A solution of iodine, I₂, in carbon tetrachloride, CCl₄, is used when iodine is needed for certain chemical tests. How much iodine must be added to prepare a 0.480 m solution of iodine in CCl₄ if 106.0 g of CCl₄ is used?

**SOLUTION**

1 **ANALYZE**

   **Given:** molality of solution = 0.480 m I₂

   **Unknown:** mass of solute

2 **PLAN**

   Your first step should be to convert the grams of solvent to kilograms. The molality gives you the moles of solute, which can be converted to the grams of solute using the molar mass of I₂.

3 **COMPUTE**

   Use the periodic table to compute the molar mass of I₂:

   \[ I₂ = 253.8 \text{ g/mol} \]

   \[ \frac{100.0 \text{ g CCl₄}}{1 \text{ kg CCl₄}} = 0.100 \text{ kg CCl₄} \]

   \[ \frac{0.480 \text{ m I₂}}{0.1 \text{ kg H₂O}} = \frac{x \text{ mol I₂}}{0.1 \text{ kg H₂O}} \]

   \[ x = \frac{100}{100} \times 0.480 = 0.480 \text{ mol I₂} \]

   \[ \frac{0.480 \text{ mol I₂}}{253.8 \text{ g/mol I₂}} = 0.122 \text{ g I₂} \]

4 **EVALUATE**

   The answer has three significant digits and the units for mass of I₂.

**PRACTICE**

1. What is the molality of a solution composed of 255 g of acetone, (CH₃)₂CO, dissolved in 200 g of water?  
   **Answer** 22 m acetone

2. What quantity, in grams, of methanol, CH₃OH, is required to prepare a 0.244 m solution in 400 g of water?  
   **Answer** 3.12 g CH₃OH

3. How many grams of AgNO₃ are needed to prepare 0.125 m solution in 250 mL of water?  
   **Answer** 5.31 g AgNO₃

4. What is the molality of a solution containing 18.2 g HCl and 250 g of water?  
   **Answer** 2.00 m

**SECTION REVIEW**

1. What quantity represents the ratio of the number of moles of solute for a given volume of solution?  
   water to make 1 L of solution. What is the concentration of this solution expressed as a molarity?

2. Five grams of sugar, C₃H₂O₁₁, are dissolved in...
**REVIEWING CONCEPTS**

1. a. What is the Tyndall effect?
   b. Identify one example of this effect.  
   c. What is a colloid, or a suspension?
   d. What is solution equilibrium?
   e. What factors determine the point at which a given solute-solvent combination reaches equilibrium?
   
2. a. What is a saturated solution?
   b. What visible evidence indicates that a solution is saturated?
   c. What is an unsaturated solution?
   d. What is meant by the solubility of a substance?
   e. What condition(s) must be specified when expressing the solubility of a substance?
   f. What rule of thumb is useful for predicting whether one substance will dissolve in another?
   g. Describe what the rule means in terms of various combinations of polar and nonpolar solutes and solvents.
   h. How does pressure affect the solubility of a gas in a liquid?
   i. What law is a statement of this relationship?
   j. If the pressure of a gas above a liquid is increased, what happens to the amount of gas that will dissolve in the liquid, if all other conditions remain constant?
   k. Two bottles of soda are opened. One is a cold bottle and the other is partially frozen. Which system will show more effervescence and why?

3. a. KNO₃ at 60°C
   b. NaCl at 50°C
   c. 40 g KCl in 100 g H₂O
   d. 100 g NaNO₃ in 100 g H₂O
   e. 50 g KNO₃ in 100 g H₂O

4. a. The heat of solution for AgNO₃ is +22.8 kJ/mol.
   b. Write the equation that represents the dissolution of AgNO₃ in water.
   c. Is the dissolution process endothermic or exothermic? Is the dissolution process endothermic or exothermic? Is it the dissolusion process endothermic or exothermic?
   d. As AgNO₃ dissolves, what change occurs in the temperature of the solution?
   e. When the system is at equilibrium, how do the rates of dissolusion and crystallization compare?
   f. If the solution is then heated, how will the rates of dissolution and crystallization be affected? Why?
   g. How will the increased temperature affect the amount of solute that can be dissolved?
   h. If the solution is allowed to reach equilibrium and is then cooled, how will the system be affected?

5. a. How does the solubility of AgNO₃ vary with the temperature of the water?
   b. Estimate the solubility of AgNO₃ at 35°C, 55°C, and 75°C.
   c. What temperature would the solubility of AgNO₃ be 275 g per 100 g of H₂O?
   d. If 100 g of AgNO₃ were added to 100 g of H₂O at 30°C, would the resulting solution be saturated or unsaturated? What would occur if 275 g of AgNO₃ were added to 100 g of H₂O at 35°C?

6. a. If a saturated solution of KNO₃ in 100 g of H₂O at 60°C is cooled to 20°C, approximately how many grams of the solute will precipitate out of the solution?

7. a. Under what circumstances might we prefer to express solution concentrations in terms of a. molarity?
   b. molality?
   c. Weight percent?
   d. How many grams of solute would be needed to make 1.00 L of a solution of 2.00 M NaCl?

8. a. How does the solubility of each of the following in grams of solute per 100 g H₂O?
   b. NaNO₃ at 10°C

9. a. How does the solubility of AgNO₃ vary with the temperature of the water?
   b. What is the molar mass of AgNO₃?
   c. What is the molarity of this solution?

10. a. Suppose you wanted to find out how many milliliters of 1.0 M AgNO₃ are needed to provide 169.88 g of pure AgNO₃.
    b. What is step 1 in solving the problem?
    c. What is the molar mass of AgNO₃?
    d. How many milliliters of solution are needed?
    e. Balance the equation:

11. a. How many milliliters of 18.0 M H₂SO₄ are required to react with 250. mL of 2.50 M Al(OH)₃, if the products are aluminum sulfate and water?
    b. 75.0 mL of an AgNO₃ solution reacts with enough Cu to produce 0.250 g of Ag by single replacement.
    c. What is the molarity of the initial AgNO₃ solution if Ca(NO₃)₂ is the other product?

12. a. Molarity 15. a. Suppose you wanted to dissolve 40.0 g NaOH in enough H₂O to make 6.00 L of solution.
   b. What is step 1 in solving the problem?
   c. What is the molar mass of NaOH?
   d. What is the molarity of this solution?
   e. What is the molarity of a solution of 14.0 g NH₄Br in enough H₂O to make 150 mL of solution?
   f. a. Suppose you wanted to produce 1.00 L of a 3.50 M solution of H₂SO₄
   g. What is the solute?
   h. What is the solvent?
   i. How many grams of solute are needed to make this solution?
   j. How many grams of solute are needed to make 2.50 L of a 1.75 M solution of Ba(NO₃)₂?
   k. How many moles of NaOH are contained in 65.0 mL of a 2.20 M solution of NaOH in H₂O? (Hint: See Sample Problem 13-2.)
   l. A solution is made by dissolving 26.42 g of (NH₄)₂SO₄ in enough H₂O to make 50.00 mL of solution.
   m. What is the molar mass of (NH₄)₂SO₄?
   n. What are the products of the solution?
   o. What is the molarity of this solution?

13. a. Suppose you wanted to find out how many milliliters of 1.0 M AgNO₃ are needed to provide 169.88 g of pure AgNO₃.
   b. What is step 1 in solving the problem?
   c. What is the molar mass of AgNO₃?
   d. How many milliliters of solution are needed?
   e. Balance the equation:

14. a. How many milliliters of 18.0 M H₂SO₄ are required to react with 250. mL of 2.50 M Al(OH)₃, if the products are aluminum sulfate and water?
    b. 75.0 mL of an AgNO₃ solution reacts with enough Cu to produce 0.250 g of Ag by single replacement.
    c. What is the molarity of the initial AgNO₃ solution if Ca(NO₃)₂ is the other product?

15. a. Molarity
    b. Suppose you wanted to dissolve 294.3 g H₂SO₄ in 1.00 kg H₂O.
    c. (1) What is the solute?
    d. (2) What is the solvent?
    e. (3) What is the molarity of this solution?
    f. What is the molarity of a solution of 63.0 g HNO₃ in 0.250 kg H₂O?
    g. a. Suppose you wanted to produce 1.00 L of a 3.50 M solution of H₂SO₄
    h. (1) What is the solute?
    i. (2) What is the solvent?
    j. (3) How many grams of solute are needed to make this solution?
    k. How many grams of solute are needed to make 2.50 L of a 1.75 M solution of Ba(NO₃)₂?
    l. How many moles of NaOH are contained in 65.0 mL of a 2.20 M solution of NaOH in H₂O? (Hint: See Sample Problem 13-2.)
    m. A solution is made by dissolving 26.42 g of (NH₄)₂SO₄ in enough H₂O to make 50.00 mL of solution.
    n. What is the molar mass of (NH₄)₂SO₄?
    o. What are the products of the solution?
    p. What is the molarity of this solution?

16. a. Suppose you wanted to find out how many milliliters of 1.0 M AgNO₃ are needed to provide 169.88 g of pure AgNO₃.
   b. What is step 1 in solving the problem?
   c. What is the molar mass of AgNO₃?
   d. How many milliliters of solution are needed?
   e. Balance the equation:

17. a. How many milliliters of 18.0 M H₂SO₄ are required to react with 250. mL of 2.50 M Al(OH)₃, if the products are aluminum sulfate and water?
    b. 75.0 mL of an AgNO₃ solution reacts with enough Cu to produce 0.250 g of Ag by single replacement.
    c. What is the molarity of the initial AgNO₃ solution if Ca(NO₃)₂ is the other product?
MIXED REVIEW

28. Na₂SO₄ is dissolved in water to make 450 mL of a 0.250 M solution.
   a. What is the molar mass of Na₂SO₄?
   b. How many moles of Na₂SO₄ are needed?

29. Citric acid is one component of some soft drinks. Suppose that a 2 L solution is made from 150 mg of citric acid, C₆H₈O₇.
   a. What is the molar mass of citric acid?
   b. What products are produced once the soft drink is opened?
   c. Would increasing the concentration of citric acid decrease the bubbling?
   d. What is the molarity of citric acid in the solution?

30. Suppose you wanted to know how many grams of KCl would be left if 350 mL of a 6.0 M KCl solution were evaporated to dryness.
   a. What is the molar mass of KCl?
   b. How would heating the solution affect the mass of KCl remaining?
   c. How many grams of KCl would remain?

31. Sodium metal reacts violently with water to form NaOH and release hydrogen gas. Suppose that 10.0 g of Na react completely with 1.00 L of water, and the final volume of the system is 1 L.
   a. What is the molar mass of NaOH?
   b. Write a balanced equation for the reaction.
   c. What is the molarity of the NaOH solution formed by the reaction?

32. In cars, ethylene glycol, C₂H₄O₂, is used as a coolant and antifreeze. A mechanic fills a radiator with 6.5 kg of ethylene glycol and 1.5 kg of water.
   a. What is the molar mass of ethylene glycol?
   b. What is the molality of the water in the solution?

CRITICAL THINKING

33. Predicting Outcomes You have been investigating the nature of suspensions, colloids, and solutions and have collected the following observational data on four unknown samples. From the data, infer whether each sample is a solution, suspension, or colloid.

DATA TABLE 1 — SAMPLES

<table>
<thead>
<tr>
<th>Sample</th>
<th>Color</th>
<th>Clarity (clear or cloudy)</th>
<th>Settle out</th>
<th>Tyndall effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>green</td>
<td>clear</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>blue</td>
<td>cloudy</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>3</td>
<td>colorless</td>
<td>clear</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>white</td>
<td>clear</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

DATA TABLE 2 — FILTRATE OF SAMPLES

<table>
<thead>
<tr>
<th>Sample</th>
<th>Color</th>
<th>Clarity (clear or cloudy)</th>
<th>On filter paper</th>
<th>Tyndall effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>green</td>
<td>clear</td>
<td>nothing</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>blue</td>
<td>cloudy</td>
<td>gray solid</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>colorless</td>
<td>cloudy</td>
<td>none</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>white</td>
<td>white</td>
<td>solid</td>
<td>no</td>
</tr>
</tbody>
</table>

Based on your inferences in Data Table 1, you decide to conduct one more test of the particles. You filter the samples and then reexamine the filtrate. You obtain the data found in Data Table 2. Infer the classifications based on the data in Table 2.

HANDBOOK SEARCH

   a. Why is aluminum such an important component of alloys?
   b. What metals make up bronze?
   c. What metals make up brass?
   d. What is steel?
   e. What is the composition of the mixture called cast iron?

36. Table 5A of the Elements Handbook contains carbon monoxide concentration data expressed as parts per million (ppm). The OSHA (Occupational Safety and Health Administration) limit for worker exposure to CO is 200 ppm for an eight-hour period.
   a. At what concentration do harmful effects occur in less than one hour?
   b. By what factor does the concentration in item (a) exceed the maximum limit set by OSHA?

TECHNOLOGY & LEARNING

34. Graphing Calculator Predicting Solubility from Tabular Data

The graphing calculator can run a program that estimates data such as solubility at a given temperature. Given solubility measurements for KCl, you will use the data to predict its solubility at 50°C. Begin by creating a table of data. Then the program will carry out an extrapolation. The last step will involve solubility predictions.

Go to Appendix C. If you are using a TI-83 Plus, you can download the program and data and run the application as directed. If you are using another calculator, your teacher will provide you with keystrokes and data sets to use. Remember that after creating your lists, you will need to name the program and check the display, as explained in Appendix C. You will then be ready to run the program. After you have graphed the data, answer these questions.

RESEARCH & WRITING

37. Find out about the chemistry of emulsifying agents. How do these substances affect the dissolution of immiscible substances such as oil and water? As part of your research on this topic, find out why eggs are an emulsifying agent for baking mixtures.

ALTERNATIVE ASSESSMENT

38. Make a comparison of the electrolyte concentration in various brands of sports drinks. Using the labeling information for sugar, calculate the molarity of sugar in each product or brand. Construct a poster to show the results of your analysis of the product labels.

39. Write a set of instructions on how to prepare a solution that is 1 M CuSO₄ using CuSO₄·5H₂O as the solute. How do the instructions differ if the solute is anhydrous CuSO₄? Your instructions should include a list of all materials needed.