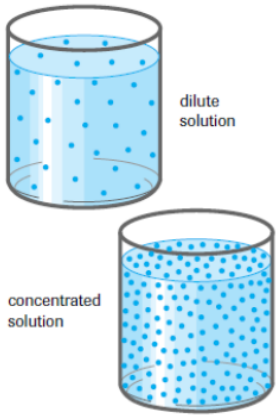
Topic 2 – Understanding Concentration of Solutions

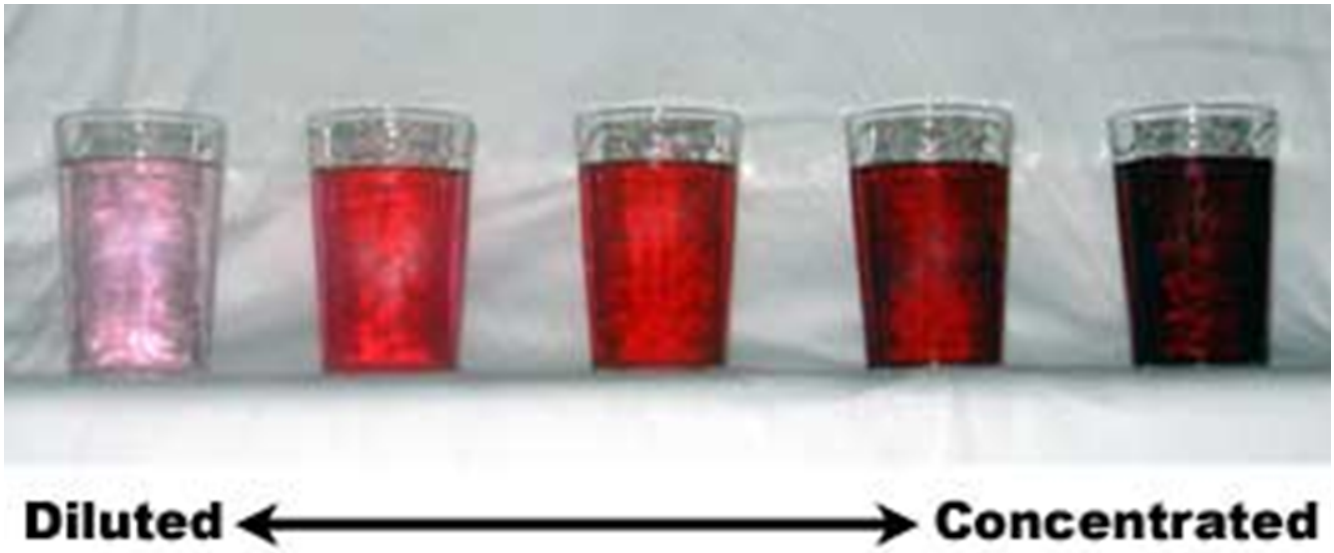


- Concentration is the **<u>ratio of the quantity of the solute to the quantity of the solution</u>**

$$\text{concentration} = \frac{\text{quantity of solute}}{\text{quantity of solution}}$$

- **<u>Dilute</u>** solution – relatively small quantity of solute when compared to the volume of solution

- **<u>Concentrated</u>** solution – relatively large quantity of solute when compared to the volume of solution



- Concentration can be expressed in a number of different ways. We will learn:

  - Percentage concentration
    - Percentage by volume
    - Percentage weight by volume
    - Percentage weight by weight
  - Parts per million concentration
  - Amount concentration (molarity)

Percentage Concentration

Percentage by Volume (% V/V)

$$c = \frac{V_{solute}}{V_{solution}} \times 100$$

units for volume must be the SAME

Example: 150mL of acetic acid solution contains 4.5mL of pure acetic acid. What is the percent by volume concentration of acetic acid.

$$C: \frac{4.5mL}{150mL} \times 100$$

$$= 3.0\% \text{ v/v}$$

Percentage Weight by Volume (% W/V)

mass in grams

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

in mL

Example: 2.0g of hydrogen peroxide is dissolved to make 75mL of solution. What is the percentage weight by volume concentration?

$$\%\ w/v: \frac{2.0g}{75mL} \times 100$$

$$: 2.7\%\ \underline{w/v}$$

Percentage Weight by Weight (% W/W)

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

units must be the SAME

Ex: A iron stake has a mass of 2.25 kg. If the stake contains 2000 g of iron, what is the %W/W of iron in the stake?

$$\%\ w/w: \frac{2.000kg}{2.25kg} \times 100$$

$$: 88.9\%\ w/w$$

Parts Per Million (ppm) Concentration

- Very low concentrations of solutes are often studied. We use ppm to report these very small concentrations.

$$c = \frac{m_{solute}\,(mg)}{V_{solution}(L)}$$

$$ppm = \frac{mg}{L}$$

For example 11 ppm of chlorine in pool water means there is 11 mg of chlorine in every liter of pool water.

$$11\,ppm = \frac{11\,mg}{1L}$$

Ex. If there is 1.0 mg of chlorine in every 250 mL of tap water, what is the parts per million concentration?

$$c = \frac{1.0\,mg}{0.250\,L} = 4.0\,ppm \text{ or } 4.0\,mg/L$$

Table 1 Maximum Acceptable Concentration (MAC) of Chemicals in Canadian Drinking Water

Substance	Typical source	MAC (ppm)
cadmium	batteries in landfills	0.005
lead	old plumbing	0.010
nitrates	fertilizers	45.0
cyanides	mining waste	0.2

Amount Concentration (molarity)

- Amount refers to the number of moles of a substance
  - **Does not** refer to mass or volume of a substance

- Amount concentration is the number of moles of solute dissolved in one liter of solution.

$$n = \frac{m}{M}$$

- This will be the major method used to determine concentration

amount concentration = **chemical amount of solute (in moles)** / **volume of solution (in liters)**

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

- Units for amount concentration is mol/L

Ex. 0.450 mol of copper (II) nitrate is dissolved to make 500 mL of solution. What is the molar concentration of the solution?

amount

$$c = \frac{n}{v} = \frac{0.450\,mol}{0.500\,L} = 0.900\,\frac{mol}{L}$$

1. Gasohol, a solution of ethanol and gasoline, is considered to be a cleaner fuel than gasoline alone. A typical gasohol mixture available across Canada contains 4.1 L of ethanol in a 55 L tank of fuel. Calculate the percentage by volume concentration of ethanol.

$$\%\ v/v = \frac{4.1\ L}{55\ L} \times 100 = 7.4545\ldots = 7.5\%\ v/v$$

2. Solder flux, available at hardware and craft stores, contains 16 g of zinc chloride in 50 mL of solution. The solvent is aqueous hydrochloric acid. What is the percentage weight by volume of zinc chloride in the solution?

$$\%\ w/v = \frac{16\ g}{50\ mL} \times 100 = 32\%\ w/v \qquad \frac{32\ g}{100\ mL}$$

3. Brass is a copper–zinc alloy. If the concentration of zinc is relatively low, the brass has a golden colour and is often used for inexpensive jewellery. If a 35.0 g pendant contains 1.7 g of zinc, what is the percentage weight by weight of zinc in this brass?

$$\%\ w/w = \frac{1.7\ g}{35.0\ g} \times 100 = 4.857\ldots = 4.9\%\ w/w$$

4. A plastic dropper bottle for a chemical analysis contains 0.11 mol of calcium chloride in 60 mL of solution. Calculate the amount concentration of calcium chloride.

$$c = \frac{n}{V} = \frac{0.11\ mol}{0.060\ L} = 1.8\ mol/L$$

5. A 300 mL ground water sample taken near a landfill reveals 32.5 mg of cadmium in the sample. What is the ppm concentration of cadmium in the water sample?

$$ppm = \frac{m}{V} = \frac{32.5\ mg}{0.300\ L} = 108\ ppm \qquad 108\ \frac{mg}{L}$$

6. Windshield washer fluid contains 250 mL of propanol mixed in every 300 mL of solution. What is the percent by volume of propanol in this solution?

$$\%\ v/v = \frac{250\ mL}{300\ mL} \times 100 = 83.3\%\ v/v$$

Example:
A bottle of hydrogen peroxide has a label which states the concentration is 3% W/V. what mass of hydrogen peroxide is present in 50mL of this solution.

$$\frac{3\,g}{100\,mL} = \frac{?\,g}{50\,mL} \qquad 1.5\,g$$

$$\%\,w/v = \frac{m}{v} \times 100 \qquad m = 1.5\,g$$

Example:
Well water in a freshly dug well contains 52ppm of calcium carbonate? What mass of calcium carbonate is present in a glass (250mL) of the well water?

$$\frac{52\,mg}{1\,L} = \frac{?\,mg}{0.250\,L}$$

$$? = 13\,mg$$

$$ppm = \frac{m}{v}$$

$$52\,ppm = \frac{m}{0.250\,L} \qquad m = 13\,mg$$

Example:
What volume of a 3.35 mol/L solution of copper (II) nitrate contains 5.00 mol of solute?

$$\frac{3.35\,mol}{1\,L} = \frac{5.00\,mol}{?\,L}$$

$$? = 1.49\,L$$

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

$$v = \frac{5.00\,mol}{3.35\,mol/L} = 1.49\,L$$

Example:
4.5 g of silver nitrate is dissolved to make 400 mL of solution. What is the amount concentration of the solution?

$$n = \frac{m}{M} = \frac{4.5\,g}{169.88\,g/mol}$$

$$= 0.02648\ldots\,mol$$

$$c = \frac{n}{v} = \frac{0.02648\ldots\,mol}{0.400\,L}$$

$$= 0.06622\ldots\,mol/L$$

$$= 0.066\,mol/L$$

Example:
A silver necklace has a total mass of 45 g. The %W/W of silver in the necklace is 95%. What mass of silver is in the necklace?

$$\frac{95\,g}{100\,g} = \frac{?\,g}{45\,g}$$

$$= 42.75\,g$$

$$= 43\,g$$

Practice Sheet 4

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?

$\frac{4.5\,g}{100\,mL} = \frac{x}{250\,mL}$ $11\,g$

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

$\frac{10\,g}{100\,mL} = \frac{x}{750\,mL}$ $x = 75\,g$

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

$C = \frac{n}{V} = \frac{1.2\,mol}{0.250\,L} = 4.8\,mol/L$

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?

$\frac{4.5\,mg}{1\,L} = \frac{100\,mg}{x\,L}$ $x = 22.2\ldots\,L$ $= 22\,L$

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

$\frac{14.6\,mol}{1\,L} = \frac{2.00\,mol}{?}$ $C = \frac{n}{V}$ $14.6\,mol/L = \frac{2.00\,mol}{V}$

$V = 0.137\,L$

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

$C = \frac{n}{V}$ $n = 6.24\,mol$

$5.20\,mol/L = \frac{n}{1.20\,L}$ $m = nM = (6.24\,mol)(58.44\,g/mol)$

$= 365\,g$

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

$Zn(NO_3)_2$ $n = \frac{m}{M} = \frac{94.2\,g}{189.43} = 0.497\ldots\,mol$

$C = \frac{n}{V} = \frac{0.497\ldots\,mol}{2.00\,L} = 0.2486\ldots\,mol/L$

$= 0.249\,mol/L$