Lesson 1 Concentration

Concentration can be expressed in many ways, as shown on the right. It is however, an amount of substance present in a given amount of sample, the units in which the sample and substance are measured in may vary.

$$\text{Concentration} = \frac{\text{amount}}{\text{Volume}}$$

$$\text{Concentration (g/L)} = \frac{\text{amount (g)}}{\text{Volume (L)}}$$

$$\%v/v = \frac{\text{amount (mL)}}{\text{volume of sample(mL)}} \times 100$$

$$\%w/v = \frac{\text{amount (g)}}{\text{volume of sample(mL)}} \times 100$$

$$\%w/w = \frac{\text{amount (g)}}{\text{mass of sample(g)}} \times 100$$

$$\text{Molarity (mol/L)} = \frac{\text{amount (mol)}}{\text{volume(L)}}$$

$$\text{ppm} = \frac{\text{amount (mg)}}{\text{volume(L)}} \quad \text{or} \quad \text{ppm} = \frac{\text{amount (mg)}}{\text{amount (kg)}}$$

For example :

- %v/v is used when one liquid substance is mixed in with another liquid. Eg: wine bottles are labelled with the concentration of ethanol clearly shown in %v/v. A concentration of 13%v/v indicates 13mL of ethanol in 100mL of wine.
- %w/v or %m/v is used to show the concentration of a solid substance present in a liquid. Eg: a 15%w/v solution of salt contains 15g of salt in 100mL of solution.
- ppm mg/L or is used to measure small quantities of air borne or water pollutants. Eg: the lead concentration of a sample of waste water is 410ppm. That means 410mg(0.41g) of lead is present in every kg of sample waste.
- Molarity (mol/L) is used to measure the concentration of chemical compounds, with a known formula, in mol/L.

Here the unit conversion is key to solving the many questions that can be asked and the ability to transform the formulae shown on the right.

Let's get straight into some examples.

1 A pure sample of NaCl was carefully weighed at 0.585g and dissolved in exactly 300 mL of water. Find the concentration of the resulting NaCl solution in: (assuming that the salt has no impact on the volume of the final solution)

- Molarity (mol/L)

Pay close attention to the units the concentration is asked for.

step 1 Find the mol of NaCl

=> n_{NaCl} = mass/Formula mass = 0.585g/ 58.5g/mol = 0.100

Step 2 divide the mol of salt by the volume (L) of water.

=> 0.100 mol / 0.300 = 0.333M

- %w/v

=> (0.580g / 300mL) X 100 = 0.193%w/v

- %w/w (assuming the density of water is 1.00 g/mL)

=> (0.580 / 300 g) X 100 = 0.193%w/v

- ppm by mass.

=> mg/L = 580 /0.300 = 193ppm =

We can transform each formula to calculate the amount of a substance or the volume of a sample depending on how the question is stated.
Example:

$$\text{Molarity (mol/L)} = \frac{\text{amount (mol)}}{\text{volume(L)}}$$

- What is the mass, in grams, of KCl in 250 mL of a 0.245M KCl?
  Step 1 Transform the formula to find the amount in mol.
  => Concentration(mol/L) X Volume(L) = mol
  => 0.245 mol/L X 0.250L = 0.06125
  Step 2 Find the mass of KCl
  => mass (g) = mol X formula mass = 0.06125 X 74.6 = 4.57g
- What volume, in mL, of a 1.32 M KCl contains exactly 23.5 g of KCl?

  Step 1 Transform the formula to find the volume in litres.
  => Volume(L) = amount(mol) / concentration(mol/L)
  Step 3 find the mol of KCl
  => 23.5g / 74.6 = 0.315 mol
  Step 4 find the volume in litres
  => Volume (L) = 0.315(mol) / 1.32 (mol / L) = 0.239L = 239 mL

- A bottle is wrongly labelled as containing 0.75M KCl. The bottle should have included the concentration in %w/v. What concentration, in %w/v, of KCl should be shown?
  => Convert 0.75mol/Litre into %w/v.
  Step 1 Convert 0.75 mol into mass of KCl in one litre of solution
- *=> mass = mol X formula mass = 0.75 X 74.6 = 55.95g*
  Step 2 Convert to %W/V
  => 55.95g exist in 1000 mL (L)
  => %w/v = (55.95/1000) X 100 = 5.595%w/v

Try the following exercises.

a) What mass of NaCl should be placed in 400 mL of pure water in order to produce a solution of NaCl with a concentration of 11.5%w/v? Assume the salt does not add to the volume of the solution.
=> mass (g) = 11.5% X volume in mL
=> mass (g) = (11.5g / 100mL) X 400 = 46.0grams

b) 13.00 mL of pure ethanol is placed in a measuring cylinder and made up to 50.0 mL with pure water. Calculate the concentration of the resulting solution in %v/v.
=> total volume = 50.0 mL
=> %v/v = (13.00mL / 50.0 mL) X 100 = 26.0%v/v

c) A bottle labelled 0.95M Na_2CO_3 is to be relabelled with the concentration in %w/v. What should the new concentration read on the new label?
=> mol of Na_2CO_3 in one litre of solution = 0.95 mol
=> mass of Na_2CO_3 in one litre of solution = 0.95 mol X 106.0 g/mol = 100.7g.
=> %w/v = (100.7g / 1000mL) X 100 =10.07% w/v

d) What is the concentration, in %w/v, of lead ions found in a 350 mL sample of waste water labelled as having a concentration of lead at 505 ppm?

=> ppm = mg/L

=> 505 = 505mg/L

=> (505g /1000mL) X 100 = 50.5%w/v

e) What volume, in litres, of solution of a 1.24 M Na_2CO_3 contains exactly 55.2 grams of Na_2CO_3?

=> mol of Na_2CO_3 = 55.2 / 106.0 = 0.521

=> V (L) = mol X concentration (mol/L)

=> V = 0.521mol X 1.24 mol/L = 0.646L = 646mL

Quiz 1 Solutions   Quiz 2 Solutions   Quiz 3 Solutions