Simple Step-by-Step Guides to Solving Chemistry Problems

Volumetric Analysis

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VOLUMETRIC ANALYSIS

A solution of accurately known concentration is called a **standard solution**. Standard solutions are used in volumetric (**titrimetric**) analysis, used to determine the unknown concentration of an identified chemical species (**analyte**). The volume of one solution that will react with a known volume of a standard solution (titrant) is determined. The point at which the exact amount of titrant added to just react with all the other reagent present is called the **end point** or equivalence point. Indicators, normally added to the solution of known volume, which change colour, are often used to determine the end point.
Volumetric analysis is widely used to determine the concentration of a broad range variety of parameters including basicity, acidity, total hardness and chloride levels.

Titrations can be categorised based on chemical reactions:

> **Acid–Base** titrations are used to determine the concentration of an acid or base by exactly neutralising the acid or base with an acid or base of known concentration. This permits to quantitative analysis of the concentration of an unknown acid or base solution.
>
> **Redox** titrations can be used to determine oxidizing or reducing agents in a solution. The reducing or oxidizing agent is used as the titrant against the other agent.
>
> **Back Titrations** are used where analytes are either partially soluble or too slow to give a reaction. A known amount of excess reagent is used. The remaining excess reagent is then titrated with another second reagent to determine how much of the excess reagent was used in the first titration, allowing the original analyte's concentration to be determined.

Example 1: Chloride concentrations in water can be determined by titration against standardised silver nitrate solutions. A 50 cm^3 water sample was titrated against 0.05 M silver nitrate solution, using potassium chromate as the indicator. This indicator changes colour when all the chloride has been precipitated out of solution as silver chloride. This colour change occurred after the addition of 10.9 cm^3 of 0.05 M silver nitrate. What is the concentration of chloride ions in the water sample?

Step 1: Write the balanced chemical equation, insert the information given in the question and identify what you are trying to calculate

	$Cl^-_{(aq)}$	+	$AgNO_{3(aq)}$	$\longrightarrow$	$AgCl_{(s)}$ + $NO_3^-{}_{(aq)}$
Volume (cm^3)	50		10.9		
Moles					
Concentration (M)	?		0.05		
Reaction coefficients	1	:	1		

Please note volumetric analysis (titrations) are predominantly concerned with the reaction coefficient (stoichiometric) relationship between the reactants. The products are included in the above table for the sake of completeness.

Step 2: If two pieces of information from volume, number of moles, and concentration are known for a given species, the third can be calculated using:

Concentration (*M*) = Number of Moles / Volume of solution (*L*)

c = n / v

OR

Number of Moles = Concentration (M) x Volume of Solution (L)

n = c x v

OR

Volume of Solution (L) = Number of Moles / Concentration (M)

v= n / c

	$Cl^-_{(aq)}$	+	$AgNO_{3(aq)}$	⟶	$AgCl_{(s)}$	+ $NO_3^-{}_{(aq)}$
Volume (cm^3)	50 (0.05 L)		10.9			
Moles			10.9 x 0.05 /1000 = 5.45 x 10^{-4}			
Concentration (M)	**?**		0.05			
Reaction coefficien	1	:	1			

Step 4: At the end point the amount of each species present is in accordance with the reaction coefficient (stoichiometric) relationship of the balanced chemical equation for the reaction. In this example the number of moles of Cl- in 50 cm^3 = the number of moles Ag+ in 10.89 cm^3

	$Cl^-_{(aq)}$	+	$AgNO_{3(aq)}$	⟶	$AgCl_{(s)}$	+ $NO_3^-{}_{(aq)}$
Volume (cm^3)	50 (0.05 L)		10.9			
Moles	5.45 x 10^{-4}		10.9 x 0.05 /1000 = 5.45 x 10^{-4}			
Concentration (M)	?		0.05			
Reaction coefficients	1	:	1			

Step 4: Since we know both the number of moles of Cl- and its volume, we can calculate its concentration.

	$Cl^-_{(aq)}$	+	$AgNO_{3(aq)}$	⟶	$AgCl_{(s)}$	+ $NO_3^-{}_{(aq)}$

Volume (cm^3)	50 (0.05 L)		10.9
Moles	5.45 x 10^{-4}		10.9 x 0.05 /1000 = 5.45 x 10^{-4}
Concentration (M)	5.45 x 10^{-4} /0.05 **=0.0109**		0.05
Reaction coefficients	1	:	1

Answer: Concentration of Cl- in tap water = **0.0109 M**

Example 2: A standard solution was prepared by dissolving 2.6061 g of anhydrous sodium carbonate in distilled water and making up to 250 cm^3. A 25 cm^3 portion of this solution was titrated against hydrochloric acid, using methyl orange as an indicator. This indicator changes colour when all the sodium carbonate has been converted into sodium chloride. 18.7 cm^3 of the acid were required for neutralisation. What is the concentration of the acid?

Step 1: Fill in the information given in the question

	$Na_2CO_{3(aq)}$	+	$2HCl_{(aq)}$	⟶	$2NaCl + CO_2 + H_2O$
Volume (cm^3)	25		18.7		
No. of moles					
Concentration (M)			**?**		
Reaction coefficients	2	:	1		

Step 2: You need to know two pieces of information (volume, number of moles or concentration) about one of the species and one piece of information about another to solve volumetric (titrimetric) problems. If this information is not given directly in the question, then it can be calculated from the information provided- in this example the concentration of Na_2CO_3.

M_r [Na_2CO_3] = 106
Number of moles of Na_2CO_3 in 2.6061 g = mass/M_r = 2.6061/106 = 0.0246
Therefore, the number of moles of Na_2CO_3 in 250 cm^3 (0.25 L) = 0.0246
25 cm^3 of the Na_2CO_3 solution contains 0.0246 x 25/250 = 2.46 x 10^{-3} moles of Na_2CO_3
Concentration (ie number if moles in 1000 cm^3) = number of moles /volume = 0.0246/0.25 = 0.098 M

	Na_2CO_3	+	$2HCl_{(aq)}$	⟶	$2NaCl + CO_2 + H_2O$
Volume (cm^3)	25		18.7		
Moles	0.098				
Concentration (M	2.46 x 10^{-3}		**?**		
Reaction coefficie	2	:	1		

Step 3:
At the end point (ie. when the indicator changes colour) there are 2 moles of HCl for every mole of Na_2CO_3.

Number of moles of HCl at the end point = 2 x the number of moles of Na_2CO_3
= 2 x 2.46 x 10^{-3}
= 4.92 x 10^{-3} moles

	$Na_2CO_{3(aq)}$	+	$2HCl_{(aq)}$	→	$2NaCl + CO_2 + H_2O$
Volume (cm^3)	25		18.7		
Moles	0.0246		0.0246 x 2 = 4.92 x 10^{-3}		
Concentration (M	0.098				
Reaction coefficie	2	:	1		

Step 4:
Thus, the number of moles of HCl in 18.7 cm^3 = 4.92 x 10^{-3} moles
Concentration is defined as the number of moles in 1 L i.e. = number of moles / volume
Convert volume from cm^3 to L , 18.7 cm^3 = 18.7/1000 = 0.0187 L
Therefore concentration of HCl = number of moles/volume = 4.92 x 10^{-3} /0.0187 = 0.263 M

	$Na_2CO_{3(aq)}$	+	$2HCl_{(aq)}$	→	$2NaCl + CO_2 + H_2O$
Volume (cm^3)	25		18.7		
Moles	0.0246		4.92 x 10^{-3}		
Concentration (M)	2.46 x 10^{-3}		**0.263**		
Reaction coefficien	2	:	1		

Answer: HCl concentration = **0.263 M**

Example 3: Magnesium oxide is not very soluble in water, and is difficult to titrate directly. Its purity can be determined by use of a 'back titration' method. 4.06 g of impure magnesium oxide was completely dissolved in 100 cm^3 of hydrochloric acid, of concentration 2.0M (in excess). The excess acid required 19.7 cm^3 of sodium hydroxide (0.20M) for neutralisation. This second titration is called a 'back-titration', and is used to determine the unreacted acid.

a) write equations for the two neutralisation reactions.

Answer:
$MgO + 2HCl \rightarrow MgCl_2 + 2HCl$
$NaOH + HCl \rightarrow NaCl + H_2O$

b) calculate the moles of hydrochloric acid added to the magnesium oxide.

Answer:
Number of moles of HCl in 100 cm^3 of 2M = volume x concentration = 100/1000 x 2 = 0.2 moles

c) calculate the moles of excess hydrochloric acid titrated.

Answer:
Number of moles in 19.7 cm^3 (0.019 L) of 0.2M HCl = volume x concentration = 0.0197 x 0.2 = 0.0197 moles

(d) calculate the moles of hydrochloric acid reacting with the magnesium oxide.

Answer:
Number of mole reacting with MgO = 0.2 – 0.01986 = 0.1804 moles

(e) calculate the moles and mass of magnesium oxide that reacted with the initial hydrochloric acid.

Answer:
M_r [MgO] = 40
According to the reaction coefficients, 2 moles of HCl react with 1 mole of MgO
Therefore, the number of moles of MgO = 0.1804 = 0.0902
Mass of MgO = number of moles x M_r = 0.0902 x 40 = 3.608 g

(f) hence the % purity of the magnesium oxide.

Answer:
% purity = 3.608/4.06 x 100 = 88.9%

Example 4: A sample of sodium hydrogencarbonate was tested for purity using the following method. 0.400g of the solid was dissolved in 100.0 cm^3 of water and titrated with 0.200 M hydrochloric acid using methyl orange indicator. 23.75 cm^3 of acid was required for complete neutralisation. Determine the mass of sodium hydrogen carbonate titrated and hence the purity of the sample.

Answer:

	$NaHCO_{3(aq)}$	+	$HCl_{(aq)}$	→	$NaCl + CO_2 + H_2O$
Volume (cm^3)	100 (0.1L)		23.75		
Moles	4.75×10^{-3}		23.75/1000 x 0.2 = 4.75×10^{-3}		
Concentration (M)	4.76×10^{-3} /0.1 = **0.0476**		0.2		
Reaction coefficient	1	:	1		

M_r [$NaHCO_3$] = 84
Number of moles in 23.75 cm^3 0.2M HCl = volume x concentration

= $23.75/1000 \times 0.2 = 4.75 \times 10^{-3}$

Volume = $100\ cm^3 = 0.1$ L

Concentration of prepared $NaHCO_3$ solution = number of moles / volume

= $4.76 \times 10^{-3}/0.1 = 0.0476$ M

At the end point the number of moles of $NaHCO_3$ = number of moles of HCl

= 4.75×10^{-3}

Mass of 4.75×10^{-3} of $NaHCO_3$ = number of moles x M_r

= $4.75 \times 10^{-3} \times 84$ = **0.399 g**

Purity (%) = 0.399/0.400 x 100

= **99.75%**

Example 5: The redox reaction between permanganate ions and iron(II) ions is:

$$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5Fe^{2+}{}_{(aq)} \rightarrow Mn^{2}{}_{(aq)} + 5Fe^{3+}{}_{(aq)} + 4H_2O_{(l)}$$

What volume (in cm^3) of permanganate solution of concentration 0.04M would react exactly with 30 cm^3 of a solution of iron(II) which has a concentration of 0.3 M?

Answer:

	MnO_4^-	+	$8H^+$	+	$5Fe^{2+}$	→	$Mn^{2+} + 5Fe^{3+} + 4H_2O$
Volume (cm^3)	1.8×10^{-3} /0.4 x 1000 = **4.5**				30		
Moles	$1/5 \times 9 \times 10^{-3}$ = 1.8×10^{-3}				30/1000 x 0.3 = 9×10^{-3}		
Concentration (M)	0.4				0.3		
Reaction Coefficient	1		8	:	5		

Number of moles in $30cm^3$, 0.3M Fe^{2+} = volume x concentration = 30/1000 x 0.3 = 9×10^{-3}

According to the reaction coefficients, at the end point number of moles of MnO_4^- = 1/5 x number of moles of Fe^{2+}

= $1/5 \times 9 \times 10^{-3}$

= 1.8×10^{-3}

Volume of $KMnO_4$ = number of moles x concentration = 1.8×10^{-3} /0.4 x 1000 = **4.5 cm^3**

Example 6: *Succinic acid has the formula $(CH_2)_n(COOH)_2$ and reacts with dilute sodium hydroxide as follows:*

$$(CH_2)_n(COOH)_{2(aq)} + 2NaOH_{(aq)} \rightarrow (CH_2)_n(COONa)_{2(aq)} + 2H_2O_{(l)}$$

2.0 g of succinic acid were dissolved in water and the solution made up to 250 cm^3. This solution was placed in a burette and 18.4 cm^3 was required to neutralise 25 cm^3 of 0.1M NaOH. Deduce the molecular formula of the acid and hence the value of n.

Answer:

	$(CH_2)_n(COOH)_{2(aq)}$	+	$2NaOH_{(aq)}$	→	$(CH_2)_n(COONa)_2$ + $2H_2O$
Volume (cm^3)	18.4 (0.0184 L)		25		
Moles	0.5 x 2.5 x 10^{-3} = 1.25 x 10^{-3}		25/1000 x 0.1 = 2.5 x 10^{-3}		
Concentration (M	1.25 x 10^{-3} /0.0184 = 0.68		0.1		
Reaction coefficie	1	:	2		

Number of moles of NaOH in 25 cm^3, 0.1M NaOH = volume x concentration = 25/1000 x 0.1 = 2.5 x 10^{-3}

At the end point, the number of moles of $(CH_2)_n(COOH)_2$ in 18.4 cm^3 = 0.5 x number of moles of NaOH

= 0.5 x 2.5 x 10^{-3} = 1.25 x 10^{-3}

Number of moles of $(CH_2)_n(COOH)_2$ in 250 cm^3 = 250/18.7 x 1.25 x 10^{-3} = 0.017 moles

Thus 0.017 moles of $(CH_2)_n(COOH)_2$ has a mass of 2 g

M_r [$(CH_2)_n(COOH)_2$] = mass / number of moles = 2 / 0.017 = **118**

M_r [CH_2] = 14

M_r [$(COOH)_2$] = 90

Thus 14n + 90 = 118

Rearranging, 14n = 118 – 90 :

n = 28/14 = **2**

PRACTICE PROBLEMS

1. If it takes 24 cm^3 of 0.1 M NaOH to neutralise 20 cm^3 of an HCl solution, what is the concentration of the HCl?

2. If it takes 1 cm^3 of 0.05 M $HN0_3$ to neutralise 25 cm^3 of NaOH solution, what is the concentration of the NaOH solution?

3. If it takes 50 cm^3 of 0.5 M KOH solution to completely neutralise 125 cm^3 of sulfuric acid solution (H_2SO_4), what is the concentration of the H_2SO_4 solution?

4. An ammonia solution was reacted with sulfuric acid as shown in the equation below.

   $$2NH_{3(aq)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)}$$

   Calculate the concentration of the ammonia solution given that it takes 30.8 cm^3 of a 1.24 M solution of sulfuric acid to neutralise 25 cm^3 of this ammonia solution for complete reaction.

5. A 50.0 cm^3 sample of sulfuric acid was diluted to 1.00 L. A sample of the diluted sulfuric acid was analysed by titrating with aqueous sodium hydroxide. In the titration, 25.0 cm^3 of 1.00 M aqueous sodium hydroxide required 20.0 cm^3 of the diluted sulfuric acid for neutralisation. Calculate the concentration of the original concentrated sulfuric acid solution.

$$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + H_2O_{(aq)}$$

Calculate the concentration of the original concentrated sulfuric acid solution.

6. How many grams of $Ca(OH)_2$ are required to neutralise 52.68 cm^3 of a 0.750 M H_2SO_4 solution?

7. What volume of 1.0M sulfuric acid will be needed to neutralise 25.00 cm of 0.8M sodium hydroxide solution?

8. Calculate the volume of 0.10M sodium hydroxide solution needed to neutralise 20.00 cm^3 of 0.25M hydrochloric acid.

9. 100 cm^3 of a magnesium hydroxide solution required 4.5 cm^3 of sulfuric acid (of concentration 0.100M) for complete neutralisation. Determine the concentration of the magnesium hydroxide in g cm^{-3}.

10. A solution made from pure barium hydroxide contained 2.74 g in exactly 100 cm^3 of water. Using phenolphthalein indicator, titration of 20.0 cm^3 of this solution required 18.7 cm^3 of a hydrochloric acid solution for complete neutralisation. Calculate the molarity of the HCl.

Answers are given on the next page.

Volumetric Analysis Answers:

1. *If it takes 24 cm^3 of 0.1 M NaOH to neutralise 20 cm^3 of an HCl solution, what is the concentration of the HCl?*

Answer:

	$NaOH_{(aq)}$	+	$HCl_{(aq)}$	→	$NaCl_{(aq)}$ + $H_2O_{(l)}$
Volume (cm^3)	24		20		
No. of moles	2.4×10^{-3}		2.4×10^{-3}		
Concentration (M)	0.1		**0.12**		
Reaction Coefficients	1		1		

Number of moles of NaOH in 24 cm^3 0.1M = volume x concentration = 24/1000 x 0.1 =2.4×10^{-3}
At the end point the number of moles of NaOH in 24 cm^3 = number of moles of HCl in 20cm^3
Therefore, number of moles of HCl in 20cm^3 (0.02 L) =2.4×10^{-3}
Concentration = number of moles / volume
= 2.4×10^{-3} / 0.02 = **0.12 M**

2. *If it takes 1 cm^3 of 0.05 M $HN0_3$ to neutralise 25 cm^3 of NaOH solution, what is the concentration of the NaOH solution?*

Answer:

	$NaOH_{(aq)}$	+	$HNO_{3(aq)}$	→	$2NaNO_{3(aq)}$ + $H_2O_{(l)}$
Volume (cm^3)	25		1		
No. of moles	5×10^{-5}		5×10^{-5}		
Concentration (mol M)	**2×10^{-3}**		0.05		
Reaction coefficients	1		1		

Number of moles of HNO_3 in 1 cm^3 (0.001 L) 0.05M = volume x concentration = 0.001 x 0.05 =5×10^{-5}
At the end point the number of moles of HNO_3 in 1 cm^3 = number of moles of NaOH in 25cm^3
Therefore, number of moles of NaOH in 25 cm^3 (0.025 L) = 5×10^{-5}
Concentration = number of moles / volume
= 5×10^{-5} / 0.025
= **2×10^{-3} M**

3. *If it takes 50 cm^3 of 0.5 M KOH solution to completely neutralise 125 cm^3 of sulfuric acid solution (H_2SO_4), what is the concentration of the H_2SO_4 solution?*

Answer:

	$2KOH_{(aq)}$	+	$H_2SO_{4(aq)}$	→	$K_2SO_{4(aq)}$ + $H_2O_{(l)}$
Volume (cm^3)	50		125		
No. of moles	0.025		0.0125		
Concentration (mol M)	0.5		**0.1**		
Reaction coefficents	2		1		

Number of moles of KOH in 50 cm^3 0.5 M = volume x concentration 50/1000 x 0.5 = 0.025
At the end point the number of moles of KOH in 50 cm^3 = 0.5 x number of moles of H_2SO_4 in 125 cm^3
Therefore, number of moles of KOH in 125 cm^3 (0.125 L) = ½ x 0.025 = 0.0125

Concentration of KOH = number of moles / volume = 0.0125 / 0.125 = **0.1 M**

4. *An ammonia solution was reacted with sulfuric acid as shown in the equation below.*

$$2NH_{3(aq)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)}$$

Calculate the concentration of the ammonia solution given that it takes 30.8 cm³ of a 1.24 M solution of sulfuric acid to neutralise 25 cm³ of this ammonia solution for complete reaction.

Answer:

	$2NH_{3(aq)}$	+	$H_2SO_{4(aq)}$	→	$(NH_4)_2SO_4$
Volume (cm^3)	25 (0.025 L)		30.8		
No. of moles	0.0382 x 2 = 0.0764		0.0382		
Concentration (M)	0.0764 /0.025 = **3.1**		1.24		
Reaction coefficients	2		1		1

Number of moles in 30.8 cm^3 of 1.24 M H_2SO_4 = volume x concentration = 30.8/1000 x 1.24 = 0.0382
At the end point, the number of moles of NH_3 = 2 x number of mole of H_2SO_4 = 0.0382 x 2 = 0.0764
Thus number of moles of NH_3 in 25 cm^3 (0.025 L) = 0.076
Concentration of NH_3 = number of moles / volume = 0.076 /0.025 = **3.1 M**

5. A 50.0 cm^3 sample of sulfuric acid was diluted to 1.00 L. A sample of the diluted sulfuric acid was analysed by titrating with aqueous sodium hydroxide. In the titration, 25.0 cm^3 of 1.00 M aqueous sodium hydroxide required 20.0 cm^3 of the diluted sulfuric acid for neutralisation. Calculate the concentration of the original concentrated sulfuric acid solution.

$$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + H_2O_{(l)}$$

Calculate the concentration of the original concentrated sulfuric acid solution.

Answer:

	$H_2SO_{4(aq)}$	+	$2NaOH_{(aq)}$	→	$Na_2SO_4 + H_2O$
Volume (cm^3)	20 (0.02L)		25		
No. of moles	0.5 x 0.025 = 0.0125		25/1000 x 1 = 0.025		
Concentration (M)	0.0125/0.02 = 0.625		1		
Reaction coefficients	1		2		

Number of moles in 25 cm^3 of 1 M NaOH = volume x concentration = 25/1000 x 1 = 0.025
At the end point, the number of moles of H_2SO_4 = 0.5 x number of mole of NaOH = 0.5 x 0.025 = 0.0125
Thus number of moles of H_2SO_4 in 20 cm^3 (0.02 L) = 0.0125
Concentration of H_2SO_4 = number of moles / volume = 0.0125/0.02 = 0.625 M
Therefore, concentration of the original H_2SO_4 sample = 1000/50 x 0.625 = **12.5 M**

6. *How many grams of $Ca(OH)_2$ are required to neutralise 52.68 cm^3 of a 0.750 M H_2SO_4 solution ?*

Answer:

	$Ca(OH)_{2(aq)}$	+	$H_2SO_{4(aq)}$	→	$CaSO_4$ + H_2O
Volume (cm^3)			52.68		
Moles	0.0395		52.68/1000 x 0.75 = 0.0395		
Concentration (M)			0.75		
Mass	**2.92**	:			
Reaction coefficien	**1**		1		

M_r [$Ca(OH)_2$] = 74
The number of moles in 52.68 cm^3 of a 0.750 M H_2SO_4 = volume x concentration = 52.88/1000 x 0.75 = 0.0395
According to the reaction coefficients, at the end point, the number of moles of $Ca(OH)_2$ = the number of moles of H_2SO_4
Thus, the number of moles of $Ca(OH)_2$ = 0.0395
Mass of 0.0395 moles $Ca(OH)_2$ = number of moles x Mr = 0.0395 x 74 = **2.92 g**

7. *What volume of 1.0M sulfuric acid will be needed to neutralise 25.00 cm of 0.8M sodium hydroxide solution?*

Answer:

	$2NaOH_{(aq)}$	+	$H_2SO_{4(aq)}$	→	Na_2SO_4 + H_2O
Volume (cm^3)	25		**10 (0.01 L)**		
Moles	25/1000 x 0.8 = 0.02		0.01/1 = 0.01		
Concentration (M)	0.8		1		
Reaction coefficient	2	:	1		

Number of moles in 25cm^3, 0.8M NaOH = volume x concentration = 25/1000 x 0.8 = 0.02
At the end point, the number of moles of H_2SO_4 = 0.5 x number of moles of NaOH = 0.5 x 0.02 = 0.01
Volume of H_2SO_4 = number of moles /concentration = 0.01 / 1 = 0.01 L = 10 cm^3

8. *Calculate the volume of 0.10M sodium hydroxide solution needed to neutralise 20.00 cm^3 of 0.25M hydrochloric acid.*

Answer:

	$NaOH_{(aq)}$	+	$HCl_{(aq)}$	→	NaCl + H_2O
Volume (cm^3)	5 x 10^{-3} /0.1 = = 0.50 L = **50**		20		
Moles	5 x 10^{-3}		20/1000 x 0.25 = 5 x 10^{-3}		
Concentration (M)	0.1		0.25		
Reaction coefficien	1	:	1		

The number of moles in 20cm^3, 0.32M HCl = volume x concentration = 20/1000 x 0.25 = 5 x 10^{-3}

At the end point, the number of moles of NaOH = number of moles of HCl = 5 x 10^{-3}
Volume of NaOH = number of moles/ concentration = 5 x 10^{-3} /0.1 = 0.05 L = 50cm^3

9. *100 cm^3 of a magnesium hydroxide solution required 4.5 cm^3 of sulfuric acid (of concentration 0.100M) for complete neutralisation. Determine the concentration of the magnesium hydroxide in g cm^{-3}.*

Answer:

	$Mg(OH)_{2(aq)}$	+	$H_2SO_{4(aq)}$	→	$MgSO_4$ + H_2O
Volume (cm^3)	100		4.5 (4.5 x 10^{-3} L)		
Moles	4.5 x 10^{-5}		4.5 x 10^{-3} x 0.1 = 4.5 x 10^{-4}		
Concentration (	4.5 x 10^{-4} /0.1 = **4.5 x 10^{-3}**		0.1		
Reaction coeffi	1	:	1		

Mr[$Mg(OH)_2$] = 58
Number of moles in 4.5 cm^3 O.1 M H_2SO_4 = volume x concentration = 4.5/1000 x 0.1 = 4.5 x 10^{-4}
At the end point, the number of moles of H_2SO_4 = Number of moles of $Mg(OH)_2$
Thus the number of moles of $Mg(OH)_2$ in 100 cm^3 (0.1 L) = 4.5 x 10^{-4}
Concentration of $Mg(OH)_2$ = number of moles / volume = 4.5 x 10^{-5} /0.1 = **4.5 x 10^{-3} M**
To convert from M to g/mol multiply by M_r
Concentration of $Mg(OH)_2$ = 4.5 x 10^{-3} x 58 = 0.26 g/L

10. *A solution made from pure barium hydroxide contained 2.74 g in exactly 100 cm^3 of water. Using phenolphthalein indicator, titration of 20.0 cm^3 of this solution required 18.7 cm^3 of a hydrochloric acid solution for complete neutralisation. Calculate the molarity of the HCl.*

Answer:

	$Ba(OH)_{2(aq)}$	+	$2HCl_{(aq)}$	→	$BaCl_2$ + $2H_2O$
Volume (cm^3)	20 (0.02L)		18.7		
Moles	20/1000 x 0.16 = 3.2 x 10^{-3}		6.4 x 10^{-3}		
Concentration (M)	0.16		1000/18.7 x 6.4 x 10^{-3} = 0.34		
Reaction coefficien	1	:	2		

M_r[$Ba(OH)_2$] = 171
Number of moles in 2.74 g $Ba(OH)_2$ = mass/M_r = 2.74/171 = 0.016
Concentration of $Ba(OH)_2$ = number of moles / volume = 0.016 /0.1 = 0.16 M
At the end point of the titration, number of moles of HCl = 2 x the number of moles of $Ba(OH)_2$
Thus number of moles of HCl in 18.7 cm^3 (0.0187 L) = 2 x number of moles Ba(OH)2 in 20cm3 (0.02 L)
= 2 x 0.02 x 0.16 = 6.4 x 10^{-3}
Concentration of HCl = number of moles/volume = 6.4 x 10^{-3} /0.0187= **0.34M**