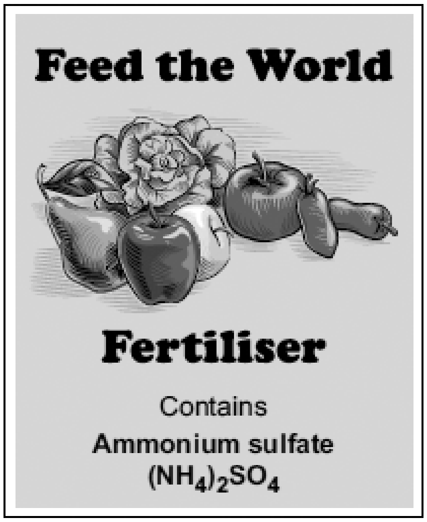
1 Ammonium sulfate is an artificial fertiliser.



(a) (i) When this fertiliser is warmed with sodium hydroxide solution, ammonia gas is given off.
Describe and give the result of a test for ammonia gas.

Test ....

....

Result ....

....

(2)

(ii) Describe and give the result of a chemical test to show that this fertiliser contains sulfate ions (SO_4^{2-}).

Test ....

....

Result ....

....

(2)

(b) Ammonium sulfate is made by reacting sulfuric acid (a *strong* acid) with ammonia solution (a *weak* alkali).

(i) Explain the meaning of *strong* in terms of ionisation.

....

(1)

(ii) A student made some ammonium sulfate in a school laboratory.

The student carried out a titration, using a suitable indicator, to find the volumes of sulfuric acid and ammonia solution that should be reacted together.

Name a suitable indicator for strong acid-weak alkali titrations.

....

(1)

(iii) The student found that 25.0 cm^3 of ammonia solution reacted completely with 32.0 cm^3 of sulfuric acid of concentration 0.050 moles per cubic decimetre.

The equation that represents this reaction is:

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

Calculate the concentration of this ammonia solution in moles per cubic decimetre.

....

....

....

....

....

Concentration = ... moles per cubic decimetre

(3)

(iv) Use your answer to (b)(iii) to calculate the concentration of ammonia in grams per cubic decimetre.

(If you did not answer part (b)(iii), assume that the concentration of the ammonia solution is 0.15 moles per cubic decimetre. This is **not** the correct answer to part (b)(iii).)

Relative formula mass of ammonia (NH_3) = 17.

....

....

....

Concentration = ... grams per cubic decimetre

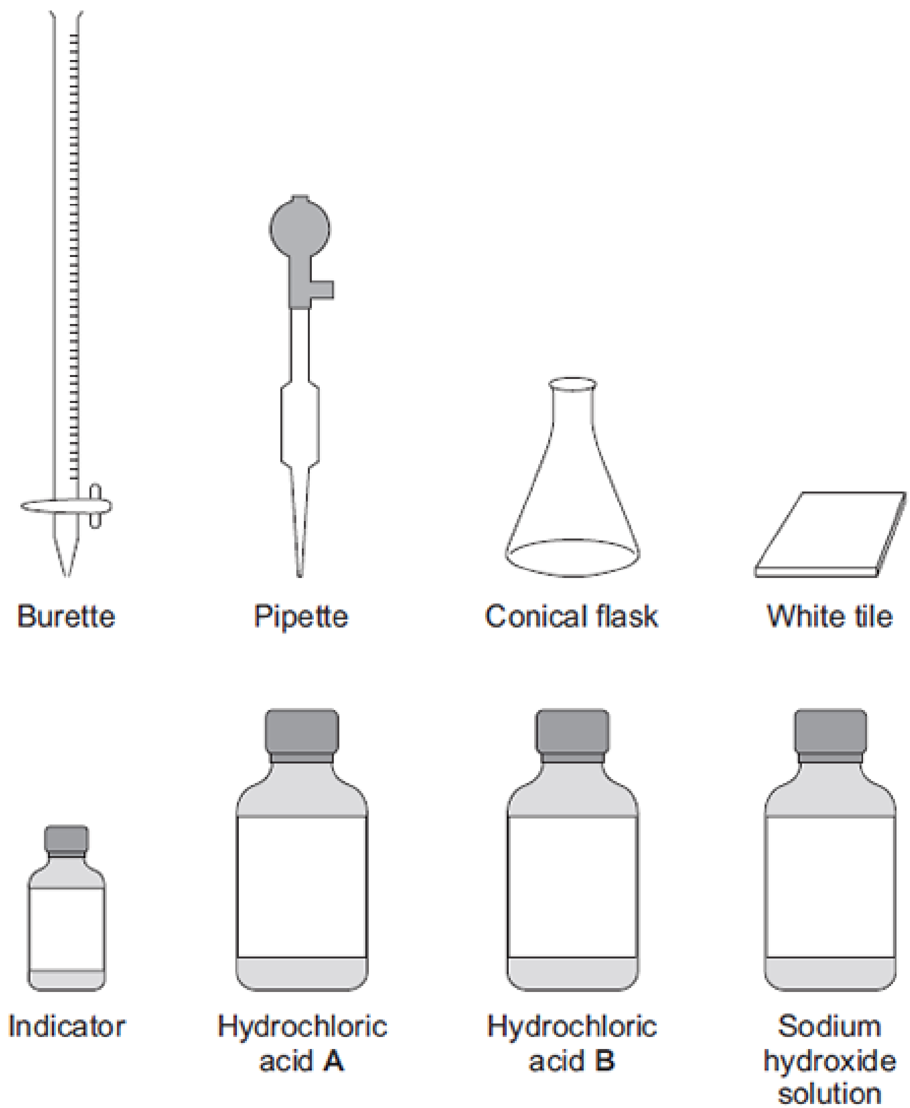
(2)

(Total 11 marks)

2 **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

A student has to check if two samples of hydrochloric acid, **A** and **B**, are the same concentration.

Describe how the student could use the apparatus and the solutions in the diagram below to carry out titrations.



(Total 6 marks)

3 In 1916, during the First World War, a German U-boat sank a Swedish ship which was carrying a cargo of champagne. The wreck was discovered in 1997 and the champagne was brought to the surface and analysed.

(a) 25.0 cm^3 of the champagne were placed in a conical flask.

Describe how the volume of sodium hydroxide solution needed to react completely with the weak acids in 25.0 cm^3 of this champagne can be found by titration, using phenolphthalein indicator.

Name any other apparatus used.

....

....

....

....

....

....

....

....

(4)

(b) The acid in 25.0 cm^3 of the champagne reacted completely with 13.5 cm^3 of sodium hydroxide of concentration 0.10 moles per cubic decimetre.

Calculate the concentration in moles per cubic decimetre of acid in the champagne.

Assume that 1 mole of sodium hydroxide reacts completely with 1 mole of acid.

....

....

....

....

Concentration = ... moles per cubic decimetre

(2)

(c) Is analysis by titration enough to decide whether this champagne is safe to drink?

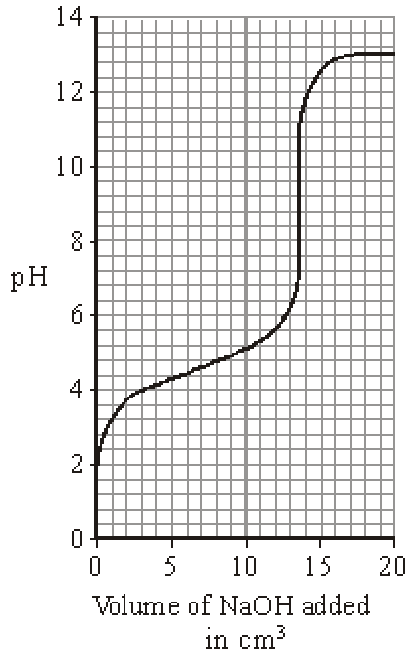
Explain your answer.

....

....

(1)

(d) The graph shows how the pH of the solution changes during this titration.



Phenolphthalein is the indicator used in this titration. It changes colour between pH 8.2 and pH 10.0.

Methyl orange is another indicator. It changes colour between pH 3.2 and pH 4.4.

Suggest why methyl orange is **not** a suitable indicator for this titration.

....

....

....

....

(2)

(Total 9 marks)

4 An oven cleaner solution contained sodium hydroxide. A 25.0 cm^3 sample of the oven cleaner solution was placed in a flask. The sample was titrated with hydrochloric acid containing 73 g/dm^3 of hydrogen chloride, HCl.

(a) Describe how this titration is carried out.

....

....

....

....

....

(3)

(b) Calculate the concentration of the hydrochloric acid in mol/dm^3.

Relative atomic masses: H 1; Cl 35.5

....

Answer = ... mol/dm^3

(2)

(c) 10.0 cm^3 of hydrochloric acid were required to neutralise the 25.0 cm^3 of oven cleaner solution.

(i) Calculate the number of moles of hydrochloric acid reacting.

....

Answer = ... mol

(2)

(ii) Calculate the concentration of sodium hydroxide in the oven cleaner solution in mol/dm^3.

....

Answer = ... mol/dm^3

(2)

(Total 9 marks)

5 A student carried out a titration to find the concentration of a solution of hydrochloric acid. The following paragraph was taken from the student's notebook.

I filled a burette with hydrochloric acid. 25.0 cm^3 of 0.40 mol/dm^3 potassium hydroxide was added to a flask. 5 drops of indicator were added. I added the acid to the flask until the indicator changed colour. The volume of acid used was 35.0 cm^3.

(a) What piece of apparatus would be used to measure 25.0 cm^3 of the potassium hydroxide solution?

....

(1)

(b) Name a suitable indicator that could be used.

....

(1)

(c) Calculate the number of moles of potassium hydroxide used.

....

....

Moles of potassium hydroxide = ... mol

(2)

(d) Calculate the concentration of the hydrochloric acid. The equation for the reaction is:

$KOH + HCl \rightarrow KCl + H_2O$

....

....

....

Concentration of hydrochloric acid = ... mol/dm^3

(2)

(Total 6 marks)

6 (a) This label has been taken from a bottle of vinegar.

Vinegar is used for seasoning foods. It is a solution of ethanoic acid in water.

In an experiment, it was found that the ethanoic acid present in a 15.000 cm^3 sample of vinegar was neutralised by 45.000 cm^3 of sodium hydroxide solution, of concentration 0.20 moles per cubic decimetre (moles per litre).

The equation which represents this reaction is

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

Calculate the concentration of the ethanoic acid in this vinegar:

(i) in moles per cubic decimetre (moles per litre);

....

....

....

....

Concentration =.................................. moles per cubic decimetre

(2)

(ii) in grams per cubic decimetre (grams per litre).

Relative atomic masses: H = 1; C = 12; O = 16.

....

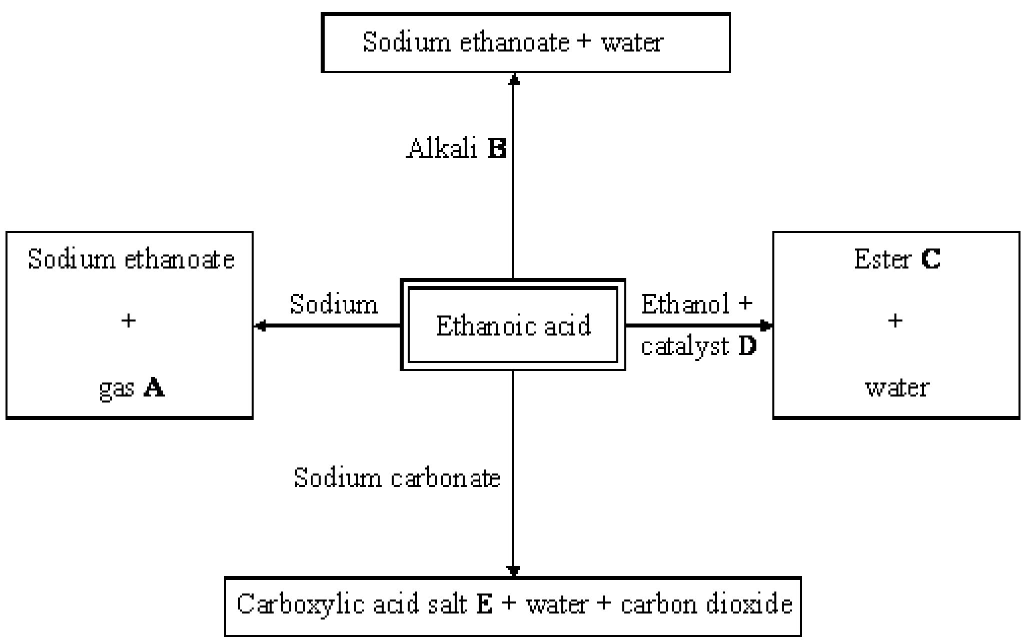
....

....

Concentration = ... grams per cubic decimetre

(2)

(b) The flow diagram shows some reactions of ethanoic acid.



Give the name of:

(i) gas **A**,

....

(1)

(ii) alkali **B**,

....

(1)

(iii) ester **C**,

....

(1)

(iv) catalyst **D**,

....

(1)

(v) carboxylic acid salt **E**.

....

(1)

(Total 9 marks)

7 A student carried out a titration to find the concentration of a solution of sulphuric acid. 25.0 cm^3 of the sulphuric acid solution was neutralised exactly by 34.0 cm^3 of a potassium hydroxide solution of concentration 2.0 mol/dm^3. The equation for the reaction is:

$$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$$

(a) Describe the experimental procedure for the titration carried out by the student.

....

....

....

....

....

....

....

....

(4)

(b) Calculate the number of moles of potassium hydroxide used.

....

Number of moles = ...

(2)

(c) Calculate the concentration of the sulphuric acid in mol/dm^3.

....

....

....

....

Concentration = ... mol/dm^3

(3)

(Total 9 marks)

8 Vinegar can be added to food. Vinegar is an aqueous solution of ethanoic acid.

Ethanoic acid is a *weak* acid.

(a) Which ion is present in aqueous solutions of all acids?

....

(1)

(b) What is the difference between the pH of a *weak* acid compared to the pH of a strong acid of the same concentration?

Give a reason for your answer.

....

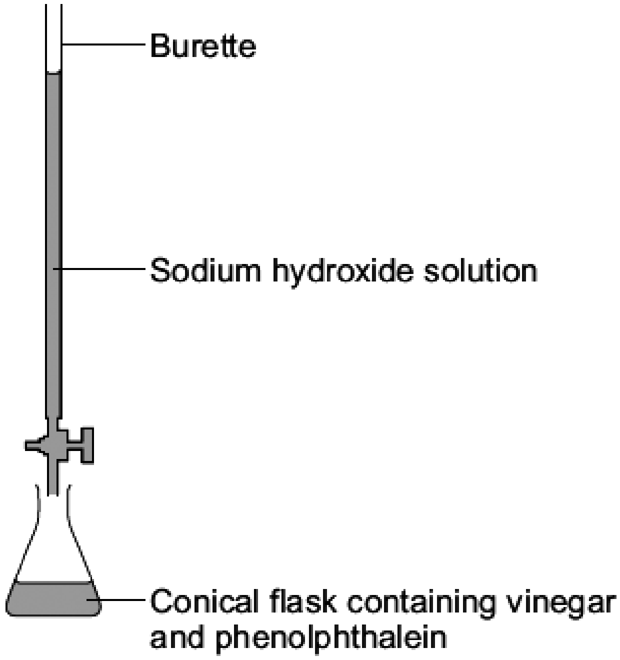
....

....

....

(2)

(c) The diagram shows the apparatus used to find the concentration of ethanoic acid in vinegar.



(i) Why should phenolphthalein indicator be used for this titration instead of methyl orange?

....

....

(1)

(ii) 25.00 cm^3 of vinegar was neutralised by 30.50 cm^3 of a solution of sodium hydroxide with a concentration of 0.50 moles per cubic decimetre.

The equation for this reaction is:

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$$

Calculate the concentration of ethanoic acid in this vinegar.

....

....

....

....

Concentration of ethanoic acid in this vinegar = ... moles per cubic decimetre

(2)

(d) The concentration of ethanoic acid in a different bottle of vinegar was 0.80 moles per cubic decimetre.

Calculate the mass in grams of ethanoic acid (CH_3COOH) in 250 cm^3 of this vinegar.
The relative formula mass (M_r) of ethanoic acid = 60.

....

....

....

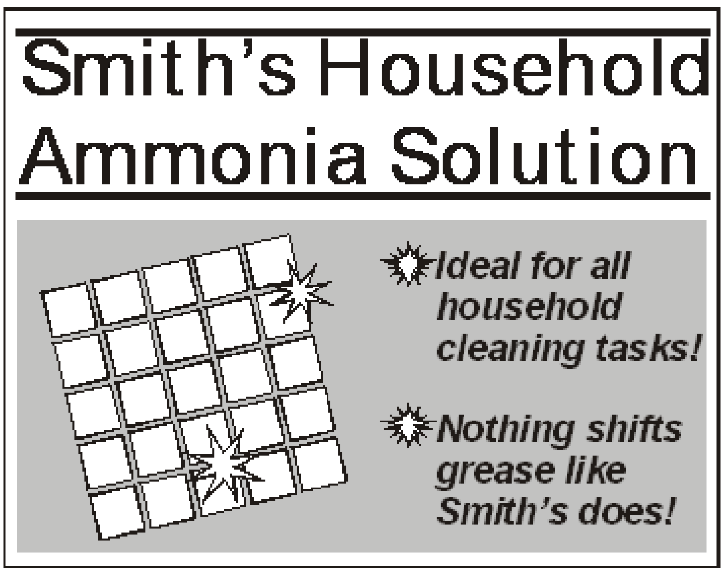
....

Mass of ethanoic acid = ... g

(2)

(Total 8 marks)

9 This label has been taken from a bottle of household ammonia solution.



Household ammonia is a dilute solution of ammonia in water. It is commonly used to remove grease from ovens and windows.

(a) The amount of ammonia in household ammonia can be found by titration.

$25.0\ cm^3$ of household ammonia is placed in a conical flask. Describe how the volume of dilute nitric acid required to neutralise this amount of household ammonia can be found accurately by titration. Name any other apparatus and materials used.

To gain full marks you should write down your ideas in good English. Put them into a sensible order and use correct scientific words.

....

....

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....

(4)

(b) In an experiment, it was found that $25.0\ cm^3$ of household ammonia was neutralised by $20.0\ cm^3$ of dilute nitric acid with a concentration of 0.25 moles per cubic decimetre.

The balanced symbol equation which represents this reaction is

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

Calculate the concentration of the ammonia in this household ammonia in moles per cubic decimetre.

....

....

....

....

Concentration = ... moles per cubic decimetre

(2)

(c) The salt, ammonium nitrate, is formed in this reaction.

Describe, and give the result of, a chemical test which shows that ammonium nitrate contains ammonium ions.

....

....

....

....

(2)

(Total 8 marks)

10 Vinegar can be added to food.

Vinegar is a solution of ethanoic acid in water.

(a) Ethanoic acid is a *weak* acid.

Draw a ring around the correct answer to complete each sentence.

(i) When dissolved in water, an acid forms a solution containing

carbonate ions.
hydrogen ions.
hydroxide ions.

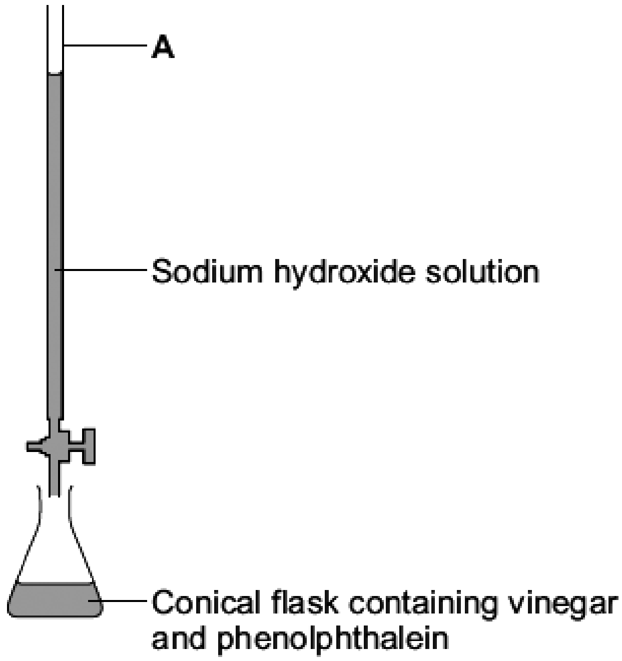
(1)

(ii) Ethanoic acid is a *weak* acid because in water it is

completely ionised.
not ionised.
partially ionised.

(1)

(b) The diagram shows the apparatus used to investigate the amount of ethanoic acid in vinegar.



(i) Draw a ring around the name of the piece of apparatus labelled **A** on the diagram.

burette **measuring cylinder** **pipette**

(1)

(ii) Phenolphthalein is added to the vinegar in the conical flask so that the end point of the titration can be seen.

What type of substance is phenolphthalein?

Draw a ring around the correct answer.

alkali **catalyst** **indicator**

(1)

(iii) How would you know that the end point of the titration has been reached?

....

....

(1)

(c) The results of the titration are shown in the table.

	Rough titration	Accurate titrations		
		1	2	3
Final reading in cm^3	22	21.30	22.50	24.40
Initial reading in cm^3	0	1.00	2.00	4.00
Volume used in cm^3	22	20.30	20.50	20.40

Calculate the best value of the mean volume from these titrations.

....

....

....

Mean volume used = ... cm^3

(2)

(d) 25.0 cm^3 of this vinegar contained 1.25 g of ethanoic acid.

Calculate the mass of ethanoic acid in 1 litre (1000 cm^3) of this vinegar.

....

....

....

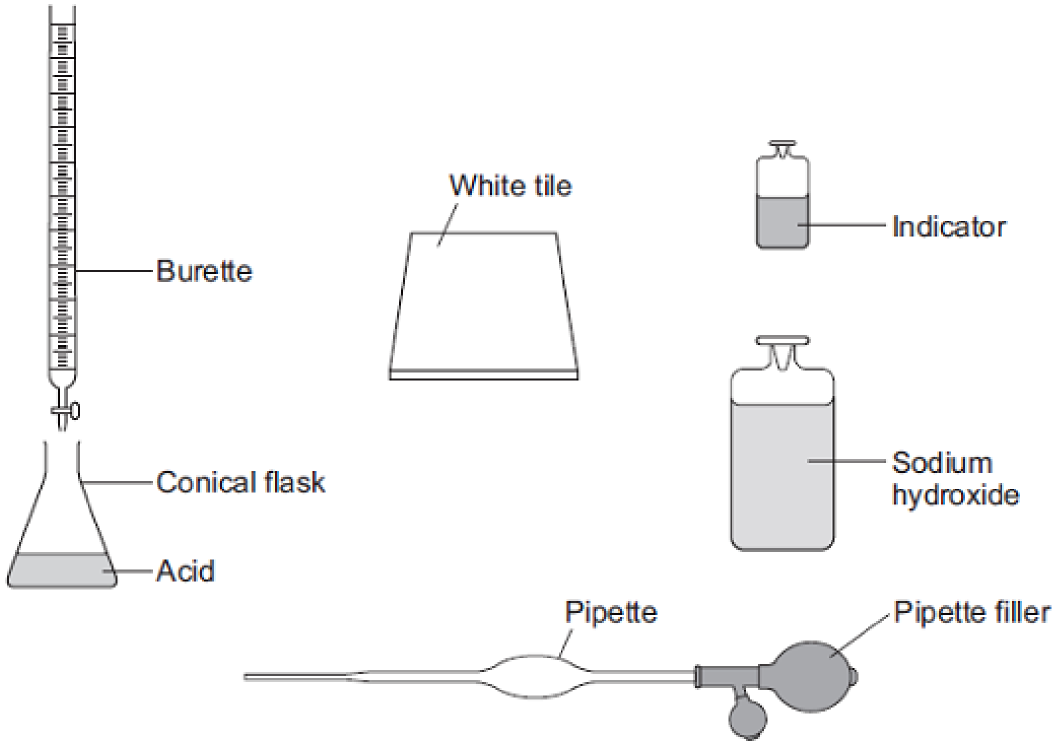
Mass = ... g

(2)

(Total 9 marks)

11 *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

A student used the equipment shown to do a titration.



Describe how the student should use this equipment to find the volume of sodium hydroxide solution that reacts with a known volume of acid.
Include any measurements the student should make.

Do **not** describe how to do any calculations.

....

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....

....

(Total 6 marks)

12 (a) A student had a colourless solution.

The student thought the solution was dilute hydrochloric acid.

(i) The student added universal indicator to this solution.

What colour would the universal indicator change to if the solution is hydrochloric acid?

....

(1)

(ii) Describe how the student could show that there are chloride ions in this solution.

....

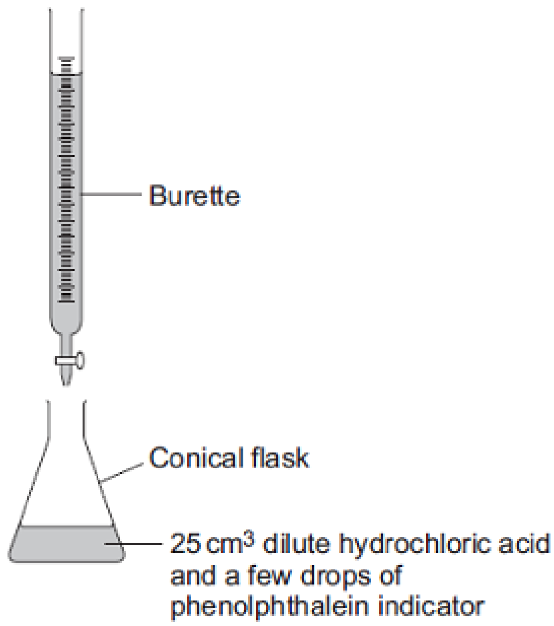
....

....

....

(2)

(b) The results of a titration can be used to find the concentration of an acid.



Describe how to use the apparatus to do a titration using 25 cm^3 of dilute hydrochloric acid.

In your answer you should include:

- how you will determine the end point of the titration
- how you will make sure the result obtained is accurate.

....

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....

....

(4)

(c) Hydrochloric acid is a strong acid.

Ethanoic acid is a *weak acid*.

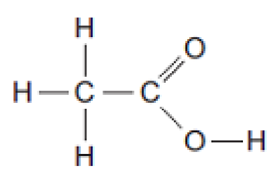
What is meant by the term *weak acid*?

....

....

(1)

(d) The displayed formula of ethanoic acid is:



(i) On the formula, draw a circle around the functional group in ethanoic acid.

(1)

(ii) Ethanoic acid and ethanol react together to make the ester ethyl ethanoate.

Draw the **displayed** formula of ethyl ethanoate.

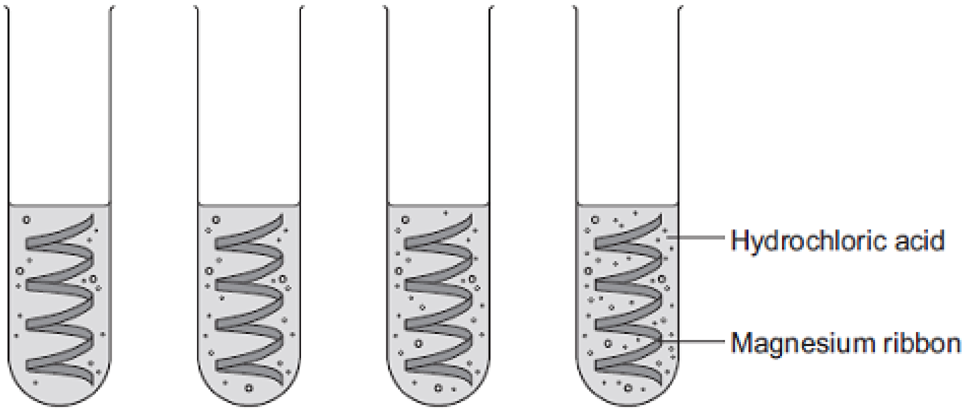
(2)
(Total 11 marks)

13 A student investigated the rate of reaction of magnesium and hydrochloric acid.

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

The student studied the effect of changing the concentration of the hydrochloric acid.

She measured the time for the magnesium to stop reacting.



Concentration of hydrochloric acid in moles per dm^3	0.5	1.0	1.5	2.0

(a) The student changed the concentration of the hydrochloric acid.

Give **two** variables that the student should control.

1 ....

2 ....

(2)

(b) (i) The rate of reaction increased as the concentration of hydrochloric acid increased.

Explain why.

....

....

....

....

(2)

(ii) Explain why increasing the temperature would increase the rate of reaction.

....

....

....

....

....

....

(3)

(c) (i) The student had a solution of sodium hydroxide with a concentration of 0.100 moles per dm^3.

She wanted to check the concentration of a solution of hydrochloric acid.

She used a pipette to transfer 5.00 cm^3 of the hydrochloric acid into a conical flask.

She filled a burette with the 0.100 moles per dm^3 sodium hydroxide solution.

Describe how she should use titration to obtain accurate results.

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....

(4)

(ii) Sodium hydroxide neutralises hydrochloric acid as shown in the equation:

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

The student found that 27.20 cm^3 of 0.100 moles per dm^3 sodium hydroxide neutralised 5.00 cm^3 of hydrochloric acid.

Calculate the concentration of the hydrochloric acid in moles per dm^3.

Give your answer to three significant figures.

....

....

....

....

....

....

Concentration of hydrochloric acid = ... moles per dm^3

(3)

(Total 14 marks)

14 Sodium hydroxide neutralises sulfuric acid.

The equation for the reaction is:

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

(a) Sulfuric acid is a strong acid.

What is meant by a strong acid?

....

....

....

(2)

(b) Write the ionic equation for this neutralisation reaction. Include state symbols.

....

(2)

(c) A student used a pipette to add 25.0 cm^3 of sodium hydroxide of unknown concentration to a conical flask.

The student carried out a titration to find out the volume of 0.100 mol / dm^3 sulfuric acid needed to neutralise the sodium hydroxide.

Describe how the student would complete the titration.

You should name a suitable indicator and give the colour change that would be seen.

....

....

....

....

....

....

....

....

....

....

(4)

(d) The student carried out five titrations. Her results are shown in the table below.

	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Volume of 0.100 mol / dm^3 sulfuric acid in cm^3	27.40	28.15	27.05	27.15	27.15

Concordant results are within 0.10 cm^3 of each other.

Use the student's concordant results to work out the mean volume of 0.100 mol / dm^3 sulfuric acid added.

....

....

....

....

Mean volume = ... cm^3

(2)

(e) The equation for the reaction is:

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

Calculate the concentration of the sodium hydroxide.

Give your answer to three significant figures.

....

....

....

....

....

....

....

Concentration = ... mol / dm^3

(4)

(f) The student did another experiment using 20 cm^3 of sodium hydroxide solution with a concentration of 0.18 mol / dm^3.

Relative formula mass (M_r) of NaOH = 40

Calculate the mass of sodium hydroxide in 20 cm^3 of this solution.

....

....

....

....

Mass = ... g

(2)

(Total 16 marks)

15 Dilute nitric acid reacts with potassium hydroxide solution.

The equation for the reaction is:

$$HNO_3 + KOH \longrightarrow KNO_3 + H_2O$$

A student investigated the temperature change in this reaction.

This is the method the student used.

Step 1 Put 25 cm^3 of dilute nitric acid in a polystyrene cup.

Step 2 Use a thermometer to measure the temperature of the dilute nitric acid.

Step 3 Use a burette to add 4 cm^3 of potassium hydroxide solution to the dilute nitric acid and stir the mixture.

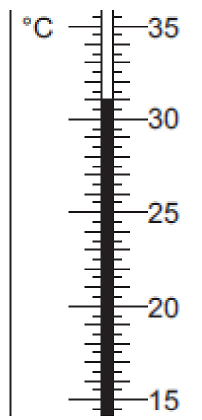
Step 4 Use a thermometer to measure the highest temperature of the mixture.

Step 5 Repeat steps 3 and 4 until 40 cm^3 of potassium hydroxide solution have been added.

The dilute nitric acid and the potassium hydroxide solution were both at room temperature.

(a) **Figure 1** shows part of the thermometer after some potassium hydroxide solution had been added to the dilute nitric acid.

Figure 1



What is the temperature shown on the thermometer?

The temperature shown is .... °C

(1)

(b) Errors are possible in this experiment.

(i) Suggest **two** causes of random error in the experiment.

....

....

....

....

(2)

(ii) Another student used a glass beaker instead of a polystyrene cup.

This caused a systematic error.

Why does using a glass beaker instead of a polystyrene cup cause a systematic error?

....

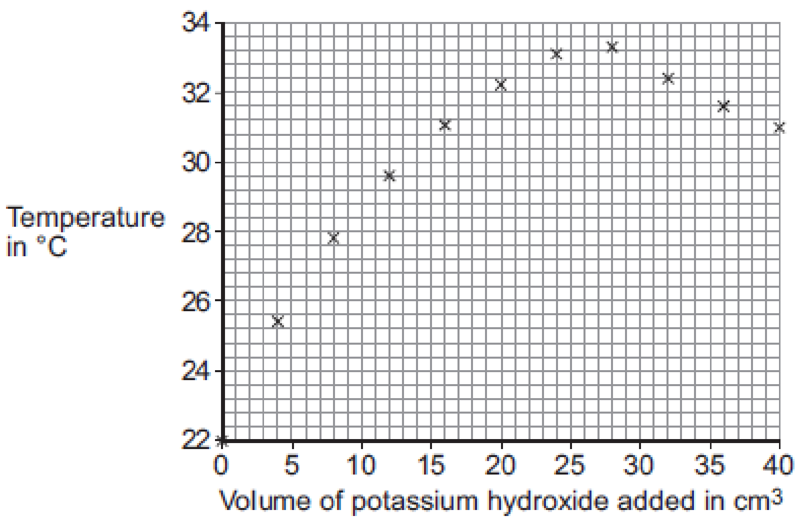
....

....

(1)

(c) The results of the student using the polystyrene cup are shown in **Figure 2**.

Figure 2



(i) How do the results in **Figure 2** show that the reaction between dilute nitric acid and potassium hydroxide solution is exothermic?

....

....

(1)

(ii) Explain why the temperature readings decrease between 28 cm^3 and 40 cm^3 of potassium hydroxide solution added.

....

....

....

(2)

(iii) It is difficult to use the data in **Figure 2** to find the exact volume of potassium hydroxide solution that would give the maximum temperature.

Suggest further experimental work that the student should do to make it easier to find the exact volume of potassium hydroxide solution that would give the maximum temperature

....

....

....

....

(2)

(d) The student did further experimental work and found that 31.0 cm^3 of potassium hydroxide solution neutralised 25.0 cm^3 of dilute nitric acid.

The concentration of the dilute nitric acid was 2.0 moles per dm^3.

$$HNO_3 + KOH \longrightarrow KNO_3 + H_2O$$

Calculate the concentration of the potassium hydroxide solution in moles per dm^3.

....

....

....

....

....

....

Concentration = ... moles per dm^3

(3)

(e) The student repeated the original experiment using 25 cm^3 of dilute nitric acid in a polystyrene cup and potassium hydroxide solution that was twice the original concentration.

She found that:

- a smaller volume of potassium hydroxide solution was required to reach the maximum temperature
- the maximum temperature recorded was higher.

Explain why the maximum temperature recorded was higher.

....

....

....

....

(2)

(Total 14 marks)

Mark schemes

1 (a) (i) *incorrect test or no test = **0** mark*

*testing the solution **or** using blue litmus = **0** mark*

(test ammonia / gas with red) litmus

accept any acid-base indicator with correct result

1

(goes) blue

OR

(conc.) HCl (1)

<u>white</u> fumes / smoke / solid (1)

allow <u>white</u> gas / vapour

OR

(test ammonia / gas with) Universal Indicator (1)

blue / purple (1)

1

(ii) *incorrect test or no test = **0** marks*

add barium chloride / $BaCl_2$ (solution)

*do **not** accept H_2SO_4 added*

or add barium nitrate / $Ba(NO_3)_2$ (solution)

allow Ba^{2+} solution / aqueous added

1

<u>white</u> precipitate / solid (formed)

allow white barium sulfate / $BaSO_4$

ignore barium sulfate / $BaSO_4$ alone

1

(b) (i) <u>fully</u> / <u>completely</u> ionised / dissociated
or hydrogen ions fully <u>dissociated</u>

accept has more ions than weaker acid / alkali of <u>same concentration</u>

ignore strongly ionised

*do **not** accept ions are fully ionised*

*ignore concentrated **or** reference to concentrations of ions*

1

(ii) methyl orange

accept correct spelling only

accept any strong acid-weak base indicator

*do **not** allow phenolphthalein / litmus / universal indicator*

1

(iii) 32 × 0.05/1000 **or** 0.0016 (mole H_2SO_4)

*accept (0.05 x 32) = (V x 25) **or** 0.05 x 32 / 25*

1

(reacts with) 2 × 0.0016 **or** 0.0032 (mole NH_3 in 25 cm^3)

*accept dividing rhs by 2 **or** multiplying lhs by 2*

1

(0.0032 × 1000/25 =) 0.128

allow ecf from previous stage

*correct answer 0.128 **or** 0.13 with or without working gains all **3** marks*

1

(iv) 2.176 **or** 2.18

correct answer with or without working

or ecf from candidate's answer to (b)(iii)

or 2.55 if 0.15 moles used

if answer incorrect or no answer

*0.128 × 17 **or** 0.13 x 17*

***or** their (b)(iii) × 17*

***or** 0.15 × 17 gains **1** mark*

2

[11]

2 Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also apply a 'best-fit' approach to the marking.

Level 3 (5 – 6 marks)
There is a description of titrations that would allow a comparison to be made between the two solutions of hydrochloric acid.

Level 2 (3 – 4 marks)
There is a description of an experimental method including addition of acid to alkali which may include an indicator or colour change and may include a measurement of volume.

Level 1 (1 – 2 marks)
There is a simple description of using some of the apparatus.

0 marks
No relevant content.

examples of chemistry points made in the response could include:

- acid in burette **or** flask
- alkali/sodium hydroxide **or** acid in burette **or** flask
- volume of acid **or** alkali measured using the pipette
- indicator in flask
- white tile under the flask
- slow addition
- swirling/mixing
- colour change of indicator
- burette volume measured

[6]

3 (a) **must** be description of a titration no titration = no marks

NaOH in <u>burette</u>

*do **not** accept biuret etc*

1

add NaOH until (indicator) changes colour

*if specific colour change mentioned, must be correct – colourless to pink / red **or** 'goes pink / red'*

*do **not** accept 'clear' for colourless*

1

note (burette) volume used **or** final reading

accept 'work out the volume'

1

one other point: eg repeat

accept:
*(white) tile **or** add dropwise / slowly **or** white background **or** swirling / mix **or** read meniscus at eye level **or** wash apparatus*

1

(b) 0.054

*for **2** marks*

*(0.1 × 13.5)/25 for **1** mark*

(c) don’t know – insufficient evidence to decide

owtte

any sensible answer

or

depends on whether acid level is considered safe or unsafe

yes, safe – acid level low / weak acids / low compared with stomach acid

owtte

any sensible answer

2

no, unsafe – acid level (too) high / other substances or bacteria may be present / insufficient evidence to decide

owtte

any sensible answer

1

(d) (methyl orange) would have changed colour (well) before the end-point / pH7 / neutral

owtte

1

weak acid present

weak acid-strong base (titration)

allow methyl orange used for strong acid-weak base titration

1

[9]

4 (a) hydrochloric acid in burette

1

indicator

1

note volume at end / neutralisation point

titre must be HC1

1

(b) 1 mole HCl = 36.5g /36.5

1

$\therefore \frac{73}{36.5}$ = 2 moles / dm^3

2 for correct answer

1

(c) (i) $\frac{10 \times 2}{1000}$

allow e.c.f. ie their (b) × $\frac{10}{1000}$
2 for correct answer

1

= 0.02 moles

1

(ii) $0.02 \times \frac{1000}{25}$ = 0.8 mol / dm^3

1

allow e.c.f. ie their (c)(i) × $\frac{1000}{25}$

1

[9]

5 (a) pipette / burette

1

(b) named indicator eg methyl orange / phenolphthalein
not *universal*
accept litmus but ***not*** *litmus paper*

1

(c) $\frac{25 \times 0.4}{1000}$
2 for correct answer

1

= 0.01

1

(d) 1KOH ≡ 1 HCl

∴ 0.01 moles HCl in 35 cm^3

1

$$\therefore \frac{0.01 \times 1000}{35} = 0.29$$

2 for correct answer
0.3 = (1) (with correct working = (2))

1

[6]

6

(a) (i) e.g. moles NaOH = moles of acid
or formula:

$$0.2 \times \frac{45}{1000} = 0.009$$

$15M_1 = 0.2 \times 45$

1

rounding to 0.01 loses mark

$$= 0.009 \times \frac{1000}{15} = 0.6(M)$$

$M_1 = 0.6(M)$

ecf for arithmetical error
*correct answer **2** marks*

1

(ii) 36
ecf – (a)(i) × 60
*correct answer **2** marks*
*0.6 × 60 gets **1** mark*
relative formula mass of ethanoic acid
*= 60 for **1** mark*
0.6 × incorrect molar mass gains second mark only

2

(b) (i) A = hydrogen / H_2

1

B = sodium hydroxide / NaOH **or**
sodium oxide / Na_2O

1

(iii) C = ethyl ethanoate (acetate) /
$CH_3COOC_2H_5$ / $CH_3CO_2C_2H_5$

1

(iv) D = (concentrated) sulphuric acid /
H_2SO_4

*do **not** accept dilute sulphuric acid*

1

E = sodium ethanoate (acetate) / CH_3COONa / CH_3CO_2Na

1

[9]

7 (a) any four from:

- sulphuric acid measure by pipette
  ***or** diagram*
- potassium hydroxide in burette
  ***or** diagram*
- if solutions reversed, award
- note initial reading
- use of indicator
- note final reading **or** amount used

4

(b) $\frac{34 \times 2}{1000}$

1

= 0.068

1

(c) ½ or 0.5 moles H_2SO_4 react with 1 mole KOH

1

moles H_2SO_4 in 25.0 cm^3 = 0.068 × 0.5

1

∴ moles H_2SO_4 in 1 dm^3 = $\frac{0.068 \times 0.5 \times 1000}{25}$ = 1.36 mol/dm^3

1

[9]

8 (a) Hydrogen / H^+

ignore state symbols

ignore proton / H

1

(b) *it = weak acid*

pH of weak acid is higher than the pH of a strong acid

allow converse for strong acids

allow correct numerical comparison

1

any **one** from:

allow converse for strong acids

- only partially dissociated (to form ions)

  allow ionises less

- not as many hydrogen ions (in the solution)

  allow fewer H^+ released

1

(c) (i) (titration of) weak acid <u>and</u> strong base

1

(ii) 0.61

*correct answer with or without working gains **2** marks*

if the answer is incorrect:

moles of sodium hydroxide = (30.5 × 0.5)/1000 = 0.01525 moles

or

*(0.5 × 30.5/25) gains **1** mark*

2

(d) 12

*correct answer with or without working gains **2** marks or even with incorrect working.*

if the answer is incorrect:

0.8 × 60 = 48g

or

evidence of dividing 48g (or ecf) by 4

or

$\frac{0.8 \times 250}{1000} = \frac{0.8}{4} =$ *0.8 × 0.25 = 0.2 mol*

or

evidence of multiplying 0.2mol (or ecf) by 60

*would gain **1** mark*

2

[8]

9 (a)

***must** be a description of a titration no titration = **0** marks*

Quality of written communication

*for correct sequencing of 2 of first 3 bullet points i.e. 1 + 2 **or** 2 + 3 **or** 1 + 3*

1

any **three** from:

- nitric acid in burette

  *do **not** accept biuret*
  can be inferred from 3rd point

- add nitric acid until indicator changes (colour)

  can be named acid-base indicator
  colour change does not have to be correct

- note (burette) volume used **or** final reading

- accuracy: e.g. repeat

  *accept white tile **or** dropwise near end **or** white background **or** swirling the flask **or** read meniscus at eye level*

3

(b) e.g. formula method:

$25 \times M_{NH3} = 0.25 \times 20$

1

$M_{NH3} = 0.2$

correct answer alone = ***2***

OR

moles NH_3 = moles HNO_3

$= \frac{20}{1000} \times 0.25 = 0.005$ moles (1)

concentration NH3

$= \frac{0.005 \times 1000}{25} = 0.2$ (1)

1

(c) sodium hydroxide **or** potassium hydroxide **or** lithium hydroxide **or** calcium hydroxide

ignore mention of alkali

1

ammonia produced

accept gas produced turns (damp) (red) litmus blue (not blue litmus) ***or*** *alkaline gas produced*

any suitable named indicator e.g. UI with consequential marking white fumes / smoke with (concentrated) HCl

do ***not*** *accept white gas wrong test =* ***0*** *marks*

1

[8]

10 (a) (i) hydrogen ions

1

(ii) partially ionised

1

(b) (i) burette

1

(ii) indicator

1

(iii) colour change or turns pink

1

(c) 20.4(0)

*correct answer with or without working gains **2** marks*

if answer incorrect allow

20.80 ***or*** $\dfrac{20.30 + 20.50 + 20.40}{3}$

*for **1** mark*

2

(d) 50 (g)

*correct answer with or without working gains **2** marks*

*if answer incorrect allow evidence of 1.25 × 40 for **1** mark*

2

[9]

11 Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information in the Marking guidance.

0 marks
No relevant content.

Level 1 (1-2 marks)
There is a simple description of using some of the equipment.

Level 2 (3-4 marks)
There is a description of an experimental method involving a measurement, **or** including addition of alkali to acid (or vice versa).

Level 3 (5-6 marks)
There is a description of a titration that would allow a successful result to be obtained.

Examples of chemistry points made in the response could include:

- acid in (conical) flask
- volume of acid measured using pipette
- indicator in (conical) flask
- sodium hydroxide in burette
- white tile under flask
- slow addition
- swirling
- colour change
- volume of sodium hydroxide added

Extra information

- allow acid in the burette to be added to sodium hydroxide in the (conical) flask
- allow any specified indicator

colour change need not be specified

[6]

12 (a) (i) red

ignore pink

1

(ii) add silver nitrate (solution)

1

white precipitate

dependent on addition of silver nitrate

ignore addition of another acid

*if hydrochloric acid added max **1** mark*

1

(b) suitable named alkali / sodium hydroxide solution in burette

1

add alkali solution until (indicator) becomes pink / red

1

*if acid to acid titration described, first two marking points **not** available* any **two** from:

- wash / rinse equipment
- add dropwise or slowly (near end point)
- swirl / mix
- read (meniscus) at eye level
- white background
- read start and final burette levels / calculate the volume needed
- repeat

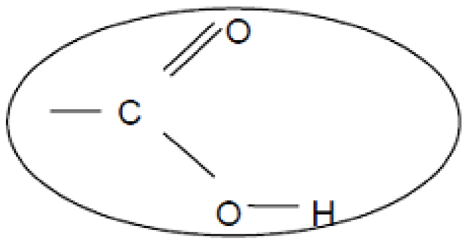
2

(c) does not ionise / dissociate completely

allow for acids of the same concentration, weak acids have a higher pH or fewer hydrogen ions

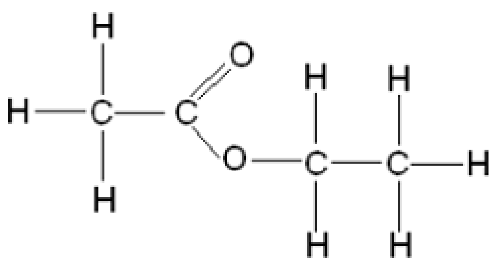
1

(d) (i) ring round COOH

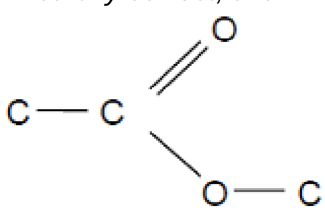


1

(ii)



*if not fully correct, allow **1** mark for correct ester group − minimum*



2

[11]

13

(a) any **two** from:

- temperature (of the HCl)
- mass or length of the magnesium
- surface area of the magnesium
- volume of HCl

2

(b) (i) (a greater concentration has) more particles per unit volume

allow particles are closer together

1

therefore more collisions <u>per unit time</u> **or** more frequent collisions.

1

(ii) particles move faster

allow particles have more (kinetic) energy

1

therefore more collisions <u>per unit time</u> **or** more frequent collisions

1

collisions more energetic (therefore more collisions have energy greater than the activation energy) **or** more productive collisions

1

(c) (i) add (a few drops) of indicator to the acid in the conical flask

allow any named indicator

1

add NaOH (from the burette) until the indicator changes colour **or** add the NaOH dropwise

candidate does not have to state a colour change but penalise an incorrect colour change.

1

repeat the titration

1

calculate the **average** volume of NaOH **or** repeat until concordant results are obtained

1

(ii) **moles of NaOH**

0.10 × 0.0272 = 0.00272 moles

*correct answer with or without working gains **3** marks*

1

Concentration of HCl

0.00272 / 0.005 = 0.544

allow ecf from mp1 to mp2

1

correct number of significant figures

1

[14]

14 (a) (sulfuric acid is) completely / fully ionised

1

In aqueous solution **or** when dissolved in water

1

(b) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

allow multiples

***1** mark for equation*

***1** mark for state symbols*

2

(c) adds indicator, eg phenolpthalein / methyl orange / litmus added to the sodium hydroxide (in the conical flask)

*do **not** accept universal indicator*

1

(adds the acid from a) burette

1

with swirling **or** dropwise towards the end point **or** until the indicator just changes colour

1

until the indicator changes from pink to colourless (for phenolphthalein) or yellow to red (for methyl orange) or blue to red (for litmus)

1

(d) titrations 3, 4 and 5

or

$$\frac{27.05 + 27.15 + 27.15}{3}$$

1

27.12 cm^3

*accept 27.12 with no working shown for **2** marks*

1

*allow 27.1166 with no working shown for **2** marks*

(e) Moles H_2SO_4 = conc × vol = 0.00271

allow ecf from 8.4

1

Ratio H_2SO_4:NaOH is 1:2

or

Moles NaOH = Moles H_2SO_4 × 2 = 0.00542

1

Concentration NaOH = mol / vol = 0.00542 / 0.025 = 0.2168

1

0.217 (mol / dm^3)

*accept 0.217 with no working for **4** marks*

1

*accept 0.2168 with no working for **3** marks*

(f) $\frac{20}{1000}$ × 0.18 = no of moles

or

0.15 × 40 g

1

0.144 (g)

1

*accept 0.144g with no working for **2** marks*

[16]

15

(a) 31

1

(b) (i) any **two** from:

- incorrect reading of thermometer / temperature
- incorrect measurement of volume of acid
- incorrect measurement of volume of alkali (burette).

2

(ii) glass is a (heat) conductor **or** polystyrene is a (heat) insulator

*answer needs to convey idea that heat lost using glass **or** not lost using polystyrene*

accept answers based on greater thermal capacity of glass (such as "glass absorbs more heat than polystyrene")

1

(c) (i) temperature increases

1

(ii) no reaction takes place **or** all acid used up **or** potassium hydroxide in excess

1

cool / colder potassium hydroxide absorbs energy **or** lowers temperature

ignore idea of heat energy being lost to surroundings

1

(iii) take more readings

ignore just "repeat"

1

around the turning point **or** between 20 cm^3 and 32 cm^3

accept smaller ranges as long as no lower than 20 cm^3 and no higher than 32 cm^3

1

(d) 1.61 **or** 1.6(12903)

*correct answer with or without working scores **3***

*if answer incorrect, allow a maximum of **two** from:*

*moles nitric acid = (2 × 25 / 1000) = 0.05 for **1** mark*

*moles KOH = (moles nitric acid) = 0.05 for **1** mark*

concentration KOH = 0.05 / 0.031

answer must be correctly rounded (1.62 is incorrect)

3

(e) same amount of energy given out

1

which is used to heat a smaller total volume **or** mixture has lower thermal capacity
or
number of moles reacting is the same
but the total volume / thermal capacity is less

*if no other marks awarded award **1** mark for idea of reacting faster*

1

[14]

Examiner reports

1

(a) (i) Half the candidates knew that ammonia turned red litmus blue and gained 2 marks. Some candidates think that ammonia bleaches litmus, or that it turns blue litmus red. A significant number thought the test for ammonia was to smell it! Candidates had to make clear in their answer that it was not the sodium hydroxide solution that was being tested. Candidates who used incorrect reagents, such as hydrochloric acid or Devarda's Alloy/aluminium, gained no credit.

(ii) Just under a half of the candidates knew the test for a sulfate. Candidates should be aware that barium is not the same substance as barium chloride, and that BaCl is not the formula of barium chloride. Other incorrect reagents included sodium hydroxide, silver nitrate, bromine water, barium sulfate and hydrochloric acid (without the barium chloride). Weaker candidates suggested using flame tests. Some candidates did not give a reagent but just suggested that a white precipitate was formed on the off-chance that credit would be given! It was not.

(b) (i) More than half of the candidates correctly explaining the meaning of strong in terms of being completely or fully ionised. The concept has nothing to do with "ions ionising", the acid/base ionising other substances, dilution/concentration, the number of ions formed or the speed of ionisation.

(ii) About half the candidates correctly identified 'methyl orange' as a suitable indicator for strong acid-weak alkali titrations. Incorrect 'indicators' included phenolphthalein (sic), litmus, universal indicator, bromine water and limewater.

(iii) It is pleasing to see that candidates are gaining in confidence with this type of calculation - a minority of candidates gained 3 marks, 2 marks respectively (they usually ignored the mole ratio factor of 2). Good candidates organised their calculation clearly and logically while weaker candidates lacked the basic skills to do so.

(iv) About a half of candidates gained credit for calculating the concentration of the ammonia solution in grams per cubic decimetre. Weaker candidates divided by 17 or divided their previous answer by 17. Some candidates felt the 17 should be multiplied by 2 and used 34 in their calculation, while others did not use either their answer from part (iii) or 0.15.

2

Foundation

This six-mark question contained the command word ‘describe’. It produced an even spread of marks. Some high quality Level 3 responses were seen which described a titration procedure that would enable a valid comparison of the two acid samples. There were some descriptions of features which would improve accuracy. Weaker responses may not have stated or implied that the procedure should be applied to both acid samples, which confined them to Level 2. Other misconceptions were that titrations can be successfully carried out by counting drops from the burette, that acid-base indicators turn clear, or that Universal Indicator could just be used directly on the acid samples and a comparison of pH made. A few students became confused with thiosulfate rate experiments they may have done, and therefore drew crosses on the white tile to become obscured (or visible) when the indicator changed colour. Most students were at least able to describe an addition of acid to alkali or vice-versa, and so gained a Level 2 mark or above, although some mistakenly added acid A to acid B.

A high standard of written communication was evident in some responses. Some students, as well as failing to organise their response in a logical or coherent way, tended to show particular problems in the spelling of apparatus words such as ‘burette’, ‘pipette’ and ‘conical’ (even though they were given in the question stem) and reagent and indicator names, and used everyday words rather than scientific terms.

Higher

This six-mark question contained the command word ‘describe’. Many high quality Level 3 responses were seen which described a titration procedure that would enable a valid comparison of the two acid samples. There were many descriptions of features which would improve accuracy. Weaker responses may not have stated or implied that the procedure should be applied to both acid samples, which confined them to Level 2. Other misconceptions were that titrations can be successfully carried out by counting drops from the burette, that acid-base indicators turn clear, or that Universal Indicator could just be used directly on the acid samples and a comparison of pH made. A few students became confused with thiosulfate rate experiments they may have done, and therefore drew crosses on the white tile to become obscured (or visible) when the indicator changed colour. Nearly all students were at least able to describe an addition of acid to alkali or vice-versa, so the number of Level 1 responses was pleasingly low.

A high standard of written communication was evident in many responses. Some students, as well as not organising their response in a logical or coherent way, tended to show particular problems in the spelling of apparatus words such as ‘burette’, ‘pipette’ and ‘conical’ (even though they were given in the question stem) and reagent and indicator names, and used everyday words rather than scientific terms.

3

In part (a) there were some excellent, accurate descriptions from some candidates. However, just over 50% of the candidates gained no credit, many left the question blank or gave a list of equipment without comment or wrote nonsense involving invented apparatus such as biurets and titrating tubes. Many incorrect colour changes were mentioned and it was insufficient to simply say that the alkali is added until the indicator shows neutral. Candidates should mention that the final burette reading was noted.

Candidates should have no problems about the spelling of burette using the 1,2-rule: the **1**$^{\mathbf{st}}$ problem letter is an r and there is **1** of those, the **2nd** problem letter is a t and there are **2** of these. The same rule applies to the spelling of pipette and potassium.

In part (b) just under a quarter of the candidates knew how to do this standard calculation. A few candidates gained partial credit for 13.5/25 = 0.54.

About 60% of the candidates gained credit in part (c). Popular incorrect responses involved the suggestion that titration was inaccurate or that neutralisation made the champagne safe. In part (d) only the best candidates gained full marks but many gained some credit for stating that methyl orange is used for strong acid/weak base titrations or for recognising that phenolphthalein is used for weak acid/strong base titrations. Weak candidates had little or no idea.

4

The titration procedure in part (a) varied from centre to centre. Candidates who had carried out a titration could describe the use of the burette and indicator and record the volume of acid required. In (b) the majority of candidates calculated the molecular mass of the hydrochloric acid but were unable to complete the calculation correctly. Part (c) was a good discriminating question. Candidates received error carried forward marks if their method was valid using an incorrect answer from (b).

5

This question was enjoyed by the more numerate candidates. Instead of ‘pipette’ or ‘burette’ in answer to part (a) most candidates gave ‘measuring cylinder’. In part (b) most candidates incorrectly answered with ‘universal indicator’.

Only the more numerate candidates could do parts (c) and (d) irrespective of whether they were good at chemistry or not. Candidates who got cm3 and dm3 confused had their errors cancelled out, and tended to get the marks in part (d), having lost them in part (c). Too many answers were given to either 1 significant figure or a lot of significant figures.

6 **Higher Tier**

This question discriminated very well between the candidates. Most candidates managed a mark in part (a)(ii) and 2 or 3 marks in part (b). Very weak candidates left much of this question blank.

(a) Many candidates were unable to calculate the concentration of ethanoic acid and the page was sometimes left blank. In (i) the popular incorrect response was 0.06. In (ii) most candidates just gained credit for calculating the relative formula mass of ethanoic acid.

(b) (i) Hydrogen was well known. The popular incorrect responses were oxygen and carbon dioxide.

(ii) The alkali was almost always correctly identified.

(iii) Many candidates had difficulty identifying the ester. Incorrect responses included ethanol ethanoate.

(iv) Strong candidates had no problem. However, many candidates simply guessed with iron, nickel, vanadium(V) oxide and platinum frequently appearing.

(v) Many candidates used the flow diagram correctly and successfully identified the carboxylic acid salt as sodium ethanoate.

7 Candidates usually scored very well or very badly. In part (a) a pipette was rarely mentioned, nor the starting volume on burette. Various names and spellings for ‘burette’ were seen. Many unsuitable indicators were cited including Fehling’s solution and iodine and the reagents were often reversed. In part (b) good candidates scored both marks but most candidates struggled. A common mistake was $100cm^3$ $1dm^3$. In part (c) many candidates ignored the 2:1 ratio and ended up with 2.72 mol dm^{-3} for 2 marks. Several ‘36/25 = 1.36’ style answers were seen which were penalised.

8

(a) The majority of students answered correctly. The most common incorrect answer was hydroxide.

(b) Most students gained least one mark, with a reasonable proportion scoring two. There was some confusion over pH scale with many thinking a stronger acid or higher concentration of hydrogen ions meant a higher pH. Some stated the pH difference without giving a reason whereas others explained strength in terms of dissociation into ions without comparing pH (presumably not noticing that the question required an answer as well as a reason). A few cited indicator colours rather than pH. As often in the past, some lost a mark through imprecise language, for example writing that in a strong acid the ions were more ionising.

(c) (i) Just over half of students answered correctly. A common fault was to write about phenolphthalein being used with a weak acid, omitting to mention a strong base. Some students wrote their answer the wrong way round; some talked about visibility of colour change.

(ii) Approximately half of the students calculated the correct answer for two marks. Only a few scored a single mark for correctly calculating the number of moles of NaOH but being unable to proceed further; the rest failed to produce any creditworthy working.

(d) Fewer (approximately one quarter) gained both marks for this calculation, but a similar number gave an answer of 48 g, thereby gaining one mark.

9

With the exception of part (a), this question discriminated well between the candidates and more able candidates produced some excellent answers.

(a) With the aid of a sympathetic mark scheme, the majority of candidates were able to obtain full marks for the titration. The spelling of burette continues to cause problems for many (biuret, buritt, drip-tap, titration test tube, ‘long measuring volume thing’ etc. continue to receive no credit) and some forgot to add an indicator. Although UI was not penalised, UI would **never** be used in a titration). Descriptions other than titrations received no credit.

(b) Only the most able candidates could calculate the concentration in moles per cubic decimetre (litre), the majority being unable to start the calculation. Those candidates who used the formula ($M_1V_1/n_1 = M_2V_2/n_2$) were usually successful: perhaps there is a moral here.

(c) Again, only the most able candidates correctly described the test for ammonium ions. Most candidates had little idea. Most tested the solution with UI (treating the ammonium compound as ammonia), some added sodium hydroxide before adding UI to the *solution*, others added sodium hydroxide with aluminium or Devarda’s Alloy (confusion with the test for nitrate ions). Some candidates suggested that a white precipitate on addition of sodium hydroxide is a positive result. (See specification topic 10.16 page 50 for the requirement.)

10

(a) (i) Nearly half the students scored no mark here because many of them thought that the acid forms ‘hydroxide ions’ when it dissolves in water.

(ii) Quite a few students thought that the ethanoic acid is ‘completely ionised’.

(b) (i) Was quite well attempted by the large majority of students.

(ii) Was quite well attempted by the large majority of students.

(iii) Nearly half of the students did not score this mark as they gave the wrong colour or said that the ‘solution turned clear’.

(c) Around a third of the students did not score this mark. Many worked out an average of the values for the final reading.

(d) The majority gained two marks but about 2a quarter of the candidates struggled with this calculation. Some divided 1000 by 25 and got the answer as 4 while others did not multiply by 1.25.

11

It should be noted that this question was marked holistically; marks were not awarded or deducted for inclusion or omission of particular points unless the method was thereby rendered unworkable and, again provided the method as a whole was workable, students were not penalised for minor errors such as an incorrect indicator colours (which were frequent). Level 2 was most commonly awarded but Level 3 was not rare; a reasonable number of students scored 6 marks. It was evident that most had either done the titration themselves or seen a demonstration. The majority of students paid insufficient attention to the taking of measurements. Some students used the white tile to test drops of the solution with the indicator, probably confusing the titration with a method for the production of a soluble salt. Others regarded the tile as a method of preventing spillages from reaching the bench. Many students used the pipette indiscriminately, filling the burette with it or using it to add indicator; this was not penalised as long as the overall method worked. Some expounded at length on the minutiae of how to use a pipette.

12

(a) (i) Under three-quarters of the students knew the colour of Universal Indicator in hydrochloric acid, with ‘orange’ being a common error. To show an orange colour the acid would have to be very dilute, certainly more dilute than is normally come across in a school laboratory.

(ii) Some very clearly explained tests were seen, with additional information such as the name of the precipitate often being given. Some students gave two alternative tests – since one of these was invariably wrong, this prevented marks being scored for the correct test. Common errors included the use of a flame test, testing for chlorine or stating that a cream precipitate would be formed.

(b) Some very clear and well organised answers were seen. However, the majority of students did not know the correct colour change for phenolphthalein (stating it would become colourless at the end point) and there was a lot of confusion between the words 'colourless' and 'clear'. Some students clearly did not read the question, deciding to use a different indicator from the one stated in the diagram. Many students failed to identify the alkali to use.

(c) This question was not well answered. Most students who scored on this part did so by referring to the incomplete ionisation of a weak acid. Many went down the pH route, stating that weak acids had a higher pH than strong acids, but almost all failing to score due to omission of a statement concerning equal concentrations (1 mol / dm^3 ethanoic acid has a lower pH thatn0.001 mol / dm^3 hydrochloric acid so simple statements concerning pH are not correct).

(d) (i) Just over three-quarters of the students could identify the functional group in ethanoic acid.

(ii) Although some clearly drawn completely correct answers were seen, most students scored zero. A disappointingly high number of answers included divalent hydrogen atoms linking together the parts of the structure derived from the acid and the alcohol, or pentavalent carbons.

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(a) The majority of students could correctly read the thermometer scale. The most common incorrect answer was 32 °C.

(b) (i) This question was generally poorly answered with students being unsure of the difference between a systematic error as opposed to a random error caused by a human mistake. Many students referred to the rate of stirring or heat loss, neither of which was given credit.
The way the errors were expressed sometimes suggested that the student knew what they meant to say but did not express it clearly, therefore making the error lie with the apparatus, e.g. the thermometer could be wrongly calibrated.

(ii) Most students scored a mark here by stating that polystyrene is a better insulator than glass or vice versa. The few incorrect responses often referred to a possible reaction between the polystyrene or the glass with the reagents, or to the glass smashing. These students probably did not know what a systematic error is.

(c) (i) Most students scored one mark here. A number did not score a mark as they tried to define exothermic and did not use the results in Figure 8 as the question asked. Some students referred to both the increase and decrease of temperature, effectively describing the changes of temperature in Figure 8, without specifying which indicated that the reaction was exothermic.

(ii) Many students gained the first marking point by stating that the reaction had finished at 28 cm^3 or that all the acid had reacted. Only a few realised the cooling effect of adding further potassium hydroxide. A small minority of students attempted an explanation using rate, bond breaking and formation or reversible reactions. A number of students suggested that energy was now being given off to the surroundings to cause the decrease in temperature. Some students used the phrase ‘fully saturated’ to indicate that the reaction had completed.

(iii) Most students appreciated that to find the exact volume of potassium hydroxide they would need to take readings at smaller intervals. Significantly fewer students appreciated that it was only necessary to do this around the turning point. Some students missed the point and suggested repeating the experiment and taking an average which would have left them no closer to determining the exact volume. Answers gaining no credit often suggested doing a titration, without suggesting smaller increments, or adding the whole volume at once.

(d) Around half of all students scored full marks here and got an answer of 1.61 moles per dm^3. Some students got the volumes the wrong way round and scored 2 marks for an answer of 2.48 moles per dm^3. A number of students had tried to answer this as if it was a reacting mass calculation and scored zero.

(e) Students found this question very challenging with few scoring 2 marks. We wanted the students to recognise that the same number of moles were reacting therefore the same amount of energy was given out but that the energy was being used to heat a smaller volume of liquid. Very few students answered the question this way.
Most students had interpreted this as a rates of reaction question. One mark was allowed for the rate of reaction increasing or a comment about the frequency of (successful) collisions increasing. Many students thought the increased concentration increased the energy of the particles. Some students suggested that as the KOH was double the concentration there would be more collisions, so more energy produced.