YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME	SUGGESTED ANSWERS
CLASS	

H2 CHEMISTRY 9729/04

Paper 4 Practical Paper

20 August 2024
2 hours 30 minutes

Candidates answer on question paper.

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Give details of the practical shift and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Qualitative Analysis Notes are printed on pages 23 and 24.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's use	
1	
2	
3	
4	
Total	

This document consists of **24** printed pages and **1** blank page.

Answer **all** the questions in the spaces provided.

1 Determination of the kinetics of a redox reaction

Equation 1 represents the reaction between iron(III) ions and iodide ions.

equation 1 $2Fe^{3+}(aq) + 2I^{-}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$

When starch is added to the reaction mixture, a blue colour is immediately seen due to the formation of an iodine–starch complex.

If a small amount of sodium thiosulfate, $Na_2S_2O_3$, is also present in the reaction mixture, the formation of the blue colour is delayed. The $Na_2S_2O_3$ reacts with I_2 as shown in equation 2.

equation 2 $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^{-}(aq)$

FA 1 is iron(III) chloride, $FeCl_3$.
FA 2 is potassium iodide, KI.
FA 3 is 0.0060 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
Solution S is starch indicator.

You will perform a series of five experiments. Then, you will graphically analyse your results to determine the order with respect to the concentration of Fe^{3+} ions, $[Fe^{3+}]$.

You will add a fixed amount of sodium thiosulfate, **FA 3**, to each of your experiments. In each experiment, you will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required. The time taken for the blue colour to form allows the reaction rate to be determined.

(a) Prepare a table in the space provided on page 4 in which to record, to an appropriate level of precision:

- all volumes, except the volume of sodium thiosulfate, potassium iodide and starch,
- all values of *t*.

Experiment 1

The end-point of the reaction is the **first** appearance of a blue colour.

1. Fill a burette with **FA 1**.
2. Transfer 20.00 cm^3 of **FA 1** into a 250 cm^3 beaker labelled “reaction mixture”.
3. Use appropriate measuring cylinder, transfer to a clean 100 cm^3 beaker.
    - 10.0 cm^3 of **FA 2**,
    - 10.0 cm^3 of **solution S**,
    - 20.0 cm^3 of **FA 3**.
4. Pour this mixture rapidly into the beaker containing **FA 1** and stir the contents using a glass rod. Start the stopwatch during this addition.
5. The mixture turns brown and then yellow before turning a blue colour. Stop the stopwatch when the solution **first** turns blue.
6. Record the time taken, *t*, to the nearest second in your table.
7. Carefully wash out the beaker. Stand it upside down on a paper towel to drain.

Experiment 2

1. Fill another burette with deionised water.
2. Transfer 6.00 cm^3 of **FA 1** into another 250 cm^3 beaker labelled “reaction mixture”.
3. Transfer 14.00 cm^3 of deionised water into the beaker containing **FA 1**.
4. Repeat points 3 – 7 from experiment 1.

Experiment 3 to 5

Carry out **three** further experiments to investigate the effect of changing the concentration of Fe^{3+}(aq) by changing the volume of aqueous **FA 1** used.

You should **not** use a volume of **FA 1** that is less than 6.00 cm^3.

In each case, you will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required.

You should alternate the use of the two 250 cm^3 beakers labelled “reaction mixture”.

Record all required volumes and time taken in your table.

Results

experiment	V_{FA1} / cm^3	$V_{deionised\ water}$ / cm^3	time/ s
1	20.00	0.00	15
2	6.00	14.00	24
3	10.00	10.00	21
4	14.00	6.00	17
5	17.00	3.00	16

(b) The rate of reaction can be found by calculating the change in concentration of $Fe^{3+}(aq)$ that occurred when enough iodine was produced to change the colour of the indicator to blue.

(i) Calculate the amount, in moles, of thiosulfate ions, $S_2O_3^{2-}$, used in each experiment.

Amount of $S_2O_3^{2-} = \frac{20}{1000} \times 0.00600 = 1.20 \times 10^{-4}$ mol

(ii) Calculate the amount of iron(III) ions, Fe^{3+}, that were used to produce the amount of iodine that react with the amount of $S_2O_3^{2-}$ in **(b)(i)**.

Mole ratio of $S_2O_3^{2-} : I_2 : Fe^{3+}$ is 2 : 1 : 2
Amount of $Fe^{3+} = 1.20 \times 10^{-4}$ mol

(iii) Calculate the change in the concentration of iron(III) ions up to the time of appearance of the blue colour.

Change in $[Fe^{2+}] = (1.20 \times 10^{-4}) \div (60 \div 1000) = 2.00 \times 10^{-4}$ mol dm^{-3}

(iv) The rate of this reaction relative to $[Fe^{3+}]$ can be determine using the following expression.

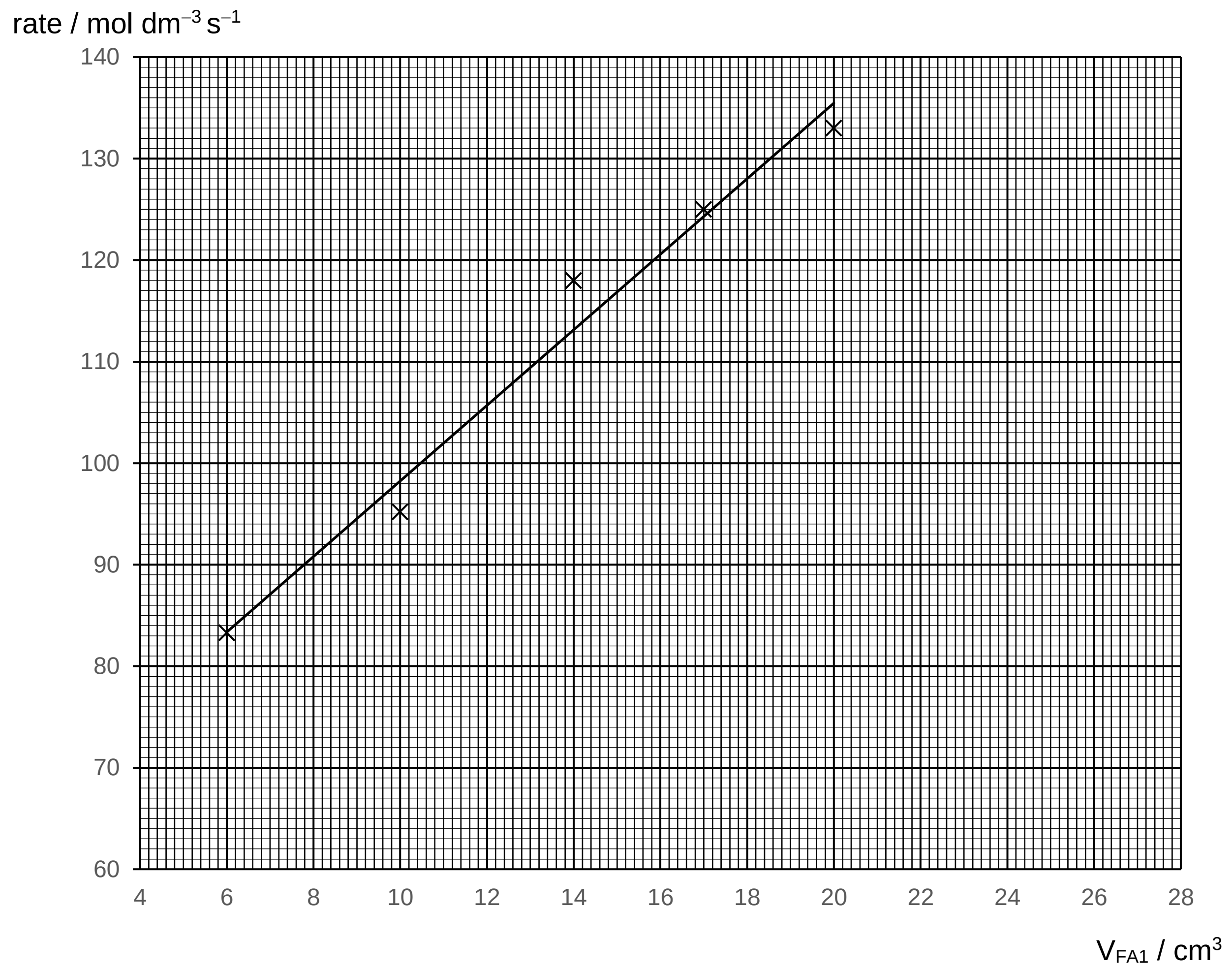
$$\text{rate} = \frac{\text{change in concentration of } Fe^{3+}(aq)}{\text{reaction time}} \times 10^6$$

Complete the table to show the volume of **FA 1**, the reaction time and the rate in Experiments 1 to 5. You should include units.

If you were unable to calculate a value for the change in concentration of $Fe^{3+}(aq)$ in **(b)(iii)**, you should assume it is 2.50×10^{-3} mol dm^{-3}. Note that this is not the correct value.

experiment	V_{FA1} / cm^3	reaction time / s	rate / mol dm^{-3} s^{-1}
1	20.00	15	133
2	6.00	24	83.3
3	10.00	21	95.2
4	14.00	17	118
5	17.00	16	125

(c) **(i)** Plot a graph of rate on the *y*-axis against volume of **FA 1** on the *x*-axis. Draw the best-fit straight line taking into account all of your plotted points.



(ii) Deduce the order of reaction with respect to [Fe^{3+}]. Use evidence from your graph in **(c)(i)** to support your answer.

Reaction is first order with respect to [Fe^{3+}].
The straight-line graph shows that rate is proportional to [Fe^{3+}] (or volume of Fe^{3+}).

(d) It was found by carrying out experiments similar to those used in **(a)**, that increasing the concentration of I^- increased the rate of the reaction.

A student suggested a modification to the method by using the same volumes of all reagents but with the concentrations of **FA 1** and **FA 2** being double their original values.

State what the effect would be on the reaction time in Experiment 1 and explain how this change would affect any possible errors in the measurements.

Reaction time is less/shorter (not faster).
The measurement will be less accurate since there is a larger percentage error in time.

(e) Another student thought that the experiment could be made more accurate by repeating Experiment 1 with the same volumes of all reagents but using 0.060 mol dm^{-3} sodium thiosulfate instead of **FA 3**. He found that the reaction mixture never turned blue.

Explain why.

$S_2O_3^{2-}$ is in excess. All the iodine reacts with $S_2O_3^{2-}$ so no iodine is left to turn starch solution blue.

2 Investigation of an inorganic and organic compound

FA 4 contains one cation and one anion.

FA 5 is a solution of an aromatic organic compound, $C_7O_3H_6$, which contains two different functional groups.

You will perform tests to identify:

- the ions present in **FA 4**,
- the functional groups in **FA 5** and hence deduce its possible structure.

The volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

If there is no observable change, write **no observable change**.

(a) (i) Carry out the following tests. Carefully record your observations in **Table 2.1**.

Table 2.1

	test	observations
1	Test the **FA 4** solution using Universal Indicator paper.	Orange colour on UI paper corresponds to pH 3.
2	Add 1 cm depth of **FA 4** to a test-tube. Add aqueous sodium hydroxide, slowly with shaking, until no further change is seen.	white ppt soluble in excess
3	Add 1 cm depth of **FA 4** to a test-tube. Add aqueous ammonia, slowly with shaking, until no further change is seen.	white ppt insoluble in excess

(ii) Identify the cation in **FA 4** and state the evidence to support your deduction.

cation	evidence
Al^{3+}	It forms a white precipitate with NaOH(aq) which is soluble in excess **and** forms a white precipitate with NH_3(aq) which is insoluble in excess.

[1]

(iii) Write ionic equations to account for your observations in test 2.

$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$

$Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$

(iv) Devise and perform a series of simple tests to identify the anion in **FA 4**. Your test should be based on the Qualitative Analysis Notes on pages 23 – 24 and should use only the bench reagents provided. Record your tests and observations in the space below.

Any test requiring heating MUST be performed in a boiling tube.

FA 4 does **not** contain carbonate, nitrite or any sulfur ions.

test	observations
To 1 cm depth of **FA 4**, add a few drops of $AgNO_3$.	No observable change
To 1 cm depth of **FA 4** in a boiling tube, add 1 cm depth of aqueous NaOH and a piece of Al foil. Heat cautiously.	(White ppt formed, soluble in excess NaOH to form a colourless solution.) Upon heating, gas evolved turned damp red litmus paper blue.

(v) Use your observations in **(a)(iv)** to deduce the identity of the anion in **FA 4**.

NO_3^-

(b) **(i)** Carry out the following tests. Carefully record your observations in **Table 2.2**.

Table 2.2

	test	observations
1	To a 2 cm depth of **FA 5** in a test tube, add a small spatula of sodium carbonate.	Effervescence observed. Gas gives a while precipitate with limewater.
2	To a 1 cm depth of aqueous iron(III) chloride in a test-tube, add 10 drops of **FA 5**.	Violet solution observed.
3	**Do not perform the following test. Observations have been recorded for you.** To a 1 cm depth of **FA 5** in a test tube, add an equal depth of aqueous bromine.	Orange solution turns colourless. White precipitate formed.

[2]

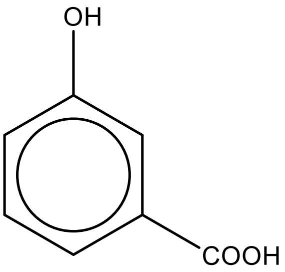
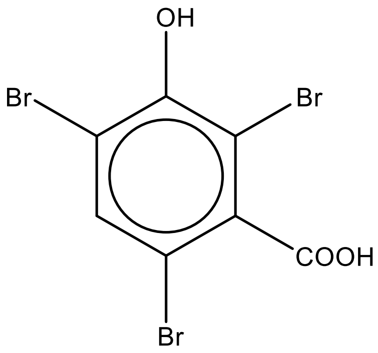
(ii) Consider your observations in **Table 2.2**.

Name the functional group that can be identified using aqueous iron(III) chloride and aqueous bromine.

phenol

(iii) In test 3, the white precipitate, **Y,** with M_r = 374.7 is formed.
[A_r of C = 12.0, H = 1.0, O = 16.0, Br = 79.9]

Consider your observations and deductions from **Table 2.2**, suggest the structure of **FA 5** and **Y**.

	
structure of **FA 5**	structure of **Y**

3 Determination of a value for the relative atomic mass, A_r, of magnesium

FA 6 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.
FA 7 is 0.120 mol dm^{-3} sodium hydroxide, NaOH
Magnesium ribbon
Solution I is bromophenol blue indicator

You are to react magnesium with **FA 6**, dilute the reaction mixture and titrate this diluted sample with **FA 7**. The data from the titration will be used to calculate the relative atomic mass, A_r, of magnesium.

(a) (i) Procedure

1. Pipette 25.0 cm^3 of **FA 6** into a 250 cm^3 beaker.
2. Weigh the magnesium ribbon and record its mass.

mass of magnesium = 0.192 g

3. Coil the magnesium ribbon loosely and add it to the **FA 6** in the beaker.
4. Stir the reaction mixture occasionally and wait until the reaction is completed.
5. Transfer all the solution from the beaker into a 250 cm^3 volumetric flask.
6. Make the solution up to the mark with deionised water and shake well to mix.
7. Label this solution **FA 8**.
8. Fill a clean burette with **FA 7**.
9. Rinse the pipette thoroughly.
10. Pipette 25.0 cm^3 **FA 8** into a 250 cm^3 conical flask.
11. Add a few drops of **solution I** to the conical flask.
12. Run **FA 7** from the burette into the conical flask. The end-point is reached when the solution just becomes green.
13. Record your titration results to an appropriate level of precision in the space on page 15.
14. Repeat steps 10 to 13 until consistent results are obtained.

Titration results

titration number	1	2
final burette reading / cm^3	29.30	29.30
initial burette reading / cm^3	0.00	0.00
volume of **FA 7** used / cm^3	29.30	29.30

(ii) From your titrations, obtain a suitable volume of **FA 7** to be used in your calculations. Show clearly how you obtained this volume.

Volume of FA 7 used = (29.30 + 29.30) ÷ 2 = 29.30 cm^3

(b) **(i)** Calculate the amount, in moles, of hydrochloric acid added to the magnesium ribbon during the preparation of **FA 8**.

Amount of HC*l* added = $\frac{25}{1000} \times 2.00 = 0.0500$ mol

(ii) Use your titration results to calculate the amount of hydrochloric acid in the volumetric flask after the reaction with magnesium during the preparation of **FA 8**. Hence calculate the amount of hydrochloric acid that reacted with the magnesium.

Amount of NaOH = $\frac{29.30}{1000} \times 0.120 = 0.003516$ mol

Amount of HC*l* in 25.0 cm^3 **FA8** = 0.003516 mol

Amount of HC*l* in 250 cm^3 **FA8** = $\frac{250}{25.0} \times 0.003516 = 0.03516 = 0.0352$ mol

Amount of HC*l* reacted = 0.0500 – 0.03516 = 0.01484 = 0.0148 mol

(iii) The reaction between magnesium and hydrochloric acid is shown.

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

Calculate the relative atomic mass, A_r, of magnesium.

Amount of Mg = 0.5 × 0.01484 = 0.00742 mol
$A_r = 0.192 \div 0.00742 = 25.9$

(c) **(i)** A student follows the procedure described and calculated the relative atomic mass of magnesium to be 24.1.
The theoretical value of the relative atomic mass of magnesium is 24.3.

Calculate the difference between the theoretical value and the student's calculated value as a percentage. This is the percentage error.

percentage error = $\frac{24.3-24.1}{24.3} \times 100\% = 0.823\%$

(ii) The student calculates that the maximum total percentage error of the whole procedure is 1.09%.

Did the student perform the experiment well? Explain your answer.

Performed well as the percentage error of the A_r obtained is less than the total percentage error of the whole procedure.

4 Planning

Acetic acid, CH_3CO_2H, can be found in vinegar and provides its signature tangy flavour to enhance culinary dishes.

Acetic acid reacts with sodium hydroxide, NaOH, according to equation 1.

equation 1 $CH_3CO_2H(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l) \quad \Delta H_n$

When CH_3CO_2H is mixed with NaOH, the neutralisation reaction releases heat causing a rise in the temperature of the solution.

A series of experiments can be carried out using different volumes of the two solutions, CH_3CO_2H and NaOH. In each experiment, the total volume of the two solutions is to be kept constant at 50 cm^3 and the change in temperature, ΔT, is to be determined. Since the total volume of mixture remains the same, the temperature rise, ΔT, is a direct measure of the heat liberated by the reaction. The maximum amount of heat is evolved when all the acid present is exactly neutralised by all the alkali present.

Plotting a graph of ΔT against the volume of CH_3CO_2H used will give 2 straight lines of best–fit.

Extrapolation of the two straight lines will produce a point of intersection from which the concentration of CH_3CO_2H and the enthalpy change of neutralisation, ΔH_n, between CH_3CO_2H and NaOH can be determined.

(a) In an experiment, 1.00 mol dm^{-3} of NaOH was reacted with acetic acid and the total volume of the two solutions used was 50 cm^3.

Assuming that the concentration of acetic acid is approximately 0.880 mol dm^{-3}, calculate the volume of acetic acid to be used so that stoichiometric amounts of acetic acid and NaOH react.

Let volume of acetic acid used be V cm^3.

$$\frac{V}{1000} \times 0.880 = \frac{(50- V)}{1000} \times 1.00$$

$0.880V = 50 - V$

V = **26.6 cm^3**

(b) Using the information given, you are required to write a plan to determine the concentration of acetic acid in vinegar, and the value of ΔH_n using a graphical method.
You may assume that the original solutions are at room temperature.
You may also assume that you are provided with:

- 250 cm^3 of approximately 0.880 mol dm^{-3} acetic acid
- 250 cm^3 of 1.00 mol dm^{-3} NaOH(aq),
- the equipment normally found in a school or college laboratory.

Your plan should include:

- brief, but specific, details of the apparatus you would use, bearing in mind the levels of precision they offer,
- the quantities you would use,
- the procedure you would follow,
- the measurements you would make to allow a suitable ΔT against the volume of CH_3CO_2H graph to be drawn.

1. Place a clean and dry polystyrene cup inside a second polystyrene cup which is placed in a 250 cm^3 beaker (to prevent the cups from tipping over).
2. Using a 50.00 cm^3 burette, transfer 10.00 cm^3 of $CH_3CO_2H(aq)$ to a 100 cm^3 beaker. Measure the initial temperature, T_1 of MOH. Wash and dry the thermometer
3. Using another burette, transfer 40.00 cm^3 of NaOH(aq) into the polystyrene cup and put a lid on.
4. Insert a 0.2 °C thermometer through the lid and ensure that the bulb of the thermometer is fully immersed in NaOH(aq). Measure the initial temperature, T_2, of NaOH(aq).
5. Open the lid of the cup and transfer the 10.00 cm^3 of $CH_3CO_2H(aq)$ into the polystyrene cup containing NaOH(aq). Close the lid quickly.
6. Stir the mixture continuously using the thermometer until the highest temperature is reached. Record this temperature, T_3.
7. Discard the contents of the polystyrene cup.
8. Wash and dry the polystyrene cup and thermometer.
9. Repeat step 1 to 8 using the following volumes.

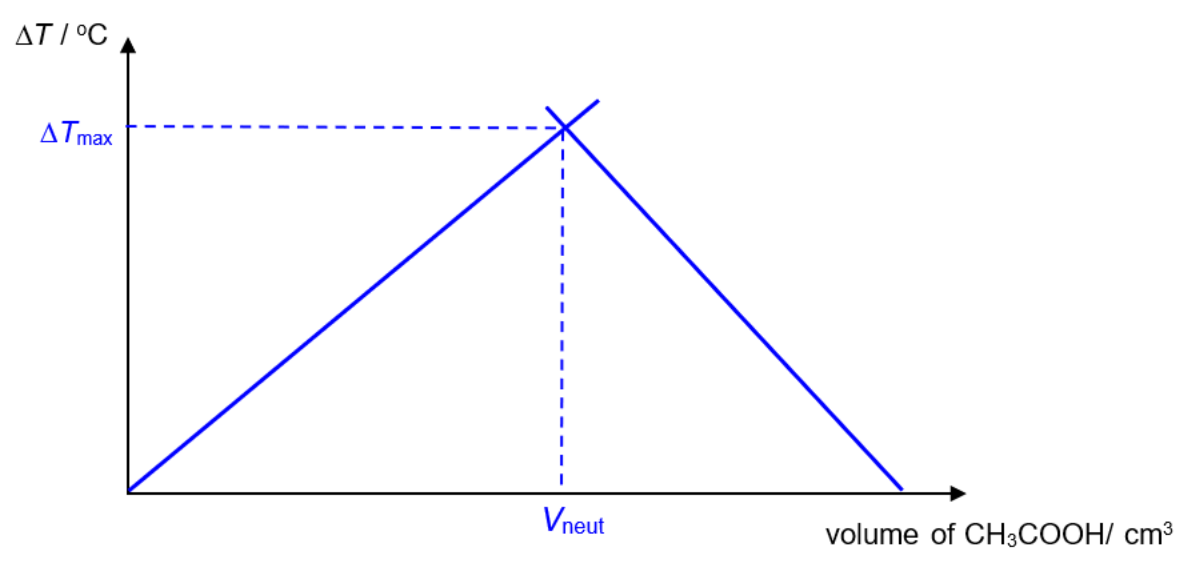
Volume of CH_3CO_2H / cm^3	Volume of NaOH / cm^3
15.0	35.0
20.0	30.0
25.0	25.0
30.0	20.0
35.0	15.0
40.0	10.0

10. Record all measurements of volume, initial temperatures, calculated weighted average of the initial temperatures and temperature change, ΔT, in an appropriate format.

(c) Sketch on Fig. 4.1, the graph you would expect to obtain from your results. Indicate clearly on your sketch how you would determine:

- V_{neut}, the volume of CH_3CO_2H used
- ΔT_{max}, the maximum temperature change

when stoichiometric amount of CH_3CO_2H and NaOH react.



(d) Outline how you would use your answers from **(c)** to determine:

(i) the concentration of acetic acid in vinegar, in mol dm^{-3}.
Express your results in terms of V_{neut}.

Volume of NaOH = $(50 - V_{neut})$
Mole ratio of CH_3CO_2H : NaOH = 1 : 1
Amount of CH_3CO_2H = Amount of NaOH
$(50 - V_{neut}) \times 1.00 = V_{neut} \times [CH_3CO_2H]$

$$[CH_3CO_2H] = \frac{(50 - V_{neut})}{V_{neut}}$$

(ii) the enthalpy change of neutralisation, ΔH_n.
Express your results in terms of $\Delta T_{max.}$ and V_{neut}.

You may assume the following:

- specific heat capacity of all solutions is 4.18 J g^{-1} K^{-1},
- density of all solutions is 1.00 g cm^{-3}.

Heat transferred = $(50 \times 4.18 \times \Delta T_{max}) / 1000$ kJ

Amount of H_2O formed = amount of NaOH = $1.00 \times \frac{(50 - V_{neut})}{V_{neut}}$

$\Delta H_{neut} = -[(50 \times 4.18 \times \Delta T_{max}) / 1000] \div [\frac{(50 - V_{neut})}{V_{neut}}]$

$= -(209 \times \Delta T_{max}) / (50 - V_{neut})$ kJ mol^{-1}

(e) A similar exothermic reaction takes place between HC*l*(aq) and NaOH(aq).

Explain how the ΔT_{max} would differ from the value obtained in **(c)** when the same experiment described in **(b)** is repeated using HC*l*(aq) of the same concentration as acetic acid.

ΔT_{max} will be higher as acetic acid is a weak acid OR HC*l* is a strong acid.

Energy will be absorbed to allow complete dissociation of acetic acid molecules OR HC*l* dissociates completely in solution.

Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	***reaction with***	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

ions	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $Cl^-(aq)$	gives white ppt. with $Ag^+(aq)$ (soluble in $NH_3(aq)$)
bromide, $Br^-(aq)$	gives pale cream ppt. with $Ag^+(aq)$ (partially soluble in $NH_3(aq)$)
iodide, $I^-(aq)$	gives yellow ppt. with $Ag^+(aq)$ (insoluble in $NH_3(aq)$)
nitrate, $NO_3^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil
nitrite, $NO_2^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, $SO_4^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}(aq)$	SO_2 liberated with dilute acids; gives white ppt. with $Ba^{2+}(aq)$ (soluble in dilute strong acids)

(c) Test for gases

ions	*reaction*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

(d) Colour of halogens

halogen	*colour of element*	*colour in aqueous solution*	*colour in hexane*
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple