Titration

Volumetric analysis is quantitative analysing measuring volumes to find the concentration of a solution. This involves reacting a solution of known concentration with one of unknown concentration to determine the **equivalence point.**

The equivalence point is reached when the reactants have completely reacted together in the ratio of the mole quantities given in the balanced equation for the reaction.

The equivalence point for

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

is when sodium hydroxide and hydrochloric acid have completely reacted in a 1:1 mole ratio. The equivalence point for

$$2KOH_{(aq)} + H_2SO_{4(aq)} \rightarrow K_2SO_{4(aq)} + 2H_2O_{(l)}$$

is when potassium hydroxide and sulfuric acid have completely reacted in a 1:1 mole ratio.

Describe the equivalence point for the reaction:

$$3KOH_{(aq)} + H_3PO_{4(aq)} \rightarrow K_3PO_{4(aq)} + 3H_2O_{(l)}$$

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The equivalence point for a neutralisation reaction is measured by choosing an acid-base indicator that changes colour about the pH of the salt solution that was formed at the equivalence point.

strong acid + strong base → neutral salt solution pH about 7 bromothymol blue or litmus indicator solution change colour about pH 7

strong acid + weak base → acid salt solution pH below 7 methyl orange indicator solution changes colour about pH 4

weak acid + strong base → basic salt solution pH above 7 phenolphthalein indicator solution changes colour about pH 9

The point at which the indicator changes colour is called the **end point**. An indicator is chosen with end point as close as possible to the equivalence point.

Preparation of a standard solution	**Example**
Procedure steps	**250 mL of 0.100 M oxalic acid**
1 Calculate mol required = molarity x volume in L	0.100 mol L^{-1} x 0.250L = 0.0250
2 Calculate required mass mol x g mol^{-1}	$(COOH)_2.2H_2O$ = 126 g mol^{-1} 0.0250 x 126 = 3.15 g
3 Weigh accurately a mass close to the required mass in a beaker	eg 3.24 g
4 Dissolve all of the measured mass in water, transfer to volumetric flask, wash inside beaker twice with water and transfer washings to volumetric flask. It is essential that all of the weighed mass enters the volumetric flask.	250 mL volumetric flask used
5 Dilute the solution to the exact volume	Mark on neck of volumetric flask
6 Stopper the flask, place a finger on stopped and the other hand on neck of flask. Invert flask and rotate to mix.	
7 Label: solution name, date, your name	Oxalic acid, 15/1/01, Joe Blow
8 Calculate concentration	(3.24/3.15) x 0.100 = 0.103 M
9 Add concentration to the label	0.103 M

1 Dilution of a solution using cV = constant

Suppose you wished to dilute some of a 0.103 M solution of oxalic acid to produce 500 mL of 0.0200 M solution.

a) Calculation method explaining reasoning

The moles of oxalic acid required in the dilute solution is cV where c is molar concentration and V is volume in L.

$cV = 0.200 \text{ mol L}^{-1} \times 0.500 \text{ L} = 0.0100 \text{ mol}$

This number of moles must be in the 0.103 M solution that is diluted

$0.0100 \text{ mol} = 0.103 \text{ mol L}^{-1} \times V$ measured in L

$V = 0.0100/0.103 = 0.0971 \text{ L} = 97.1 \text{ mL}$

Thus water is added to 97.1 mL of 0.103 M solution to a total volume of 500 mL of solution to obtain 0.0200 M solution.

a) Quick calculation method using $c_1V_1 = c_2V_2$

$\mathbf{c_1V_1 = c_2V_2}$

$0.103 \times V_1 = 0.0200 \times 500$

$V_1 = (0.0200 \times 500) / 0.103 = 97.1$

V_1 is in mL because V_2 was in mL

97.1 mL is diluted to make the 500 mL solution.

1 Calculate the volume of 10 M hydrochloric acid needed to prepare 500 mL of 0.10 M hydrochloric acid solution.

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2 If 2.0 L of 2.0 M sodium hydroxide solution is diluted to a total volume of 10 L of solution what is the concentration of the diluted solution?

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1 Calculating unknown concentration of a titration solution using]

$$\frac{C_aV_a}{a} = \frac{C_bV_b}{b}$$ **for (a)Acid + (b)Base**

If the balanced equation for an acid-base titration is:

(a)Acid + (b)Base $\rightarrow$ (s)Salt + (w)Water

$\frac{C_aV_a}{a} = \frac{C_bV_b}{b}$ where C = molar concentration V = volume (V{acid} and V{base} must be in same units eg both mL of both L) a and b are the coefficients for acid and base in the balanced equation).

Note that it is essential that you have the correct formula for acid, base, salt and water and that the equation is correctly balance before you can use this method.

In titration V(acid) and V(base) are measured. An unknown concentration can be calculated if the other concentration – the standard solution concentration – is known.

Example: 25.0 mL of 0.0100 M barium hydroxide is neutralised by 34.3 mL of an unknown concentration hydrochloric acid solution.

correct formulas: $HCl + Ba(OH)_2 \rightarrow BaCl_2 + H_2O$

balanced equation: $2HCl + Ba(OH)_2 \rightarrow BaCl_2 + 2H_2O$

$$\frac{C_a \times 34.3}{2} = \frac{0.0100 \times 25.0}{1}$$

ca = (0.0100 × 25.0 × 2) / 34.3 = 0.0146 M hydrochloric acid

1 25.0 mL of 0.124 M hydrochloric acid is neutralised by 0.0500 M sodium hydroxide solution in a titration.

What volume of NaOH(aq) was used?

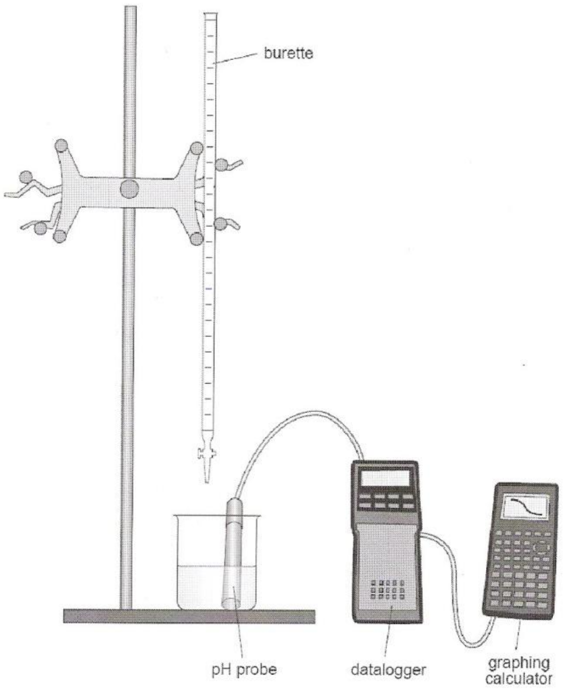
2 25.0 mL of 0.124 M sulfuric acid is neutralised by 0.0500 M sodium hydroxide solution in a titration.

What volume of NaOH(aq) was used?

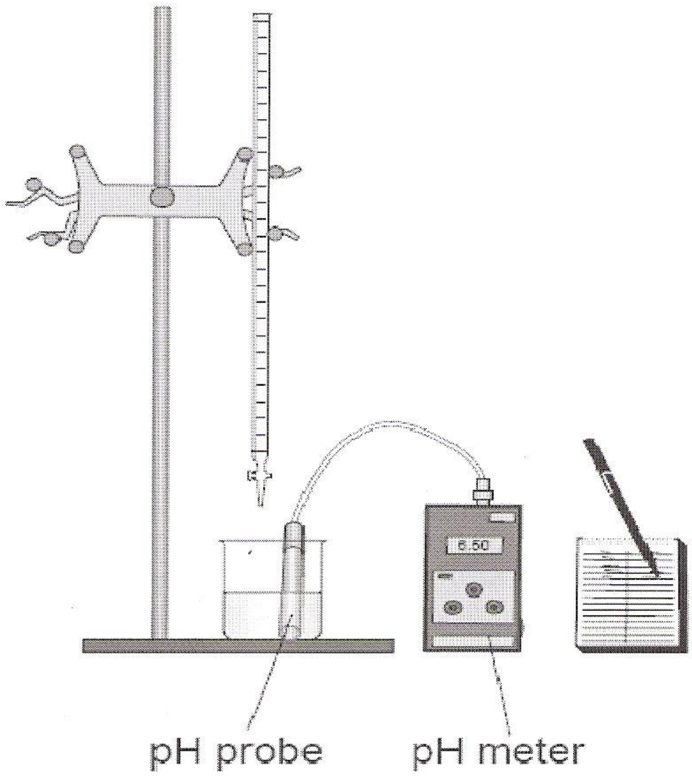
Using a datalogger to measure the equivalence point

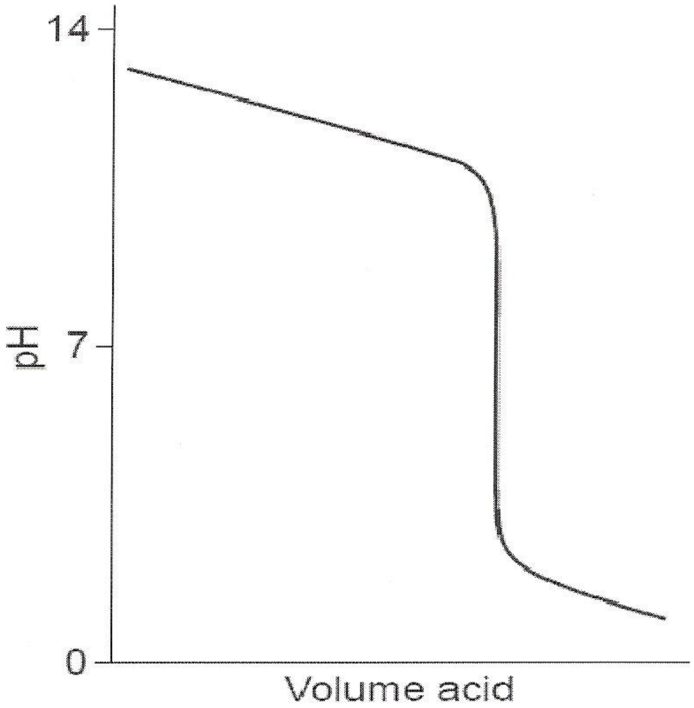
A datalogger stores data input electronically. The data can be displayed on a graphics screen or transferred to a computer.

Probes are available for attachment to many dataloggers to measure pH and electrical conductivity. The pH changes rapidly at equivalence while a graph of the electrical conductivity changes slope at equivalence.

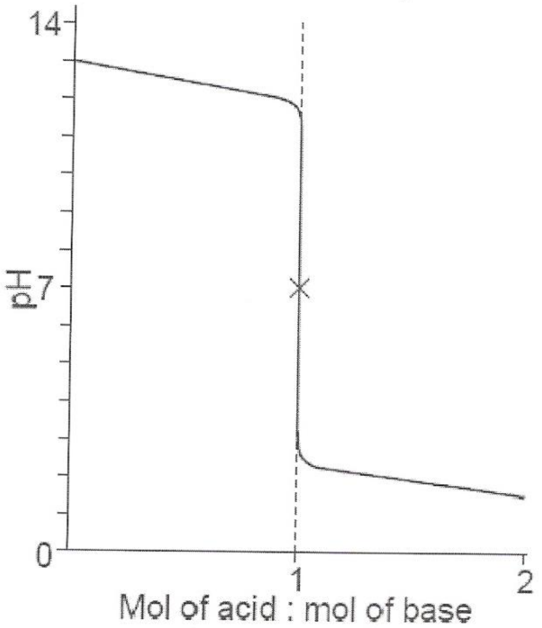


If a datalogger is not available the measurements made using a pH meter or conductivity meter can be logged by recording the measurements in table format using pen and paper.

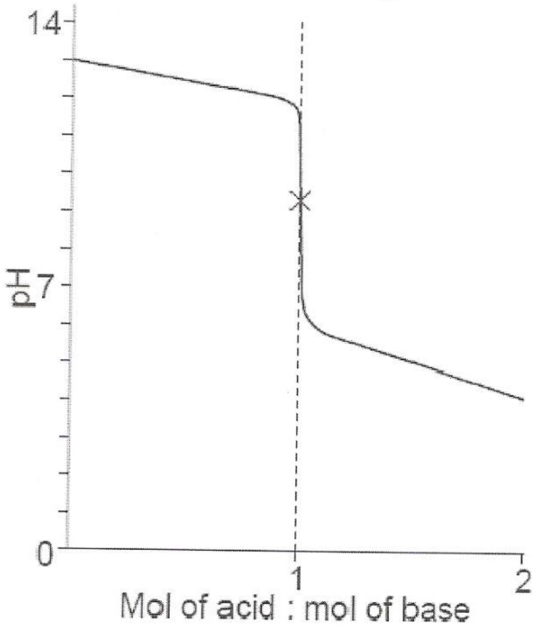

6.50
pH probe
pH meter


14
7
0
pH
Volume acid

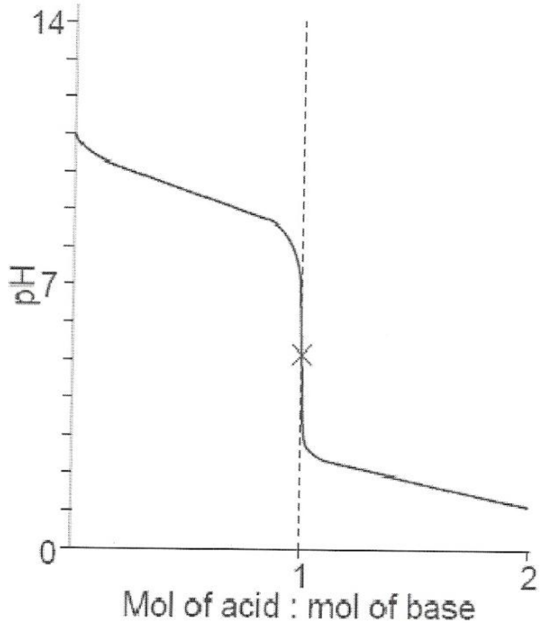
1 strong acid/strong base



2 weak acid/strong base



3 strong acid/weak base



4 weak acid/weak base