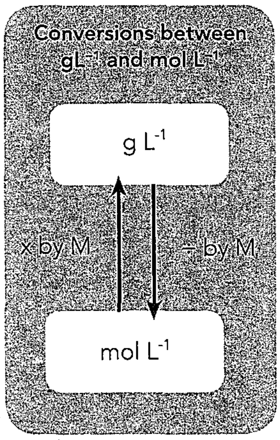
Worked Example 9.1

A solution of sodium carbonate is made up by dissolving 4.65 g of this substance to make up 250.0 mL of solution. Calculate the concentration of this solution in:
(a) moles per litre; (b) grams per litre.

(a) Firstly determine moles of solute.



$$n = \frac{m}{M} = \frac{4.65}{105.99} = 0.0439 \text{ mol}$$

Hence find concentration of Na_2CO_3 solution.

$$c = \frac{n}{V} = \frac{0.0439}{0.250} = 0.175 \text{ mol L}^{-1}$$

(b) To find concentration in g L^{-1}.

$$c = \frac{\text{mass of solute}}{\text{volume of solution}} = \frac{4.65 \text{ g}}{0.250 \text{ L}} = 18.6 \text{ g L}^{-1}$$

Worked Example 9.2

(a) The concentration of ethanoic (acetic) acid (CH_3COOH) in a sample of vinegar is 38.5 g L^{-1}. What is the concentration in mol L^{-1}?
(b) A salt solution (NaCl) has a concentration of 0.150 mol L^{-1}. What is the concentration in g L^{-1}?

(a) c (CH_3COOH) in vinegar = 38.5 g L^{-1}

$$\textit{or} \quad = \frac{38.5}{60.05} = 0.641 \text{ mol L}^{-1}$$

(b) c (NaCl) in saline solution = 0.150 mol L^{-1}

$$\textit{or} \quad = (0.150)\,(58.44) = 8.77 \text{ g L}^{-1}$$

Worked Example 9.3

The typical analysis for different spring waters varies with their source. One particular brand indicates total dissolved solids of only 80 ppm. What mass of solids would be contained in a 1.50 L bottle of this water? (Assume 1 L of spring water weighs 1 kg.)

c (solids) = 80 ppm = 80 mg per kg
$\therefore$ mass of solids = (80 mg) (1.5) = 120 mg = 0.12 g

Worked Example 9.4

A particular brand of beer contains 2.5% (w/w) alcohol (ethanol, CH_3CH_2OH). Determine:
(a) the ethanol concentration in mol L^{-1}
(b) the mass of ethanol in a 200.0 mL glass of this beer.

Assume density of the beer is 1.00 g mL^{-1}.

(a) 2.5% = 2.5 g / 100 g beer

= 25 g / 1000 mL beer (density = 1.00 g mL^{-1})

$$= \frac{25}{46.07} \quad (M_{ethanol} = 46.07 \text{ g mol}^{-1}) = 0.543 \text{ mol L}^{-1}$$

(b) mass of ethanol = 2.5 g / 100 g $\therefore$ = 5.0 g in 200 mL

Question 9.17

A solution of NaOH has a concentration of 1.75 mol L^{-1}.

(a) How many moles of NaOH would 5.0 L of this solution contain?

(b) What mass of NaOH would be needed to make up 250 mL of this solution?

Question 9.18

A 2.50 kg sample of sea water was evaporated to dryness and 86.5 g of solids remained. Further analysis showed that 73.4 g of the solids were sodium chloride (NaCl). The density of the sea water was also determined to be 1.03 g mL^{-1}.

(a) Calculate the concentration of the solids in:

(i) % by mass

(ii) ppm

(b) Calculate the concentration of NaCl in sea water in:

(i) ppm

(ii) moles per litre

Hint: You may need to use density = mass/volume to find the volume of the 2.50 kg sample of sea water.

Question 9.19

Determine the concentration in g L^{-1} and mol L^{-1} of the solute in each of the following solutions.

(a) 20.0 g of potassium nitrate (KNO_3) in 250 mL of solution.

(b) 87.7 g of alcohol (ethanol – CH_3CH_2OH) in a 750 mL bottle of wine.

(c) 75.6 g of ethanoic acid (CH_3COOH) in a 2.0 L container of vinegar.

(d) 44.5 g of sucrose ($C_{12}H_{22}O_{11}$) in a 375 mL can of soft drink.

9.15

(a)

(i) An increase in temperature increases solubility of solids.

(ii) An increase in temperature decreases solubility of gases.

(b) Yes, solubility of sugar at 50°C = 257 g/100g.
$\therefore$ 514 g would dissolve in 200 mL of water (we only put in 500 g).

(c)

(i) Crystals will appear when solution is saturated.
100 g/250 mL H_2O = 40 g/100 g H_2O
$\therefore$ occurs at $\approx$ 27°C.

(ii) saturated solution.

(iii) supersaturated solution.

9.16

(a) (i) Freezing point is lowered.
(ii) Boiling point is raised.

(b) Directly related to concentration of solute particles (mol L^{-1}), e.g. 200 g of MgF_2 has more effect than 200 g of NaCl because of the greater mol L^{-1} concentration and hence more ions in solution.

(c) Salt lowers the F.P. of water and hence the ice melts.

(d) Ethylene glycol lowers the F.P. of water and hence prevents the water in radiators from freezing in cold climates. In warm climates it allows water to reach a higher temperature before it boils.

(e) As water evaporates the remaining solution becomes more concentrated (salt does not evaporate) and hence boiling point is raised.

(f) A solute decreases the vapour pressure of a liquid, e.g. adding salt to boiling water reduces the vapour pressure of the water and hence boiling stops. At a higher temperature the vapour pressure of the water again reaches atmospheric pressure and boiling occurs.

9.17

(a) $n = cV = (1.75)(5.0) = 8.75$ mol

(b) for 250 mL of NaOH solution
$n = cV = (1.75)(0.25) = 0.4375$ mol
$m(NaOH) = nM = (0.4375)(40.0)$
$= 17.5$ g

9.18

(a)

(i) % solids (by mass)

$$= \frac{86.5}{2500} \times 100 = 3.46\%$$

(ii) $$\text{ppm} = \frac{86500 \text{ mg}}{2.50 \text{ kg}} = 34600 \text{ ppm}$$

(b)

(i) $$\text{ppm (NaCl)} = \frac{73400 \text{ mg}}{2.50 \text{ kg}} = 29360 \text{ ppm}$$

(ii) $$n\text{ (NaCl)} = \frac{m}{M} = \frac{73.4}{58.44} = 1.26 \text{ mol}$$

$$\text{Volume } H_2O = \frac{m}{\rho} = \frac{2.50}{1.03} = 2.427 \text{ L}$$

$$\therefore c\text{ (NaCl)} = \frac{n}{V} = \frac{1.25}{2.427} = 0.515 \text{ mol L}^{-1}$$

9.19

(a) $M(KNO_3) = 101.1$ g mol^{-1}

$$c = \frac{20 \text{ g}}{0.250 \text{ L}} = 80.0 \text{ g L}^{-1}$$

or $c = (80.0) \div (101.1) = 0.791$ mol L^{-1}

$$\text{or } c = \frac{n}{V} = \frac{20.0/101.1}{0.250} = 0.791 \text{ mol L}^{-1}$$

(b) $$c = \frac{87.7 \text{ g}}{0.750 \text{ L}} = 117 \text{ g L}^{-1}$$

or $c = (117) \div (46.068) = 2.54$ mol L^{-1}

$$\text{or } c = \frac{n}{V} = \frac{87.7/46.068}{0.750} = 2.54 \text{ mol L}^{-1}$$

(c) $$c = \frac{75.6 \text{ g}}{2.0 \text{ L}} = 37.8 \text{ g L}^{-1}$$

or $c = (37.8) \div (60.05) = 0.629$ mol L^{-1}

$$\text{or } c = \frac{n}{V} = \frac{75.6/60.05}{2.0} = 0.629 \text{ mol L}^{-1}$$

(d) $$c = \frac{44.5 \text{ g}}{0.375 \text{ L}} = 119 \text{ g L}^{-1}$$

or $c = (119) \div (342.3) = 0.348$ mol L^{-1}

$$\text{or } c = \frac{n}{V} = \frac{44.5/342.3}{0.375} = 0.348 \text{ mol L}^{-1}$$

9.20

(i) soluble – $Zn(NO_3)_2$, $AlCl_3$, $(NH_4)_3PO_4$ $MgSO_4$, $BaCl_2$, Na_2CO_3, $NaNO_3$, $NaCl$

(ii) slightly soluble - $PbCl_2$, $Ca(OH)_2$, $CaSO_4$, Ag_2SO_4, $PbBr_2$

(iii) insoluble - AgI, $BaSO_4$, $AgCl$, $PbSO_4$, $Mg(OH)_2$, $AgBr$

9.21

(a) No precipitate.

(b) $Zn(NO_3)_{2(aq)} + 2NaOH_{(aq)} \rightarrow Zn(OH_2)_{(s)} + 2NaNO_{3(aq)}$
$Zn^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Zn(OH)_{2(s)}$

(c) $CaCl_{2(aq)} + 2AgNO_{3(aq)} \rightarrow 2AgCl_{(s)} + Ca(NO_3)_{2\,(aq)}$
$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

(d) $BaCl_{2(aq)} + (NH_4)_2SO_{4\,(aq)} \rightarrow BaSO_{4\,(s)} + 2NH_4Cl_{\,(aq)}$
$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4\,(s)}$

(e) $Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \rightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$
$Pb^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow PbI_{2(s)}$