Solution and concentration calculations – answers at the end of the booklet

a) Calculate the concentration of a solution (in moldm^{-3}) which contains 0.2 moles of sodium chloride dissolved in 25cm^3 (1)

b) A solution of ammonium iodide (NH_4I) is made by dissolving 2.9 grams in 250 cm^3 of water. Calculate the concentration of the solution in mol dm^{-3} (2)

c) A solution of magnesium carbonate, $MgCO_3$, has a concentration of 0.4 mol dm^{-3}. Calculate its concentration in g dm^{-3} (2)

d) A solution was made by bubbling 72 cm^3 of ammonia gas (at room temperature and pressure) into 50 cm^3 of water. Calculate the concentration of the resulting solution assuming all the ammonia dissolved. (2)

e) What mass of hydrated sodium carbonate, $Na_2CO_3.10H_2O$, must be dissolved in 250cm^3 of solution in order to give a concentration of 0.0500 mol dm^{-3}? (3)

Calculations from experiments – answers at the end of the booklet

a) What is the minimum volume of 2.00 mol dm^{-3} hydrochloric acid needed to react with 1.20 g magnesium carbonate, $MgCO_3$?

$$2HCl + MgCO_3 \rightarrow MgCl_2 + CO_2 + H_2O$$ (4)

b) 25.0 cm^3 of a 0.200 mol dm^{-3} solution of sodium carbonate was neutralised by 20.0 cm^3 of dilute hydrochloric acid. Find the concentration, in g dm^{-3}, of the acid using the equation for the reaction below.

$$Na_2CO_3\ (aq) + 2HCl\ (aq) \rightarrow 2NaCl\ (aq) + CO_2\ (g) + H_2O\ (l)$$ (3)

c) What volume of oxygen (at RTP) could be obtained from decomposition of 100 cm^3 of a 2.00 mol dm^{-3} solution of hydrogen peroxide?

$$2H_2O_2 \rightarrow 2H_2O + O_2$$ (3)

Extension question (hints on the next page)

This is a deliberately challenging question! The idea is to see how many parts of the calculation you are able to do – not necessarily to be able to get to the right answer straight away. On the next page the steps have been broken down for you.

A sample of sodium hydrogen carbonate crystals, $Na_2CO_3.10H_2O$, had been heated too strongly and lost some of its waters of crystallisation.

2.696 g of the solid were dissolved in water and made up to 250 cm^3 in a volumetric flask.

In a series of titrations, 25.0 cm^3 portions of the solution were titrated with 0.10 mol dm^{-3} hydrochloric acid, giving the results shown below:

Titration number	1 (rough)	2	3
Final burette reading / cm^3	22.00	23.00	22.15
Initial burette reading / cm^3	1.00	2.35	1.60

Determine the percentage of loss of mass from the crystals using these titration results.

(10 marks)

Extension question - hints on how to break down this question (explanation will also be given on video)

Step one: analyse the titration results to find the number of moles of hydrochloric acid used.

- Work out the volume of acid added (the titre) for each of the three sets of titration results
- Choose only *concordant* results – they must differ by no more than 0.2 cm^3. (*hint - only two results are concordant)*.
- Find the mean of these results to get your volume of acid in cm^3.
- Convert the volume to dm^3 and use the concentration of acid given to work out number of moles of HCl in the titration volume.

Step two: use moles of acid in titration to work out moles of sodium carbonate in the solid sample.

- Write a balanced equation for the reaction between sodium carbonate and hydrochloric acid (use the formula Na_2CO_3, without the waters of crystallisation as these would just form part of the solution when the solid dissolves).
- Work out the moles of sodium carbonate in the 25cm^3 titration sample using the moles of acid and the ratio in the balanced equation.
- There would be 10x as many moles in the original solid sample, because it was made up to 250cm^3 and then only 25cm^3 samples were titrated.

Step three: work out how the mass of the sample has changed.

- Work out the Mr of the hydrated salt, $Na_2CO_3.10H_2O$.
- You know how many moles of Na_2CO_3 there are in the sample, so you can work out the maximum mass of the sample – what it would be if all the water were still present.
- You know the actual mass of the sample, so you can work out how much mass was lost by heating.
- Now divide the mass lost by the original (maximum) mass to get the percentage of mass lost.

Solution and concentration calculations - answers

a) Calculate the concentration of a solution (in mol dm^{-3}) which contains 0.2 moles of sodium chloride dissolved in 25cm^3 (1)

25 / 1000 = 0.025 dm^3

Concentration = 0.2 / 0.025 = 8.0 mol dm^{-3}

b) A solution of ammonium iodide (NH_4I) is made by dissolving 2.9 grams in 250 cm^3 of water. Calculate the concentration of the solution in mol dm^{-3} (2)

M_r NH_4I = 145

Moles = 2.9 / 145 = 0.0200 vol = 250 / 1000 = 0.250 dm^3

Concentration = 0.0200 / 0.25 = 0.0800 mol dm^{-3}

c) A solution of magnesium carbonate, $MgCO_3$, has a concentration of 0.4 mol dm^{-3}. Calculate its concentration in g dm^{-3} (2)

M_r $MgCO_3$ = 84

Mass = 84 x 0.4 = 33.6

Concentration = 33.6 g dm^{-3}

d) A solution was made by bubbling 72 cm^3 of ammonia gas (at room temperature and pressure) into 50 cm^3 of water. Calculate the concentration of the resulting solution assuming all the ammonia dissolved. (2)

Volume ammonia = 72 / 1000 = 0.072 dm^3

Moles ammonia = 0.072 / 24 = 0.003 mol

(you could also make this one step by dividing 72 by 24000)

Volume solution = 50 / 1000 = 0.05 dm^3

Concentration = 0.003 / 0.05 = 0.06 mol dm^{-3}

e) What mass of hydrated sodium carbonate, $Na_2CO_3.10H_2O$, must be dissolved in 250cm^3 of solution in order to give a concentration of 0.0500 mol dm^{-3}? (3)

Volume of solution = 250/1000 = 0.25 dm3

Moles = 0.25 x 0.05 = 0.0125

Mr $Na_2CO_3.10H_2O$ = 106 (Na_2CO_3) + 180 ($10H_2O$) = 286

Mass = 0.0125 x 286 = 3.575 g

Calculations from experiments - answers

a) What is the minimum volume of 2.00 mol dm^{-3} hydrochloric acid needed to react with 1.20 g magnesium carbonate, $MgCO_3$? (4)

$$2HCl + MgCO_3 \rightarrow MgCl_2 + CO_2 + H_2O$$

Mr $MgCO_3$ = 84

Mol $MgCO_3$ = 1.2 / 84 = 0.01429

Mol HCl = 0.01429 x 2 = 0.02858

Volume of HCl = moles / concentration = 0.02858 / 2 = 0.01429 dm^3

(x 1000 = 14.29 cm^3)

b) 25.0 cm^3 of a 0.200 mol dm^{-3} solution of sodium carbonate was neutralised by 20.0 cm^3 of dilute hydrochloric acid. Find the concentration, in g dm^{-3}, of the acid using the equation for the reaction below.

Na_2CO_3 (aq) + 2HCl (aq) → 2NaCl (aq) + CO_2 (g) + H_2O (l) (3)

Mol sodium carbonate = 0.2 x (25/1000) = 0.005
Mol HCl = 0.005 x 2 = 0.01
Concentration in mol dm^{-3} = 0.01 / (20/1000) = 0.5 mol dm^{-3}
M_r HCl = 36.5
Concentration in g dm^{-3} = 0.5 x 36.5 = 18.25 g dm^{-3}

c) What volume of oxygen (at RTP) could be obtained from decomposition of 100 cm^3 of a 2.00 mol dm^{-3} solution of hydrogen peroxide?

$2H_2O_2$ → $2H_2O$ + O_2 (3)

Volume hydrogen peroxide = 100/1000 = 0.1 dm^3

Mol hydrogen peroxide = 0.1 x 2 = 0.2 mol

Mol oxygen = 0.2 / 2 = 0.1 mol

Volume oxygen = 0.1 x 24 = 2.4 dm^3 OR 2400 cm^3