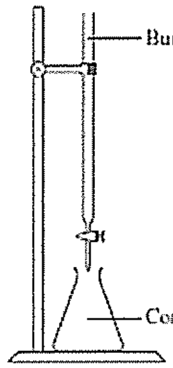
Titrating NaOH and Acetic Acid

Procedure:

Step 1. Rinse a clean 250 mL conical (erlenmeyer) flask with water.

Step 1. Rinse a clean 25.00 mL pipette (pipet) with vinegar.
Pipette 25.00 mL of vinegar into the 250 mL conical (erlenmeyer) flask.



Step 2. Add 2 drops of phenolphthalein indicator to the vinegar.
(The solution will remain colourless)

Step 3. Rinse a clean 50.00 mL burette (buret) with standardised 1.00 mol L^{-1} aqueous sodium hydroxide solution.
Fill the burette (buret) with this standardised 1.00 mol L^{-1} NaOH(aq).

Step 4. Set up the equipment as in the diagram on the right.

Step 5. Run NaOH(aq) from the burette (buret) into the conical (erlenmeyer) flask until the solution changes colour from colourless to pink.

Step 6. Repeat the titration carefully several times until concordant titres are achieved.

Sample Results

	Trial 1 / mL	**Trial 2 / mL**	**Trial 3 / mL**
Final volume of NaOH(aq)	21.82	21.79	21.81
Initial volume of NaOH(aq)	0.00	0.00	0.00
Titre /mL ***(volume of NaOH(aq) used)***	21.82	21.79	21.81

Average Titre /mL

$$\frac{21.82 + 21.79 + 21.81}{3} = 21.81$$

Calculating the Concentration of Acetic Acid in Vingear in mol L^{-1}

a. Write the balanced chemical equation for the neutralisation reaction:

word equation	acetic acid (ethanoic acid)	+ sodium hydroxide	→	sodium acetate (sodium ethanoate)	+ water
balanced chemical equation	$CH_3COOH(aq)$ +	$NaOH(aq)$	→	$CH_3COO^-Na^+(aq)$	+ H_2O

b. Extract all the relevant data from the experiment.

balanced chemical equation	$CH_3COOH(aq)$	+ $NaOH(aq)$ →	$CH_3COO^-Na^+(aq) + H_2O$
volume /mL	25.00	21.81	
concentration /mol L^{-1}	?	1.00	

c. Check the data for consistency:
Concentrations are usually given in M or mol L^{-1} but volumes are often given in mL.
You will need to convert the mL to L for consistency. The easiest way to do this is to multiply the volume in mL x 10^{-3} (which is the same as dividing the volume in mL by 1000)

relevant species	**acid** $CH_3COOH(aq)$	**base** $NaOH(aq)$
volume /mL	25.00	21.81
volume /L	25.00/1000 = 0.02500	21.81/1000 = 0.02181
concentration /mol L^{-1}	?	1.00

d. Calculate the moles of NaOH(aq), n(NaOH)
moles = concentration in mol L^{-1} x volume in L = n = c x V

volume of NaOH(aq) = v(NaOH) = 0.02181 L
concentration of NaOH(aq) = c(NaOH) = 1.00 mol L-1

moles NaOH(aq) = n(NaOH) = c(NaOH) x V(NaOH)
n(NaOH) = 0.02181 x 1.00 = 0.02181 mol

e. Use the balanced chemical equation to determine the stoichiometric (mole) ratio of acid to base:

n(acid):n(base) that is $n(CH_3COOH)$:n(NaOH) is 1:1

f. Use the stoichiometric (mole) ratio to calculate the moles of acetic acid

1 mole of NaOH neutralises 1 mole of CH_3COOH

therefore 0.02181 moles of NaOH neutralises 0.02181 moles of CH_3COOH

moles of acetic acid = $n(CH_3COOH)$ = 0.02181 mol

g. From the volume of vinegar (acetic acid solution) and the moles of acetic acid, calculate its concentration (c) in mol L^{-1} :

concentration (mol L^{-1}) = moles ÷ volume (L)

concentration of acetic acid = moles of acetic acid ÷ volume of acetic acid in L

moles of acetic acid = $n(CH_3COOH)$ = 0.02181 mol

volume of acetic acid solution (vinegar) = $v(CH_3COOH)$ = 0.02500 L

concentration of acetic acid solution (vinegar) = $n(CH_3COOH) \div v(CH_3COOH)$

$c(CH_3COOH) = 0.02181 \div 0.02500 = 0.8724$ mol L^{-1}

Concentration of acetic acid in vinegar in mol L^{-1} (molarity) is 0.8724 mol L^{-1}

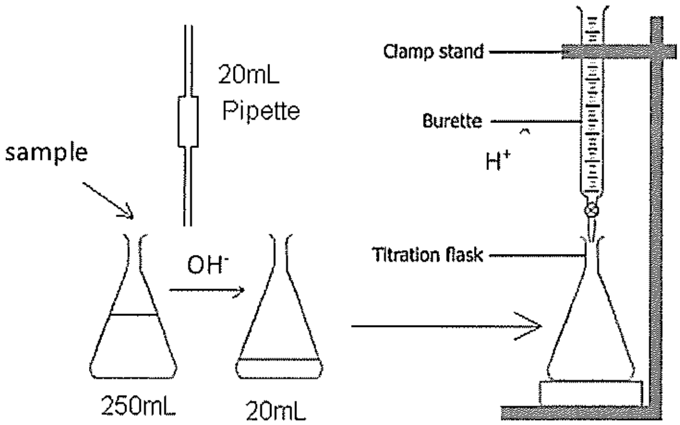
How to do a Titration Calculation

Example: A 2.34g sample of an impure substance that is known to contain sodium hydroxide has been given to you. The sample was dissolved in distilled water and made up to the mark in a 250mL volumetric flask. 18.5mL of a 0.200M standardized solution of Hydrochloric acid, was required to react with 20mL aliquots of the sodium hydroxide solution. Determine the percentage purity of the sample.

Calculate:

a. The number of moles of H^+ which reacted.
b. The number of moles of OH^- in the 20.0mL sample.
c. The number of moles of OH^- in the 250.0mL solution.
d. The mass of OH^- in the whole solution.
e. The percentage purity of the sample.

Step 1 – Draw a diagram.



Step 2 – Determine the number of moles of H^+ which reacted.

n(H^{+-}) = c x V

= 0.200 x 0.0185

= <u>3.70 x 10^{-3} mol</u>

Step 3 – Use the equation to determine the number of moles of OH^- which reacted with the H^+. This is in the 20.0mL sample.

$n(OH^-)_{in\ 20mL}$ = 1/1 x n(H^+)

= 1 x (3.70 x 10^{-3})

= <u>3.70 x 10^{-3} mol</u>

Step 4 – We know the number of moles of OH^- in 20.0mL of sample. We want to know the number of moles of OH^- in the 250.0mL solution. We can use the concentration.

$c(OH^-)$ = n/V in 20mL

= $3.70 \times 10^{-3} / 0.02$

= <u>0.185 $mol.L^{-1}$</u>

Then in 250.0mL n = c x V

= (0.185) x 0.250

= <u>4.62×10^{-2} mol</u>

We can combine these steps:

Since $c_{in\ 250mL} = c_{in\ 20mL}$

$n_1/V_1 = n_2/V_2$

$n(OH^-)_{in\ 250mL} = 250/20 \times n(OH^-)_{in\ 20mL}$

= $250/20 \times 3.70 \times 10^{-3}$

= <u>4.62×10^{-2}mol</u>

Step 5 – We now have the number of moles of OH^- in the 250.0mL flask. We now determine the mass.

$n(OH^-) = n(NaOH)$

m(NaOH) = n x M M(NaOH) = 40.1 $g.mol^{-1}$

= $(4.62 \times 10^{2}) \times 40.1$

= <u>1.85g</u>

Step 6 – This is the mass of pure NaOH in the sample. We divide this by the sample mass to determine purity.

% purity = mass(pure) / mass(sample) x 100

= (1.85 / 2.34) x 100

= <u>79.2%</u>

Random Error and Systematic Error

Definitions

All experimental uncertainty is due to either random errors or systematic errors. **Random errors** are statistical fluctuations (in either direction) in the measured data due to the precision limitations of the measurement device. Random errors usually result from the experimenter's inability to take the same measurement in exactly the same way to get exact the same number. **Systematic errors,** by contrast, are reproducible inaccuracies that are consistently in the same direction. Systematic errors are often due to a problem which persists throughout the entire experiment.

Note that systematic and random errors refer to problems associated with making measurements. ***Mistakes*** made in the calculations or in reading the instrument ***are not considered in error analysis.*** It is assumed that the experimenters are careful and competent!

How to minimize experimental error

Type of Error	**Example**	**How to minimize it**
Random errors	You measure the mass of a ring three times using the same balance and get slightly different values: 17.46 g, 17.42 g, 17.44 g	Take more data. **Random errors** can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations.
Systematic errors	The cloth tape measure that you use to measure the length of an object had been stretched out from years of use. (As a result, all of your length measurements were too small.) The electronic scale you use reads 0.05 g too high for all your mass measurements (because it is improperly tared throughout your experiment).	**Systematic errors** are difficult to detect and cannot be analyzed statistically, because all of the data is off in the same direction (either to high or too low). Spotting and correcting for systematic error takes a lot of care. • How would you compensate for the incorrect results of using the stretched out tape measure? • How would you correct the measurements from improperly tared scale?

Equipment Tolerance

	Burette accuracy /mL	
Capacity, mL	**Class A**	**Class B**
10	0.02	0.04
25	0.03	0.06
50	0.05	0.10
100	0.10	0.20

Class B volumetric glassware has ±mL tolerances twice those of Class A glassware.

Most popular burettes are 10 mL, 25 mL and 50 mL types. 10 mL burettes are usually graduated each 0.05 mL, while 25 mL and 50 mL burettes are usually graduated each 0.1 mL. That means that 50 mL burettes have the highest resolution. 0.050 mL out of 50 mL is 0.1%, and that's about maximum precision that we can get from volume measurement when using burette. In turn that's also about the maximum precision of the titration. We will use these numbers - 50 mL burette, 0.050 mL volume, 0.1% accuracy - throughout the site, when discussing different aspects of titration.

It can be interesting to check relative accuracies of volumetric glass calculated with the use of the tolerances data.

capacity mL	pipette		burette		flask	
	tolerance mL	relative (%)	tolerance mL	relative (%)	tolerance mL	relative (%)
1	0.006	0.60			0.010	1.00
2	0.006	0.30			0.015	0.75
3	0.010	0.33			0.015	0.50
4	0.010	0.25				
5	0.010	0.20			0.020	0.40
10	0.020	0.20	0.020	0.25	0.020	0.20
15	0.030	0.20				
20	0.030	0.15				
25	0.030	0.12	0.030	0.15	0.030	0.12
50	0.050	0.10	0.050	0.13	0.050	0.10
100	0.080	0.08	0.100	0.13	0.080	0.08
200	0.100	0.05			0.100	0.05
250					0.120	0.05
500					0.150	0.03
1000					0.300	0.03
2000					0.500	0.03