Chemistry 20

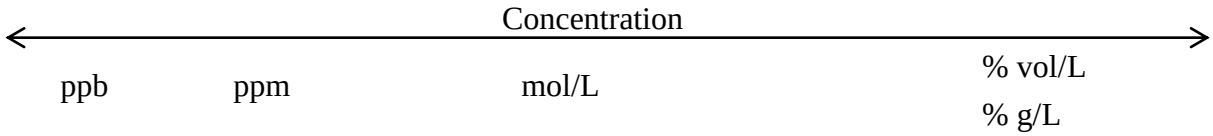
Lesson 16 – Concentration

I. Concentration

Concentration (c) is a measure of the amount of solute in a given amount of solution. (See pages 203 to 210 in *Nelson* Chemistry.) Generally:

$$c = \frac{\text{amount of solute}}{\text{amount of solution}}$$

Solutions can have a tremendous range of concentrations, from **dilute** solutions (small amount of solute relative to solvent) to **concentrated** solutions (large amount of solute relative to solvent). With such a range, there are many ways to state concentration:



The following equations may be used for calculating concentration (c) in different contexts:

% by mass $c = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$ or $c = \frac{m_{solute}}{m_{solution}} \times 100\%$ (unit is %)

% by volume $c = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$ or $c = \frac{v_{solute}}{v_{solution}} \times 100\%$ (unit is %)

ppm (parts per million) $c = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$ or $c = \frac{m_{solute}}{m_{solution}} \times 10^6$ (unit is ppm)

The main equation that we will be working with is **molar concentration** or **amount concentration**.

molar concentration $c = \frac{\text{moles of solute}}{\text{litres of solution}}$ or $c = \frac{n}{v}$ (unit is mol/L)

II. Examples

Example 1

If 5.0 g of salt is mixed with 50.0 g of water, what is the percent by mass?

$$c = \frac{m_{solute}}{m_{solution}} \times 100\%$$

$$c = \frac{5.0g}{5.0g + 50.0g} \times 100\%$$

$$c = \mathbf{9.1\%}$$

Example 2

How many grams of fat are in a 90 g serving of cereal if the percent by mass is 15%?

$$c = \frac{m_{solute}}{m_{solution}} \times 100\%$$

$$c = \frac{m_{fat}}{m_{cereal}} \times 100\%$$

$$m_{fat} = \frac{c}{100} \times m_{cereal}$$

$$m_{fat} = \frac{15}{100} \times 90g$$

$$m_{fat} = \mathbf{14g}$$

Example 3

What is the percent volume for a solution where 50 mL of methanol is added to water to produce 0.350 L of solution?

$$c = \frac{v_{solute}}{v_{solution}} \times 100\%$$

$$c = \frac{50mL}{350mL} \times 100\%$$

$$c = \mathbf{14\%}$$

Example 4

Water hardness is a measure of the calcium ion concentration. The hardness of Calgary water is rated at 165 ppm. What mass of calcium ions is found in one cubic meter (1000 kg) of Calgary water?

$$c = \frac{m_{solute}}{m_{solution}} \times 10^6$$

$$m_{solute} = \frac{c}{10^6} \times m_{solution}$$

$$m_{solute} = \frac{165}{10^6} \times 1000kg$$

$$m_{solute} = \mathbf{165g}$$

Example 5

0.50 mol of KCl is dissolved to produce 250 mL of solution. What is the molar concentration?

$$c = \frac{n}{v} = \frac{0.50\text{mol}}{0.250\text{L}}$$

$$c = \mathbf{2.0}\ \text{mol/L}$$

Example 6

How many moles of potassium permanganate are found in 200 mL of a 0.0010 mol/L solution?

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

$$n = c\ v$$

$$n = 0.0010\ \text{mol/L}\ (0.200\text{L})$$

$$n = \mathbf{0.00020\ mol}$$

Example 7

What is the molar concentration if 14.8 g of potassium chloride is dissolved to make 175 mL of solution?

$$M_{KCl} = 74.55\ \text{g/mol}$$

$$n = \frac{m}{M} = \frac{14.8\text{g}}{74.55\ \text{g/mol}}$$

$$n = 0.19852\ \text{mol}$$

$$c = \frac{n}{v} = \frac{0.19852\text{mol}}{0.175\text{L}}$$

$$c = \mathbf{1.13}\ \text{mol/L}$$

III. Assignment

1. Extra-strength pickling vinegar is labelled 7% acetic acid by volume. What volume of pure solute is in a 250 mL cup of pickling vinegar?
2. The brine (sodium chloride) solution in a home water-softening, system has a salt concentration of 25% W/V. What mass of salt is dissolved if the brine tank holds 50 L of solution?
3. If the average concentration of PCBs (polychlorinated biphenyl compounds) in the body tissue of a human is 4.0 ppm, what mass of PCBs is present in a 64 kg person?
4. A typical household ammonia solution has a concentration of 1.24 mol/L. What volume of this solution would contain 0.500 mol of NH_3?
5. Calculate the parts per million concentration of fluoride ion in a 600 g water sample that contains 0.750 mg of fluoride.
6. In studies of air quality, the air is monitored for a variety of contaminants, including sulphur dioxide, $SO_{2\ (g)}$. Calculate the parts per million of sulphur dioxide present in a 1500 g air sample that contains 0.013 g of sulphur dioxide.

7. A culture medium used to grow specific types of bacteria contains 0.0050 g of adenine per 500 g of solution. Calculate the parts per million of adenine in the medium solution.

8. The sodium ion content in a bottle of mineral water is 34 ppm. If there is 300 g of mineral water in the bottle, how many grams of sodium ions are present?

9. Calculate the molar concentration of 250 mL of a solution containing 0.243 mol of potassium hydroxide.

10. Calculate the molar concentration of a cleaning solution if 50.0 mL of the solution contains 3.05 g of sodium hydroxide.

11. Calculate the molar concentration of a pickling brine containing 235 g of sodium chloride in 3.0 L of pickling solution.

12. Calculate the molar concentration of a fertiliser solution if 500.0 mL of the solution contains 1.84 g of copper (II) sulphate,

13. When the water was evaporated from 25.0 mL of calcium chloride solution, 1.24 g of solid salt remained. Calculate the molar concentration of the solution.

14. What mass of sodium hydrogen sulphate is required to prepare 500.0 mL of a 0.200 mol/L solution of hydrogen sulphate, to be used as a cleaning agent?

15. How many grams of sodium phosphate are required to prepare 200 mL of a 0.12 mol/L cleaning solution?

16. A fertiliser solution used in a greenhouse must have a potassium oxide concentration of 0.0017 mol/L. What mass of potassium oxide is required to make 20 L of fertiliser?

17. Seawater contains 0.055 mol/L of magnesium ions. Calculate the mass of magnesium ions in 50.0 L of seawater.

18. Hard water contains dissolved calcium ions. If a 45 L container of water has a calcium ion concentration of 0.0150 mol/L, how many grams of calcium are in the container?

19. Commercial concentrated sulphuric acid has a concentration of 18.0 mol/L. What volume of sulphuric acid contains 250 g of hydrogen sulphate?

20. Commercial sodium hydroxide has a concentration of 19.4 mol/L sodium hydroxide. How many millilitres of sodium hydroxide solution can be prepared from 59 g of sodium hydroxide?

21. The concentration of hydrochloric acid in gastric juice is approximately 8.0×10^{-2} mol/L. What volume of stomach acid contains 5.0 g of hydrogen chloride?

22. What volume of mineral water containing 0.015 ppm arsenic, $As^{3+}_{(aq)}$, would have to be consumed to ingest 1.0 mg of arsenic. Assume the density of mineral water is 1.0 g/mL.

23. Vinegar contains 0.83 mol/L acetic acid. (a) What volume of vinegar would you have to consume in order to have eaten 1.0 g of acetic acid? (b) If the average volume of vinegar used on a plate of French fries is 8.0 mL, how many grams of acetic acid are consumed?