Figure 1
This model illustrates sucrose dissolved in water. The model, showing electrically neutral particles in solution, agrees with the evidence that a sucrose solution does not conduct electricity.

Figure 2
This model represents the dissociation of sodium chloride into positive and negative ions.

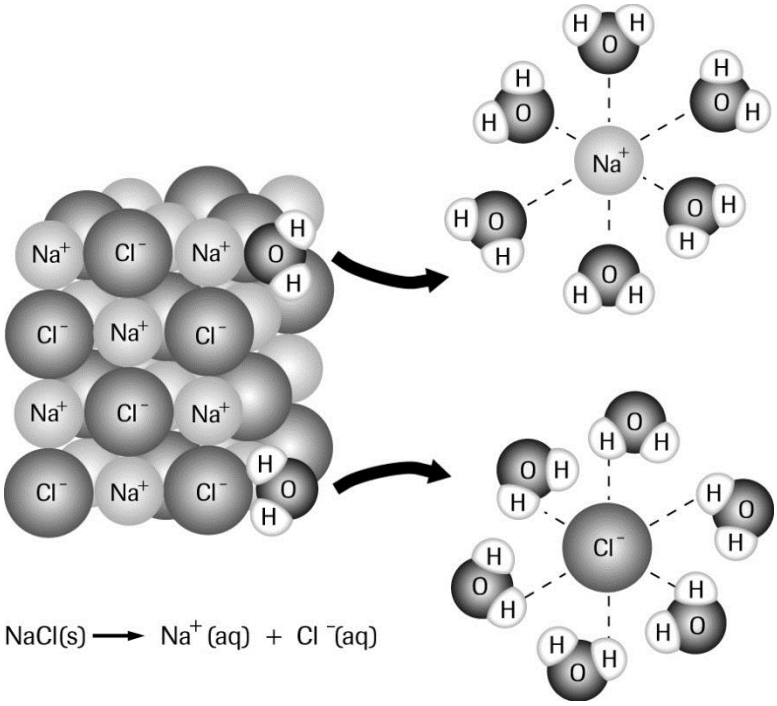


Figure 3
Draw a model to represents the ionization of CH_3COOH into positive and negative ions.

Summary: Concentration of a Solution

SUMMARY *Concentration of a Solution*

Type	Definition	Units
percentage by volume	$c = \frac{V_{\text{solute}}}{V_{\text{solution}}} \times 100\%$	% V/V (or mL/100 mL)
mass by volume	$c = \frac{m_{\text{solute}}}{V_{\text{solution}}} \times 100\%$	% W/V (or g/100 mL)
by mass	$c = \frac{m_{\text{solute}}}{m_{\text{solution}}} \times 100\%$	% W/W (or g/100 g)
parts per million	$c = \frac{m_{\text{solute}}}{m_{\text{solution}}}$	ppm (or mg/kg)
amount	$c = \frac{n_{\text{solute}}}{V_{\text{solution}}}$	mol/L

Solution Concentration

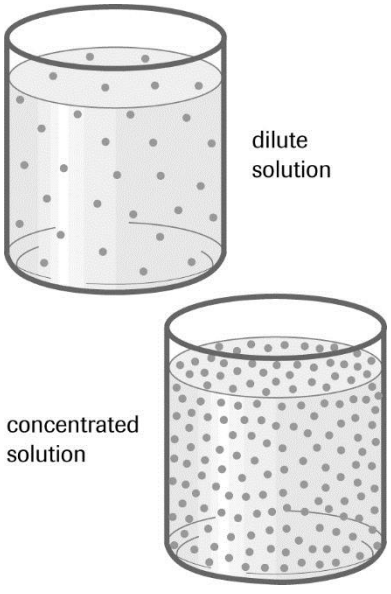


Figure 1
The theoretical model of the dilute solution shows fewer solute entities (particles) per unit volume compared with the model of the concentrated solution.

Student Worksheet
Explaining Solutions, Extra Exercises

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1. The following substances are common chemicals:
   butane, $C_4H_{10}(g)$ (lighters)
   ethanol, $C_2H_5OH(l)$ (alcoholic drinks)
   dichloromethane, $CH_2Cl_2(l)$ (solvent in correction fluid)
   (a) Classify the type(s) of intermolecular forces present among molecules of each of these substances.

   (b) Predict the solubility (low, moderate, or high) of each substance in water.

2. Why are ionic compounds highly soluble in water, compared with their solubility in any other solvent?

3. List the three features of a water molecule that make water the best solvent.

4. For each of the following substances, write the chemical formula including pure state of matter at SATP, predict the solubility (low/high) in water, and if appropriate, write a balanced dissociation equation.
   (a) silver sulfide

   (b) ammonium borate

   (c) copper(II) nitrate trihydrate

   (d) glucose, $C_6H_{12}O_6(s)$

Student Worksheet

Concentration 1, Extra Exercises

Use concentration as a conversion factor to calculate the quantity requested in each question below. Communicate your problem-solving approach, including units and correct certainty.

1. Cow's milk contains 4.5 g of lactose per 100 mL of milk. What mass of lactose is present in 250 mL (one glass) of milk?

2. A 10% W/V salt solution is used in making pickles. What mass of salt is present in 750 mL of this solution?

3. A 250 mL measuring cup of cleaning solution contains 1.2 mol of dissolved ammonia. What is the amount concentration of this solution?

4. Fish require a concentration of about 4.5 ppm (4.5 mg/L) of dissolved oxygen in water. What volume of water would contain 100 mg of oxygen?

5. What volume of concentrated 14.6 mol/L phosphoric acid would contain 2.00 mol of solute?

6. What mass of table salt is needed to prepare 1.20 L of 5.20 mol/L solution?

7. What is the amount concentration of zinc nitrate if 94.2 g of solute is dissolved to make 2.00 L of solution?

Student Worksheet

Dilution, Extra Exercises

In the following questions, "concentrated" refers to the concentration of the most common commercial reagents as listed in the table of Commercial Concentrated Reagent Solutions on the inside back cover of the textbook.

1. An ammonia solution is made by diluting 150 mL of the concentrated commercial reagent until the final volume reaches 1000 mL. What is the final amount concentration?

2. What volume of a 500 ppm reagent solution is required to prepare a 2.5 L solution with a 100 ppm concentration?

3. A 500 mL bottle of concentrated acetic acid is diluted to make a 5.0% solution. Find the volume of diluted solution that is prepared.

4. In a chemical analysis, a 25.0 mL sample was diluted to 500.0 mL and analyzed. If the diluted solution had an amount concentration of 0.108 mol/L, what was the amount concentration of the original sample?

5. If a 355 mL can of soda pop is diluted to a final volume of 1.00 L, what can be said quantitatively about the concentration of the diluted solution as compared with the original solution?

Student Worksheet Solutions

Solutions to Explaining Solutions, Extra Exercises

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1. The following substances are common chemicals:
2. butane, $C_4H_{10}(g)$ (lighters)
3. ethanol, $C_2H_5OH(l)$ (alcoholic drinks)
4. dichloromethane, $CH_2Cl_2(l)$ (solvent in correction fluid)
   (a) Classify the type(s) of intermolecular forces that are present among molecules of each of these substances.
   butane, London dispersion forces
   ethanol, London dispersion, dipole–dipole, hydrogen-bonding forces
   dichloromethane, London dispersion and dipole–dipole
   (b) Predict the solubility (low, moderate, or high) of each substance in water.
   butane, low
   ethanol, high
   dichloromethane, moderate
2. Why are ionic compounds highly soluble in water, compared with their solubility in any other solvent?
   Ionic compounds contain electrically charged ions. The very polar water molecules are able to form many attractions to both the positive and negative ions.
3. List the three features of a water molecule that make water the best solvent.
   Water molecules have a small size, are highly polar, and have a considerable capacity for hydrogen bonding.
4. For each of the following substances, write the chemical formula including pure state of matter at SATP, predict the solubility (low/high) in water, and if appropriate write a balanced dissociation equation.
   (a) silver sulfide
   $Ag_2S(s)$
   low
   (b) ammonium borate
   $(NH_4)_3BO_3(s)$
   high
   $(NH_4)_3BO_3(s) \rightarrow 3\ NH_4^+(aq) + BO_3^{3-}(aq)$
   (c) copper(II) nitrate trihydrate
   $Cu(NO_3)_2 \cdot 3H_2O(s)$
   high
   $Cu(NO_3)_2 \cdot 3H_2O(s) \rightarrow Cu_2^+(aq) + 2\ NO_3^-(aq) + 3\ H_2O(l)$
   (d) glucose, $C_6H_{12}O_6(s)$
   high

Student Worksheet Solutions

Solutions to Concentration 1, Extra Exercises

Use concentration as a conversion factor to calculate the quantity requested in each question below. Communicate your problem-solving approach, including units and correct certainty.

1. Cow's milk contains 4.5 g of lactose per 100 mL of milk. What mass of lactose is present in 250 mL (one glass) of milk?

$$m_{\text{lactose}} = 250\,\text{mL} \times \frac{4.5\,\text{g}}{100\,\text{mL}} = 11\,\text{g}$$

2. A 10% W/V salt solution is used in making pickles. What mass of salt is present in 750 mL of this solution?

$$m_{\text{NaCl}} = 750\,\text{mL} \times \frac{10\,\text{g}}{100\,\text{mL}} = 75\,\text{g}$$

3. A 250 mL measuring cup of cleaning solution contains 1.2 mol of dissolved ammonia. What is the amount concentration of this solution?

$$c_{\text{NH}_3} = \frac{1.2\,\text{mol}}{0.250\,\text{L}} = 4.8\,\text{mol/L}$$

4. Fish require a concentration of about 4.5 ppm (4.5 mg/L) of dissolved oxygen in water. What volume of water would contain 100 mg of oxygen?

$$V_{\text{H}_2\text{O}} = 100\,\text{mg} \times \frac{1\,\text{L}}{4.5\,\text{mg}} = 22\,\text{L}$$

5. What volume of concentrated 14.6 mol/L phosphoric acid would contain 2.00 mol of solute?

$$V_{\text{H}_3\text{PO}_4} = 2.00\,\text{mol} \times \frac{1\,\text{L}}{14.6\,\text{mol}} = 0.137\,\text{L}$$

6. What mass of table salt is needed to prepare 1.20 L of 5.20 mol/L solution?

$$n_{\text{NaCl}} = 1.20\,\text{L} \times \frac{5.20\,\text{mol}}{1\,\text{L}} = 6.24\ \text{L}$$

$$m_{\text{NaCl}} = 6.24\,\text{L} \times \frac{58.44\,\text{g}}{1\,\text{mol}} = 365\,\text{g}$$

7. What is the amount concentration of zinc nitrate if 94.2 g of solute is dissolved to make 2.00 L of solution?

$$n_{\text{Zn(NO}_3)_2} = 94.2\,\text{g} \times \frac{1\,\text{mol}}{189.40\,\text{g}} = 0.497\,\text{mol}$$

$$c_{\text{Zn(NO}_3)_2} = \frac{0.497\,\text{mol}}{2.00\,\text{L}} = 0.249\,\text{mol/L}$$

Student Worksheet Solutions

Solutions to Dilution, Extra Exercises

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1. An ammonia solution is made by diluting 150 mL of the concentrated commercial reagent until the final volume reaches 1000 mL. What is the final amount concentration?
   $\boldsymbol{V_i c_i = V_f c_f}$
   $\boldsymbol{150\ mL \times 14.8\ mol/L = 1000\ mL \times c_f}$
   $\boldsymbol{c_f = 2.22\ mol/L}$

2. What volume of a 500 ppm reagent solution is required to prepare a 2.5 L solution with a
   100 ppm concentration?
   $\boldsymbol{V_i c_i = V_f c_f}$
   $\boldsymbol{V_i \times 500\ ppm = 2.5\ L \times 100\ ppm}$
   $\boldsymbol{V_i = 0.50\ L}$

3. A 500 mL bottle of concentrated acetic acid is diluted to make a 5.0% solution. Find the volume of diluted solution that is prepared.
   $\boldsymbol{V_i c_i = V_f c_f}$
   $\boldsymbol{500\ mL \times 99.5\% = V_f \times 5.0\%}$
   $\boldsymbol{V_f = 10\ L}$

4. In a chemical analysis, a 25.0 mL sample was diluted to 500.0 mL and analyzed. If the diluted solution had an amount concentration of 0.108 mol/L, what was the amount concentration of the original sample?
   $\boldsymbol{V_i c_i = V_f c_f}$
   $\boldsymbol{25.0\ mL \times c_i = 500.0\ mL \times 0.108\ mol/L}$
   $\boldsymbol{c_i = 2.16\ mol/L}$

5. If a 355 mL can of soda pop is diluted to a final volume of 1.00 L, what can be said quantitatively about the concentration of the diluted solution as compared with the original solution?
   $\boldsymbol{V_i c_i = V_f c_f}$
   $\boldsymbol{0.355\ L \times c_i = 1.00\ L \times c_f}$
   $\boldsymbol{c_f = 0.355 c_i}$