Concentration of Solutions

The **concentration** of a solution is the amount of solute in a given amount of solvent or solution. Concentration may be described qualitatively using the words *concentrated* or *dilute*. In general, a concentrated solution contains a large amount of solute. Conversely a dilute solution contains a small amount of solute.

Expressing Concentration

The concentration of a solution may also be expressed quantitatively. Some commonly used quantitative descriptions are percent by mass, percent by volume, molarity, and molality. Each of these expresses the concentration as a ratio of measured amounts of solute and solvent.

Percent by mass usually describes solutions in which a solid is dissolved in a liquid.

$$percent\ by\ mass = \frac{mass\ of\ solute}{mass\ of\ solution} \times 100$$

Example 1
In order to maintain a sodium chloride ($NaCl$) concentration similar to ocean water, an aquarium must contain $3.6\ g\ NaCl$ per $100.0\ g$ of water. What is the percent by mass of sodium chloride in the solution?

Percent by volume usually describes solutions in which both solute and solvent are liquids.

$$percent\ by\ volume = \frac{volume\ of\ solute}{volume\ of\ solution} \times 100$$

Example 2
Rubbing alcohol is a solution of isopropyl alcohol in water. What is the percent by volume of isopropyl alcohol in a solution that contains $700\ mL$ of isopropyl alcohol and $300\ mL$ of water?

One of the most common units of solution concentration is molarity. **Molarity** (M) is the number of moles of solute dissolved per liter of solution. Molarity is also known as molar concentration. The unit M is read as molar. Thus, a liter of solution containing one mole of solute is a $1M$ solution, which is read as a one molar solution.

$$molarity(M) = \frac{moles\ of\ solute}{liters\ of\ solution}$$

Example 3
A $100.5\ mL$ intravenous (IV) solution contains $5.10\ g$ of glucose ($C_6H_{12}O_6$). What is the molarity of this solution? The molar mass of glucose is $180.16\ g/mol$.

The volume of a solution changes with temperature as it expands or contracts. This change in volume changes the molarity of the solution. Mass, however, does not change with temperature. Because of this, it is sometimes more useful to describe solutions in terms of how many moles of solute are dissolved in a specific mass of solute.

The ratio of the number of moles of solute dissolved in one kilogram of solvent is called the **molality**.

$$molality(m) = \frac{moles\ of\ solute}{kilograms\ of\ solvent}$$

The unit of molality is moles per kilogram.

Example 4
In the lab, a student adds $4.5\ g$ of sodium chloride ($NaCl$) to $100\ g$ of water. Calculate the molality of the solution.

Diluting Solutions

In the laboratory, we normally use concentrated solutions of standard molarities called stock solutions. For example, concentrated hydrochloric acid (HCl) is $12M$. A less concentrated solution can be prepared by adding more solvent to the stock solution. The process of adding solvent to a solution in order to reduce its concentration is known as **dilution**.

The following equation can be used to determine how much solvent to add to a stock solution in order to dilute it.

$$M_1V_1 = M_2V_2$$

M_1 and V_1 represent the molarity and volume of the stock solution and M_2 and V_2 represent the molarity and volume of the dilute solution.

Example 5
What volume, in milliliters of $2.00M$ calcium chloride ($CaCl_2$) stock solution would you use to make $0.50\ L$ of $0.300M$ calcium chloride solution?

Concentration Worksheet

1. What is the percent by mass of $NaHCO_3$ in a solution containing $20\ g\ NaHCO_3$ dissolved in $600\ mL\ H_2O$?

2. You have $1500.0\ g$ of a bleach solution. The percent by mass of the solute sodium hypochlorite, $NaOCl$, is 3.62%. How many grams of $NaOCl$ are in the solution?

3. In question 2, how many grams of solvent are in the solution?

4. What is the percent by volume of ethanol in a solution that contains $35\ mL$ of ethanol dissolved in $115\ mL$ of water?

5. If you have $100.0\ mL$ of a 30.0% aqueous solution of ethanol, what volumes of ethanol and water are in the solution?

6. What is the percent by volume of isopropyl alcohol in a solution that contains $24\ mL$ of isopropyl alcohol in $1.1\ L$ of water?

7. What is the molarity of an aqueous solution containing $40.0\ g$ of glucose ($C_6H_{12}O_6$) in $1.5\ L$ of solution?

8. What is the molarity of a bleach solution containing $9.5\ g$ of $NaOCl$ per liter of bleach?

9. Calculate the molarity of $1.60\ L$ of a solution containing $1.55\ g$ of dissolved KBr.

10. How many grams of $CaCl_2$ would be dissolved in $1.0\ L$ of a $0.10M$ solution of $CaCl_2$?

11. A liter of $2M\ NaOH$ solution contains how many grams of $NaOH$?

12. How many grams of $CaCl_2$ should be dissolved in $500.0\ mL$ of water to make a $0.20M$ solution of $CaCl_2$?

13. How many grams of $NaOH$ are in $250\ mL$ of a $3.0M\ NaOH$ solution?

14. What is the molality of a solution containing $10.0\ g\ Na_2SO_4$ dissolved in $1000\ g$ of water?

15. What is the molality of a solution containing $30\ g$ of naphthalene ($C_{10}H_8$) dissolved in $500\ g$ of toluene?

16. What volume of a $3.00M\ KI$ stock solution would you use to make $0.300\ L$ of a $1.25M\ KI$ solution?

17. How many milliliters of a $5.0M\ H_2SO_4$ stock solution would you need to prepare $100.0\ mL$ of $0.25M\ H_2SO_4$?

18. If you dilute $20.0\ mL$ of a $3.5M$ solution to make $100.0\ mL$ of solution, what is the molarity of the dilute solution?

Answers

1. 3%
2. $54.3\ g$
3. $1445.7\ g$
4. 23%
5. ethanol: $30.0\ mL$, water: $70.0\ mL$
6. 2.1%
7. $0.148M$
8. $0.128M$
9. $8.13\times10^{-3}M$
10. $11\ g$
11. $80\ g$
12. $11\ g$
13. $30.\ g$
14. $0.0704\ mol/kg$
15. $0.468\ mol/kg$
16. $125\ mL$
17. $5.0\ mL$
18. $0.70M$