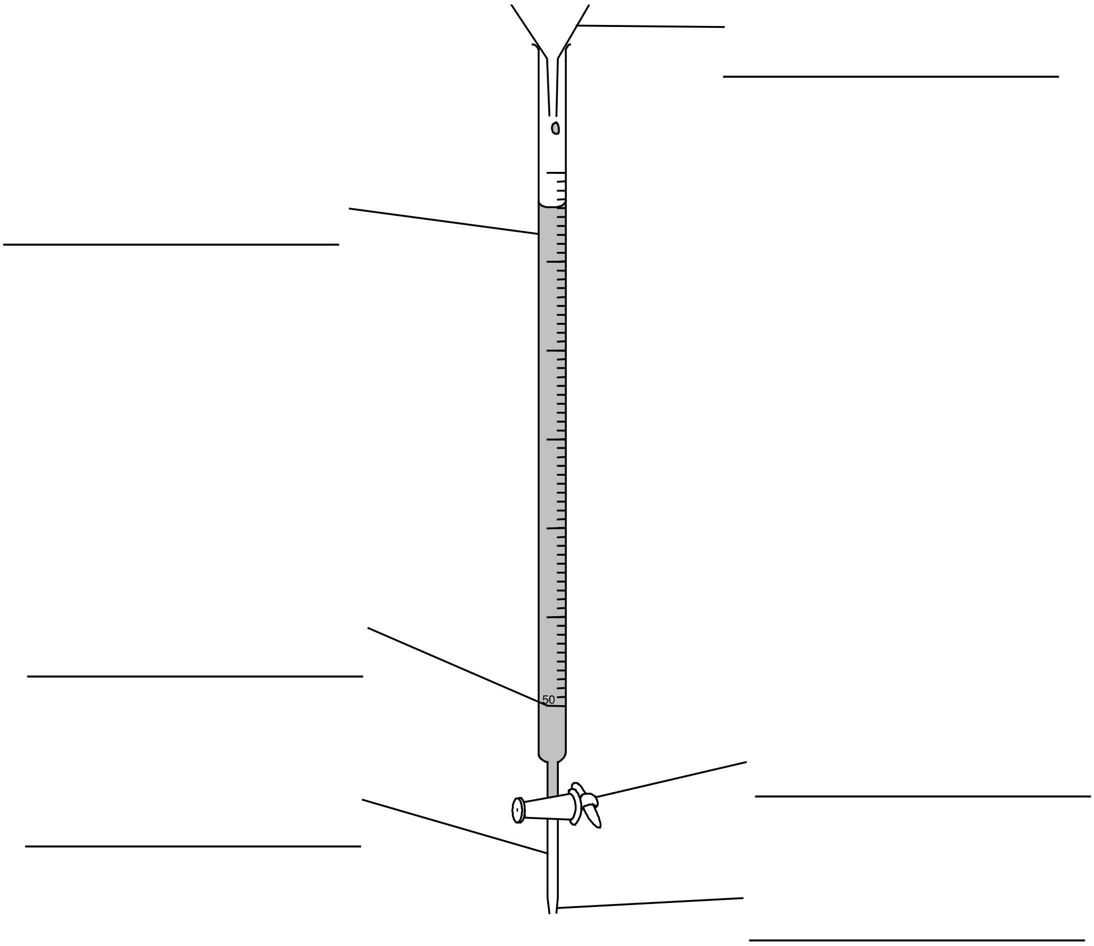
Chemistry: Chapter 19 Volumetric analysis involving acids and alkalis

Combined Science (Chemistry Part): Chapter 19 Volumetric analysis involving acids and alkalis

Sections 19.1−19.3

|!|ELA041919001O|!|

(a) A 50.0 cm^3 burette being used in a titration is shown below.



Label the various parts of the set-up.

(b) Before use, a burette should be washed with distilled water and then with the solution it is to deliver. Why?

(c) Point out ONE error in the set-up.

[7M]

##

(a) From top to bottom:
filter funnel, barrel (OR tube), 50.0 cm^3 mark, stopcock, jet, tip [3]

(b) The burette has to be washed with distillated water to get rid of impurities, which may affect titration results. [1] It is then washed with the solution to get rid of the distillated water which may cling to the inner wall of the tube during the previous washing. [1] If a little bit of distillated water was still left, the solution would be slightly diluted. [1]

(c) The filter funnel should *not* be left in the burette after use, otherwise drops may run into the burette and affect the burette reading. [1]

##

|!|ELA0419190002O|!|

(a) Name a suitable indicator for titration of each of the following neutralizations:

(i) $HCl(aq)$ versus $Na_2CO_3(aq)$

(ii) $H_2SO_4(aq)$ versus $NH_3(aq)$

(iii) $CH_3COOH(aq)$ versus $NaOH(aq)$

(iv) $HNO_3(aq)$ versus $KOH(aq)$

(b) Indicator paper should NOT be used to detect the end point of a titration. Why?

(c) Litmus is usually NOT used to detect end point. Why?

[7M]

##

(a) (i) Methyl orange [1]
(ii) Methyl orange [1]
(iii) Phenolphthalein [1]
(iv) Methyl orange (or phenolphthalein) [1]

(b) It would be quite difficult to observe the colour change of a small piece of paper soaked in solution. [1] Moreover, the colour of the indicator paper would fade if left in solution for too long. [1]

(c) Litmus does not give a sharp colour change. [1]

##

Section 19.4

|!|ELA041919003O|!|

A factory has acidic waste water to be neutralized. Analysis shows that the waste water has a hydrogen ion concentration of 0.60 mol dm^{-3}. Calculate the mass of slaked lime $Ca(OH)_2$ that should be added to each dm^3 of the waste water to completely neutralize the acid.

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[4M]

##

$Ca(OH)_2(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + 2H_2O(l)$ [1]

From the equation, the mole ratio of $Ca(OH)_2 : H^+ = 1:2$

Number of moles of $Ca(OH)_2$ needed = $0.6 \times \frac{1}{2}$ mol = 0.30 mol [1]

Mass of $Ca(OH)_2$ needed = $0.30 \times [40.1 + 2 \times (16.0 + 1.0)]$ g = 22.23 g [1]

##

|!|ELB041919004O|!|

Many oven cleaners contain a powder, but a few contain a liquid. One brand of oven cleaner contains 350 cm^3 of liquid (which is in fact sodium hydroxide solution) per bottle. 25.0 cm^3 of the liquid were diluted to 250 cm^3. 25.0 cm^3 of the diluted solution required 28.5 cm^3 of 0.100 M sulphuric acid for neutralization. Calculate the mass of sodium hydroxide contained in one bottle of the oven cleaner.

[7M]

##

$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$ [1]

From the equation, the mole ratio of H_2SO_4 to NaOH = 1:2 [1]

25.0 cm^3 of the diluted solution required 28.5 cm^3 of 0.100 M H_2SO_4 for neutralization. [1]

25.0 cm^3 of the original solution required $28.5 \times \frac{250}{25.0}$ cm^3 = 285 cm^3 of 0.100 M H_2SO_4 for neutralization. [1]

350 cm^3 of the original solution required $285 \times \frac{350}{25.0}$ cm^3 = 3990 cm^3 of 0.100 M H_2SO_4 for neutralization. [1]

No. of moles of H_2SO_4 required to neutralize 350 cm^3 of the original solution

$= 0.100 \times \frac{3990}{1000}$ mol = 0.399 mol [1]

No. of moles of NaOH in a bottle of the oven cleaner = 0.399 × 2 mol = 0.798 mol

Molar mass of NaOH = 23.0 + 16.0 + 1.0 = 40.0 g mol^{-1}

Mass of NaOH = 0.798 × 40.0 = 31.9 g [1]

The oven cleaner contains 31.9 g of sodium hydroxide.

##

|!|ELB0419190050|!|

(a) What volume of hydrogen chloride gas, measured at room conditions, is required to make 100 cm^3 of 0.25 M hydrochloric acid? (Hint: The volume of 1 mole of any gas at room conditions is 24.0 dm^3)

(b) What volume of water must be added to 25 cm^3 of 1.0 M sodium hydroxide solution to make it 0.20 M?

(c) Concentrated sulphuric acid of density 1.84 g cm^{-3} contains 98% by mass of sulphuric acid. What volume of the concentrated acid should be diluted to prepare 250 cm^3 of 0.50 M solution?

(d) (i) Solution *X* contains 20.0 g of sodium hydroxide per 250 cm^3 of solution. Calculate the molarity of the solution.

(ii) Solution *Y* contains 18.0 g of a solid acid (H_nA) per 100 cm^3 of solution. The molecular mass of the acid is 90.0. Calculate the molarity of the solution.

(iii) 50.0 cm^3 of solution *X* are found to react completely with 25.0 cm^3 of solution *Y*.

(1) Calculate the number of moles of sodium hydroxide in 50.0 cm^3 of solution *X*.

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(2) Calculate the number of moles of H_nA in 25.0 cm^3 of solution *Y*.

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(3) How many moles of sodium hydroxide react completely with 1 mole of H_nA?

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(4) What is the value of n in H_nA?

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(5) Write an equation for the reaction which takes place between solutions *X* and *Y*.

[17 M]

##

(a) No. of moles of HCl = $0.25 \times \frac{100}{1000}$ mol = 0.025 mol [1]

Volume of HCl gas = $0.025 \times 24\,000$ cm^3 = 600 cm^3 [1]

(b) No. of moles of NaOH remains unchanged on dilution.

$(MV)_{\text{before dilution}} = (MV)_{\text{after dilution}}$

$1.0 \times \frac{25}{1000} = 0.20 \times \frac{V}{1000}$ [1]

Volume of 0.20 M NaOH solution = $1.0 \times \frac{25}{1000} \times \frac{1000}{0.20}$ cm^3 = 125 cm^3 [1]

Volume of water added = (125 – 25) cm^3 = 100 cm^3 [1]

(c) No. of moles of H_2SO_4 = $0.50 \times \frac{250}{1000}$ mol = 0.125 mol [1]

Mass of H_2SO_4 = $0.125 \times (1.0 \times 2 + 32.1 + 16.0 \times 4)$ g = 12.3 g [1]

Mass of concentrated sulphuric acid = $12.3 \times \frac{100}{98}$ g = 12.6 g [1]

Volume of concentrated sulphuric acid = $\frac{12.6}{1.84}$ cm^3 = 6.85 cm^3 [1]

(d) (i) Molar mass of NaOH = 23.0 + 16.0 + 1.0 = 40.0 g mol^{-1} [1]

Molarity of solution *X* = $\frac{\left(\frac{20.0}{40.0}\right)}{\left(\frac{250}{1000}\right)}$ = 2.00 M [1]

(ii) Molarity of solution $Y = \dfrac{\left(\dfrac{18.0}{90.0}\right)}{\left(\dfrac{100}{1000}\right)} = 2.00$ M [1]

(iii) (1) No. of moles of NaOH = $2.00 \times \dfrac{50.0}{1000}$ mol = 0.100 mol [1]

(2) No. of moles of $H_nA = 2.00 \times \dfrac{25.0}{1000} = 0.0500$ mol [1]

(3) No. of moles of NaOH reacted with 1 mol of $H_nA = \dfrac{0.100}{0.05} = 2$ mol [1]

(4) n = 2 [1]

(5) $H_2A(aq) + 2NaOH(aq) \rightarrow Na_2A(aq) + 2H_2O(l)$ [1]

##

|!|ELA041919006O|!|

In an experiment to determine the concentration of ammonia solution, 25.0 cm^3 of the ammonia solution was transferred into a conical flask and titrated against 0.1 M sulphuric acid. A few drops of indicator were added. The titration results are listed in the table below:

	1	2	3	4
Final reading (cm^3)	15.90	16.70	18.40	18.50
Initial reading (cm^3)	0.00	1.50	3.10	3.40

(a) Which indicator is suitable for this titration?

____

(b) What will be the colour change of the indicator at the end point?

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(c) (i) Calculate the reasonable average volume of sulphuric acid used.

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(ii) Calculate the molarity of the ammonia solution.

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(d) Name the salt formed and suggest ONE common use of the salt.

[8M]

##

(a) Methyl orange [1]

(b) From yellow to orange [1]

(c) (i) Ignore the first titration data.

Average volume of sulphuric acid used = $\frac{(15.20+15.30+15.10)\text{cm}^3}{3}$

= 15.20 cm^3 [1]

(ii) $2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$

Number of moles of sulphuric acid used = $0.1 \times \frac{15.20}{1000}$ mol

= 0.00152 mol [1]

From the equation, mole ratio of $NH_3 : H_2SO_4 = 2 : 1$

Number of moles of ammonia in 25.0 cm^3 ammonia solution = 0.00152 × 2 mol = 0.00304 mol [1]

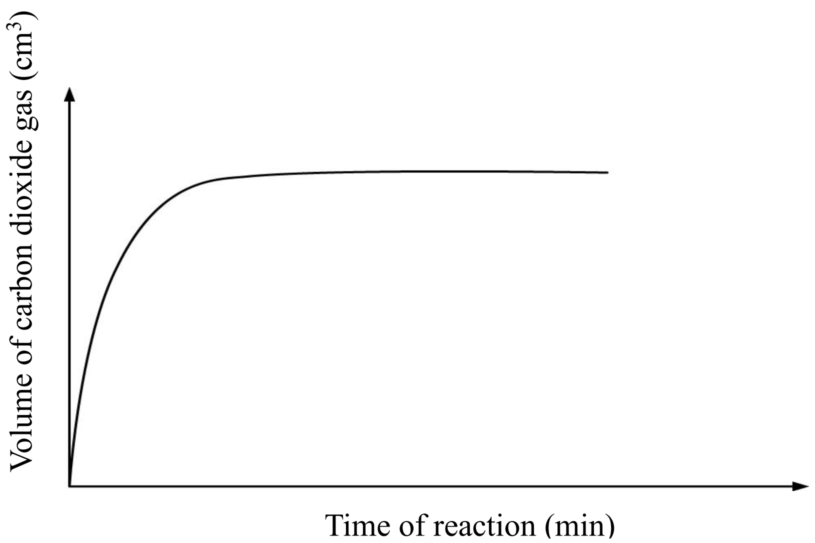
Molarity of ammonia solution = $\frac{0.00304}{\frac{25.0}{1000}}$ M = 0.122 M [1]

(d) Ammonium sulphate [1] It is used to make fertilizer. [1]

##

|!|ELB041919007O|!|

In an experiment, 100 cm^3 of 1.0 M hydrochloric acid was added to 0.1 g of calcium carbonate granules. The graph below shows the results obtained in the experiment.



(a) Write a chemical equation for the reaction between 1.0 M hydrochloric acid and calcium carbonate granules.

____

(b) (i) The experiment was repeated using the same amount of calcium carbonate and 1.0 M ethanoic acid instead of 1.0 M hydrochloric acid. Sketch, on the same graph, the results that would be obtained in the repeated experiment.

(ii) Would the total volumes of carbon dioxide gas collected be the same for both experiments? Explain your answer.

____

(c) 1.0 M hydrochloric acid and 1.0 M ethanoic acid have different electrical conductivities. State and explain which solution has higher electrical conductivity.

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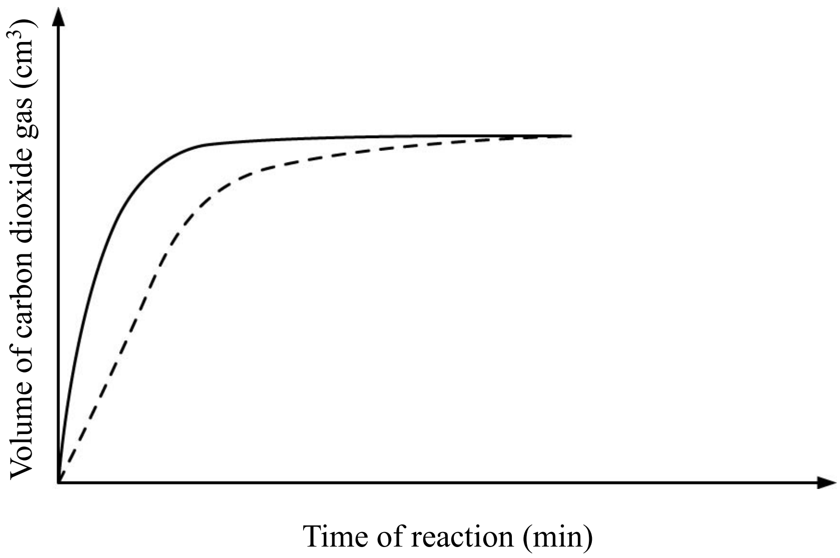
[6M]

##

(a) $2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$ [1]

(b) (i)



[1]

(ii) Yes. This is because calcium carbonate is the limiting reagent. [1]

(c) 1.0 M hydrochloric acid should have higher electrical conductivity. [1]
1.0 M hydrochloric acid is a strong acid which completely ionizes in water, [1] while 1.0 M ethanoic acid is a weak acid which slightly ionizes in water. [1]

##

|!|ELA0419190080|!|

Calculate the volume of 0.10 M nitric acid required to react completely with 50.0 cm^3 of 0.05 M ammonia solution.

[4M]

##

$HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)$ [1]

Number of moles of NH_3 in 50.0 cm^3 of 0.05 M NH_3

$= 0.05 \times \dfrac{50.0}{1000}$ mol

$= 2.5 \times 10^{-3}$ mol [1]

From the equation, mole ratio of $HNO_3 : NH_3 = 1 : 1$ [1]

Number of moles of HNO_3 in 0.10 M HNO_3

$= 2.5 \times 10^{-3}$ mol [1]

Volume of HNO_3 required to react with NH_3

$$0.10 = \frac{2.5 \times 10^{-3}}{\text{Volume of } HNO_3 \text{ required}}$$

Volume of HNO_3 required = 0.025 dm^3
= 25.0 cm^3 [1]
##

|!|ELA041919009O|!|
Calculate the molarity of the nitric acid, 25.0 cm^3 of which completely neutralizes:
(a) 25.0 cm^3 of 0.2 M sodium hydroxide solution.

(b) 20.0 cm^3 of 0.040 M sodium carbonate solution.

(c) 30.0 cm^3 of 0.10 M ammonia solution.

[9M]

##

(a) $HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$

Number of moles of NaOH in 25.0 cm^3 of 0.2 M NaOH

$= 0.2 \times \frac{25.0}{1000}$ mol

= 0.005 mol [1]

From the equation, mole ratio of HNO_3 : NaOH = 1 : 1

Number of moles of HNO_3 used

= 0.005 mol [1]

Molarity of HNO_3

$= \frac{0.005}{\frac{25.0}{1000}}$ M

= 0.2 M [1]

(b) $2HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + CO_2(g) + H_2O(l)$

Number of moles of Na_2CO_3 in 20.0 cm^3 of 0.040 M Na_2CO_3

$= 0.040 \times \frac{20.0}{1000}$ mol

= 0.0008 mol [1]

From the equation, mole ratio of HNO_3 : Na_2CO_3 = 2 : 1 [1]

Number of moles of HNO_3 used

$= 0.0008 \times 2$

= 0.0016 mol [1]

Molarity of HNO_3

$$= \frac{0.0016}{\frac{25.0}{1000}} \text{ M}$$

= 0.064 M [1]

(c) $HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)$

Number of moles of NH_3 in 30.0 cm^3 of 0.10 M NH_3

$$= 0.10 \times \frac{30.0}{1000} \text{ mol}$$

= 0.003 mol [1]

From the equation, mole ratio of $HNO_3 : NH_3 = 1 : 1$

Number of moles of HNO_3 used

= 0.003 mol [1]

Molarity of HNO_3

$$= \frac{0.003}{\frac{25.0}{1000}} \text{ M}$$

= 0.12 M [1]

##

|!|ELA0419190010O|!|

25.0 cm^3 of sodium carbonate solution was titrated against 0.50 M hydrochloric acid. 22.0 cm^3 of the hydrochloric acid was required for complete neutralization of the carbonate. Find the concentration of the sodium carbonate solution in

(a) molarity,

(b) g dm^{-3}.

[4M]

##

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

Number of moles of HCl in 22.0 cm^3 of 0.50 M HCl

$= 0.50 \times \frac{22.0}{1000}$ mol

= 0.011 mol [1]

From the equation, mole ratio of HCl : Na_2CO_3 = 2 : 1

Number of moles of Na_2CO_3 in 25.0 cm^3 of solution

$= \frac{0.011}{2}$ mol

$= 5.5 \times 10^{-3}$ mol [1]

Concentration of Na_2CO_3

$= \frac{5.5 \times 10^{-3}}{\frac{25.0}{1000}}$ M

= 0.22 M [1]

(b) Molar mass of Na_2CO_3

$= (23.0 \times 2 + 12.0 + 16.0 \times 3) = 106.0$ g mol^{-1}

From (a), molarity of Na_2CO_3 is 0.22 mol dm^{-3},

Concentration of Na_2CO_3 in g dm^{-3}

$= 0.22 \times 106.0$ g dm^{-3}

$= 23.3$ g dm^{-3} [1]

##

|!|ELA041919011O|!|

Lemons contain a solution of citric acid. The formula of citric acid is $C_6H_8O_7$. A solution known to contain 1.6 g of citric acid was found to require 25.0 cm^3 of 1 M sodium hydroxide solution for neutralization.

(a) What is the molar mass of citric acid?

(b) How many moles of citric acid are present in the solution?

(c) How many moles of sodium hydroxide are present in 25.0 cm^3 of 1.0 M sodium hydroxide?

(d) Is citric acid monobasic, dibasic or tribasic?

[5M]

##

(a) Molar mass of $C_6H_8O_7$

$= (12.0 \times 6 + 1.0 \times 8 + 16.0 \times 7)$

$= 192.0$ g mol^{-1} [1]

(b) Number of moles of $C_6H_8O_7$ in the solution

$= \frac{1.6}{192.0}$ mol

$= 8.33 \times 10^{-3}$ mol [1]

(c) Number of moles of NaOH in 25.0 cm^3 of 1 M sodium hydroxide

$= 1 \times \frac{25.0}{1000}$ mol

= 0.025 mol [1]

(d) $\dfrac{\text{Number of moles of citric acid}}{\text{Number of moles of NaOH}}$

$= \dfrac{8.33 \times 10^{-3}}{0.025}$

$= \dfrac{1}{3}$ [1]

So, citric acid is tribasic. [1]

##

|!|ELA0419190120|!|

25.0 cm^3 of a solution of a tribasic acid H_3Y (containing 4.9 g of the acid per dm^3) required 37.5 cm^3 of 0.1 M sodium hydroxide solution for complete neutralization.

(a) Write a full equation for the reaction.

____

(b) How many moles of sodium hydroxide are used to neutralize the acid?

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(c) How many moles of the acid are present in 25.0 cm^3 of the solution?

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(d) How many moles of the acid are present in 1.0 dm^3 of the solution?

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(e) What is the molar mass of the acid?

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[6M]

##

(a) $H_3Y(aq) + 3NaOH(aq) \rightarrow Na_3Y(aq) + 3H_2O(l)$ [1]

(b) $H_3Y(aq) + 3NaOH(aq) \rightarrow Na_3Y(aq) + 3H_2O(l)$

Number of moles of NaOH in 37.5 cm^3 of 0.1 M NaOH

$= 0.1 \times \frac{37.5}{1000}$ mol

$= 3.75 \times 10^{-3}$ mol [1]

(c) From the equation, mole ratio of H_3Y : NaOH = 1 : 3 [1]

Number of moles of H_3Y in 25.0 cm^3 of solution

$= \frac{3.75 \times 10^{-3}}{3}$ mol

$= 1.25 \times 10^{-3}$ mol [1]

(d) Number of moles of H_3Y in 1.0 dm^3 of the solution

$= 1.25 \times 10^{-3} \times \frac{1000}{25.0}$ mol

= 0.05 mol [1]

(e) Let M be the molar mass of the H_3Y.

$M = \frac{4.9}{0.05}$

$M = 98.0$ g mol^{-1} [1]

##

|!|ELA0419190130|!|

4.15 g of a sample of hydrated sodium carbonate, of formula $Na_2CO_3 \cdot nH_2O$, is dissolved in water and the solution made up to 250.0 cm^3. With methyl orange as indicator, 25.0 cm^3 of this solution requires 29.0 cm^3 of 0.05 M sulphuric acid for neutralization. Calculate n, the number of molecules of water of crystallization in a formula unit of the sodium carbonate hydrate sample.

[5M]

##

$Na_2CO_3 \cdot nH_2O(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + CO_2(g) + (n + 1)\ H_2O(l)$ [1]

Molar mass of $Na_2CO_3 \cdot nH_2O$ = (106.0 + 18.0n) g mol^{-1}

Number of moles of H_2SO_4 in 29.0 cm^3 of 0.05 M H_2SO_4

$= 0.05 \times \frac{29.0}{1000}$ mol

$= 1.45 \times 10^{-3}$ mol [1]

From the equation, mole ratio of $Na_2CO_3 \cdot nH_2O : H_2SO_4 = 1 : 1$

Number of moles of $Na_2CO_3 \cdot nH_2O$ in 25.0 cm^3 solution

$= 1.45 \times 10^{-3}$ mol [1]

Number of moles of $Na_2CO_3 \cdot nH_2O$ in 250.0 cm^3 solution

$= 1.45 \times 10^{-3} \times \frac{250.0}{25.0}$ mol

= 0.0145 mol [1]

$\therefore \frac{4.15}{106.0 + 18.0n} = 0.0145$

n = 10 [1]

##

|!|ELA041919014O|!|

4.77 g of an impure sample of anhydrous sodium carbonate required 31.5 cm^3 of 1 M sulphuric acid for complete neutralization. What is the percentage purity of anhydrous sodium carbonate in the sample?

[5M]

##

$Na_2CO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + CO_2(g) + H_2O(l)$ [1]

Number of moles of H_2SO_4 in 31.5 cm^3 of 1 M H_2SO_4

$= 1 \times \frac{31.5}{1000}$ mol

= 0.0315 mol [1]

From the equation, mole ratio of $H_2SO_4 : Na_2CO_3 = 1 : 1$

Number of moles of Na_2CO_3 in the sample

= 0.0315 mol [1]

Molar mass of Na_2CO_3

= 106.0 g mol^{-1}

Mass of Na_2CO_3 in the sample

= 0.0315 × 106.0 g

= 3.339 g [1]

Percentage purity of the Na_2CO_3 sample

$= \frac{3.339}{4.77} \times 100\%$

= 70 % [1]

##

|!|ELA0419190015O|!|

0.985 g of an anhydrous metal carbonate (formula XCO$_3$) required 40.0 cm^3 of 0.25 M hydrochloric acid for complete neutralization. Calculate the relative atomic mass of the metal *X*.

[4M]

##

$XCO_3 + 2HCl \rightarrow XCl_2 + CO_2 + H_2O$ [1]

Number of moles of HCl in 40.0 cm^3 of 0.25 M HCl

$= 0.25 \times \frac{40.0}{1000}$ mol = 0.01 mol [1]

From the equation, mole ratio of XCO_3 : HCl = 1 : 2

Number of moles of XCO_3 reacted with HCl

$= \frac{0.01}{2}$ mol

$= 5 \times 10^{-3}$ mol [1]

Let the relative atomic mass of X be y,

$$\frac{0.985}{y + 12.0 + 16.0 \times 3} = 5 \times 10^{-3}$$

$$y = 137.0 \text{ [1]}$$

##

|!|ELA041919016O|!|

Sodium chloride can be prepared in the school laboratory by reacting 0.5 M sodium hydroxide solution with dilute hydrochloric acid. A student carried out a titration to find out how much dilute hydrochloric acid was needed to react with 25.0 cm^3 of 0.5 M sodium hydroxide.

(a) Write a full chemical equation for the reaction.

(b) Draw a labelled diagram for the set-up of the titration.

(c) Methyl orange can be used to determine the end point of the titration. State the colour change at the end point.

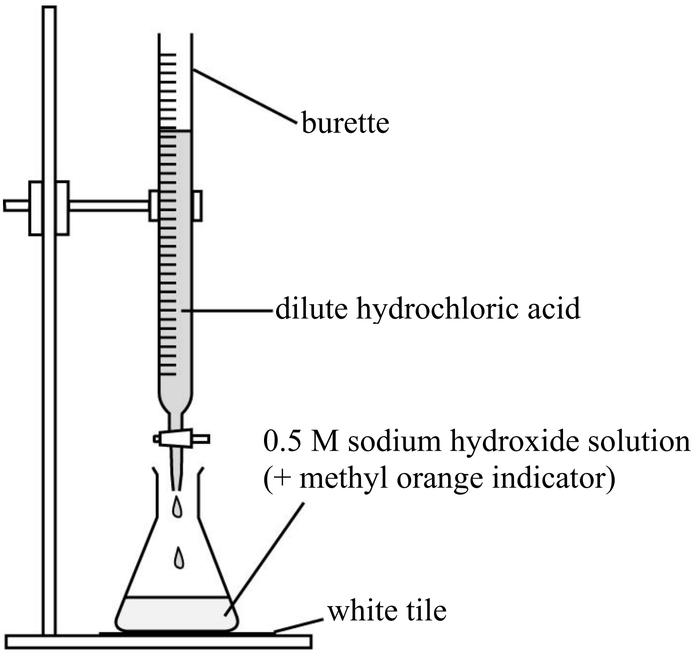
(d) Suggest how the student can prepare large pieces of dry sodium chloride crystals using the titration results.

[6M]

##

(a) $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ [1]

(b)



For correct drawing [1]

For correct labeling [1]

(c) From yellow to orange [1]

(d) Repeat the titration, but do not add indicator. Boil the solution to concentrate it. Then cool the hot concentrated sodium chloride solution under room conditions. Large pieces of sodium chloride crystals will separate out. Filter the crystals and dry in an oven. [2]

##