AQA Chemistry GCSE Student calculation sheet C4.8

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Titration calculations

Specification references

- C3.4 Using concentrations of solutions in mol/dm^3 (H)
- MS 1a, 1c, 3b, 3c
- WS 4.2, 4.3, 4.6

Aims

This worksheet will give you practice in converting between numbers of moles, volume, and concentration. It will also give you practice in completing titration calculations.

Learning outcomes

After completing this worksheet, you should be able to:

- calculate the unknown concentration of a reactant in a neutralisation reaction when the volumes are known and the concentration of one reactant is also known.

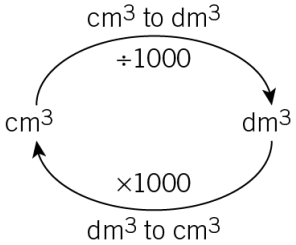
Setting the scene

In an acid–base titration, the concentration of one solution is determined by finding out exactly how much of a second solution with a known concentration is needed to neutralise it.

In order to be able to successfully complete titration calculations you need to be confident in converting between the amount in moles, the volume of a solution, and the concentration of the solution, using the equation:

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{amount of substance (mol)}}{\text{volume (dm}^3\text{)}}$$

The important thing to note is that the volume of the solution must be given in units of decimetres cubed (dm^3). 1 dm^3 is equal to 1000 cm^3 so to convert between the two units you need to multiply or divide by a factor of 1000. The diagram below will help you with this conversion:



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Worked example

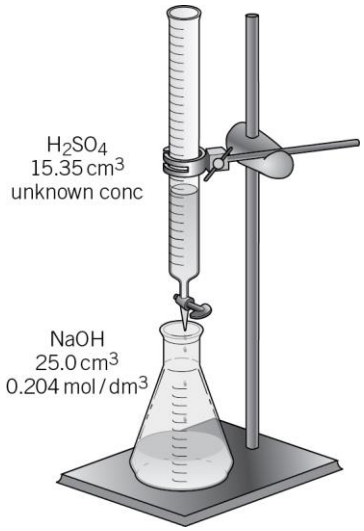
In a titration experiment, 25.0 cm^3 of sodium hydroxide, NaOH, with a concentration of 0.204 mol/dm^3 was transferred via pipette into a conical flask. Sulfuric acid, H_2SO_4, of unknown concentration was added by burette until the NaOH was neutralised. 15.35 cm^3 of the solution of sulfuric acid was needed for neutralisation.

Calculate the concentration of the sulfuric acid.

Give your answer to three significant figures.

Step 1

First, sketch out a picture of the titration equipment to help you visualise the process.



Step 2

Next, you need to calculate the amount of substance, in moles, of either the acid or the alkali where you know both the volume used and the concentration.

In this case, you know the concentration and volume of the alkali, NaOH.

To calculate the amount of NaOH in moles, you need to rearrange the equation below to make the 'amount of substance' the subject:

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{amount of substance (mol)}}{\text{volume (dm}^3\text{)}}$$

You do this by multiplying both sides by volume:

$$\textit{volume (dm}^3\textit{)} \times \text{concentration (mol/dm}^3\text{)} = \frac{\text{amount of substance (mol)}}{\cancel{\text{volume (dm}^3\text{)}}} \times \cancel{\textit{volume (dm}^3\textit{)}}$$

The volumes on the right cancel out to give you:

$$\text{volume (dm}^3\text{)} \times \text{concentration (mol/dm}^3\text{)} = \text{amount of substance (mol)}$$

Before you can substitute the volume of the NaOH into this rearranged equation, you need to convert its units into dm^3.

To do this, divide the volume in cm^3 by 1000:

$$\frac{25.0\ cm^3}{1000}$$

$$= 0.025\ dm^3$$

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You are now ready to calculate the amount of NaOH in moles:

$$\text{amount of NaOH (mol)} = 0.025\ \text{dm}^3 \times 0.204\ \text{mol/dm}^3$$

$$= 0.0051\ \text{mol}$$

Step 3

You then need to calculate the amount of H_2SO_4 in moles at neutralisation. Before you can do the calculation, you need to write a balanced symbol equation for the neutralisation reaction:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

Step 4

Now you can work out the amount of H_2SO_4 in moles that was required to neutralise the 0.0051 moles of NaOH.

From the balanced equation you know that 1 mole of H_2SO_4 neutralises 2 moles of NaOH.

Therefore, the amount of H_2SO_4 required to neutralise 0.0051 moles of NaOH is:

$$0.0051 \div 2 = 0.00255\ \text{moles.}$$

Step 5

Finally, you can calculate the concentration of the H_2SO_4 solution.

You know that the 0.00255 moles of H_2SO_4 required to neutralise the NaOH was contained in 15.35 cm^3 of the solution. Therefore, you can calculate the concentration of the H_2SO_4 by dividing the amount in moles by its volume.

Once again, the volume in cm^3 first needs to be converted to dm^3:

$$\frac{15.35\ \text{cm}^3}{1000}$$

$$= 0.01535\ \text{dm}^3$$

Now you can calculate the concentration of the H_2SO_4 using the equation from above:

$$\text{concentration (mol/dm}^3) = \frac{\text{amount of substance (mol)}}{\text{volume (dm}^3)}$$

$$= \frac{0.00255\ \text{mol}}{0.01535\ \text{dm}^3}$$

$$= 0.1661\ \text{mol/dm}^3$$

$$= 0.166\ \text{mol/dm}^3\ \text{(to 3 significant figures)}$$

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Questions

1 For each of the titration experiments described below, sketch a diagram to show which reagent is in the burette and which reagent is in the conical flask. Include in your diagram the concentration and volume of each reagent.

a 25.0 cm^3 of a solution of sodium hydroxide, NaOH, with a concentration of 0.115 mol/dm^3 was transferred via pipette into a conical flask. Hydrochloric acid, HCl, of unknown concentration was added from a burette until neutralisation. 12.00 cm^3 of the hydrochloric acid, HCl, was needed for neutralisation. (*2 marks*)

b 25.0 cm^3 of a solution of sodium hydroxide, NaOH, with an unknown concentration was transferred via pipette into a conical flask. Hydrochloric acid, HCl, with a concentration of 0.128 mol/dm^3 was added from a burette until neutralisation. 35.20 cm^3 of the hydrochloric acid, HCl, was needed for neutralisation. (*2 marks*)

c In a titration experiment, 16.85 cm^3 of a solution of sodium hydroxide, NaOH, with a concentration of 0.108 mol/dm^3 was needed to neutralise exactly 20.0 cm^3 of sulfuric acid, H_2SO_4, with an unknown concentration. (*2 marks*)

2 **a** Calculate the amount in moles in each of the following solutions:

i 0.0350 dm^3 of a solution with a concentration of 0.108 mol/dm^3 (*1 mark*)

ii 41.8 cm^3 of a solution with a concentration of 0.0501 mol/dm^3 (*2 marks*)

b Calculate the concentration of each of the following solutions:

i 0.0250 dm^3 of a solution that contains 0.345 mol of substance (*1 mark*)

ii 18.90 cm^3 of a solution that contains 0.480 mol of substance (*2 marks*)

3 In a titration experiment, 20.0 cm^3 of sodium hydroxide, NaOH, with an unknown concentration was placed in a conical flask. 25.10 cm^3 of a solution of hydrochloric acid, HCl, with a concentration of 0.128 mol/dm^3 was needed for neutralisation.

Give all your answers to the relevant questions below to three significant figures.

a Sketch a diagram to show the titration set up at the point neutralisation is reached. (*2 marks*)

b Calculate the amount in moles of HCl in 25.10 cm^3 of a solution with a concentration of 0.128 mol/dm^3. (*2 marks*)

c Write an equation for the neutralisation reaction between HCl and NaOH. (*1 mark*)

d Use your answer to parts **b** and **c** to determine the amount of NaOH in 20.0 cm^3 of NaOH that is exactly neutralised by the HCl. (*1 mark*)

e Calculate the concentration of the NaOH solution in the conical flask.

(*2 marks*)

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4 A student carries out a titration to determine the concentration of a solution of nitric acid. She titrates the solution of nitric acid against a standard solution of sodium hydroxide with a known concentration of 0.0998 mol/dm^3. She finds that 21.80 cm^3 of the nitric acid solution is needed to exactly neutralise 25.0 cm^3 of the sodium hydroxide solution.

Calculate the concentration of the nitric acid solution. Give your answer to three significant figures.

The equation for the neutralisation reaction is

$$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$$

(*4 marks*)

5 A student used a pipette to add 25.0 cm^3 of KOH of unknown concentration to a conical flask.

The student carried out a titration experiment to find the volume of 0.150 mol/dm^3 H_2SO_4 needed to neutralise the KOH.

The student found that, on average, 17.20 cm^3 of the H_2SO_4 solution was required for neutralisation.

a Write a balanced symbol equation for the neutralisation reaction between H_2SO_4 and KOH. (*1 mark*)

b Calculate the concentration of the KOH solution. (*5 marks*)

Maths skills links

You will also need to be able to convert between volumes that use different units, and to be able to rearrange equations, when calculating the amounts of substances in equations and the volumes of gases.