VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME .....

CT GROUP .....

CHEMISTRY 9729/04

Paper 4 Practical **27 August 2025**

Candidates answer on the Question Paper. **2 hours 30 minutes**

Additional Materials: As listed in the instructions below

READ THESE INSTRUCTIONS FIRST

Write your name and CT group on all the work you hand in.
Give details of the shift and laboratory in the boxes provided.
Write in dark blue or black pen.
You may use a 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 **19** and **20**.

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	**/ 14**
2	**/ 17**
3	**/ 12**
4	**/ 12**
Total	**/ 55**

This document consists of **19** printed pages and **1** blank page.

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

1 Determination of the molar enthalpy change of reaction

When zinc powder is added to an aqueous solution of copper(II) ions, a displacement reaction occurs.

$$Cu^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Cu(s)$$

In this question, you will perform an experiment to determine a value for ΔH.

You are provided with:
- solid **FA 1**, zinc
- **FA 2**, containing 0.80 mol dm^{-3} copper(II) ions

(a) (i) You will measure the temperature of the contents in a polystyrene cup at regular time intervals, before and after zinc is added. You will analyse your results graphically to obtain an accurate value of the temperature change caused by the reaction.

You will use this value to calculate the heat change, q, for the experiment and hence determine a value for the molar enthalpy change of the reaction, ΔH.

In the space provided on page 4, prepares tables in which to record for your experiment:
- all weighings to an appropriate level of precision,
- all values of temperature, T, to an appropriate level of precision,
- all values of time, t, recorded to 0.5 min.

It is important that you measure each temperature at the specified time.

Procedure

1. Weigh the capped container containing solid **FA 1**.

2. Place one polystyrene cup inside another polystyrene cup and place both in a glass beaker.

3. Use the measuring cylinder to transfer 30 cm^3 of **FA 2** into the cup.

4. Carefully stir the **FA 2** in the polystyrene cup with the thermometer. Read and record the temperature, T. Start the stopwatch (t = 0.0 min). The stopwatch must be left to run for the rest of the experiment.

5. Continue to stir **FA 2**. Read and record T every 0.5 minutes for two minutes.

6. At **exactly** 2.5 minutes, transfer all the solid **FA 1** to the polystyrene cup. Stir the mixture but do not read T.

7. Continue to stir the mixture. Read and record T at t = 3.0 min and every 0.5 minutes until t = 8.0 min.

8. Reweigh the empty capped container.

Note: You should keep **FA 2** for use in Question 2.

Question 1 continues on the next page.

Results

[2]

(ii) Plot a graph of temperature, T, on the y-axis, against time, t, on the x-axis, on the grid in Fig. 1.1.

Draw a best-fit straight line taking into account all of the points before t = 2.5 min.

Draw another best-fit straight line taking into account all of the points after the temperature of the mixture has started to fall steadily.

Extrapolate both lines to t = 2.5 min. [3]

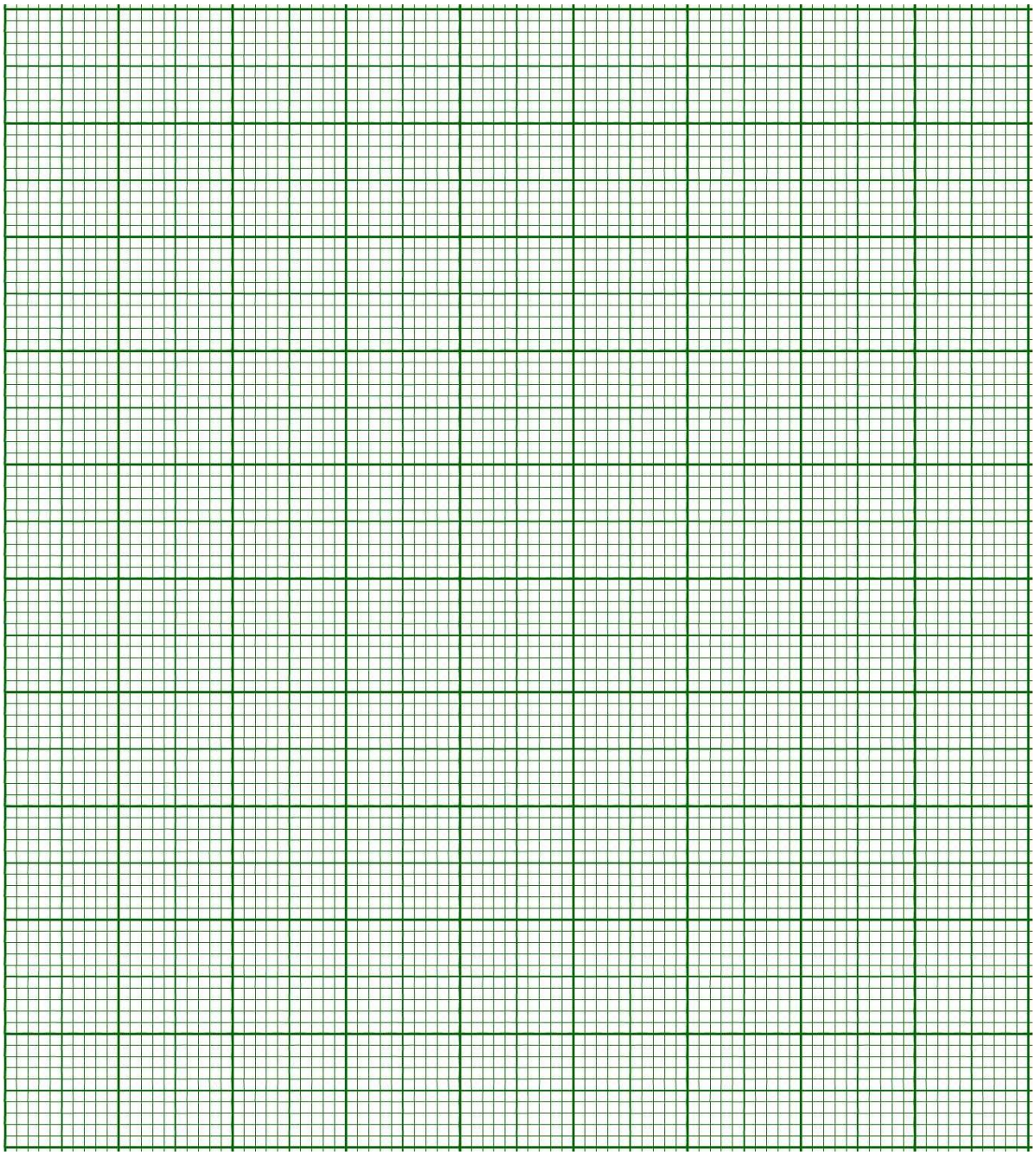

Fig. 1.1

(iii) From your graph, read the minimum temperature, T_{min}, and the maximum temperature, T_{max}, at t = 2.5 min. Record these values in the spaces below.

Calculate the temperature change, ΔT, at t = 2.5 min.

T_{min} = ...

T_{max} = ...

ΔT = ...

[3]

(iv) Calculate the heat change, q, for your experiment using the value you calculated in **(a)(iii)**.

Assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1}, and that the density of the reaction mixture is 1.00 g cm^{-3}.

q = ... [1]

(v) Determine the molar enthalpy change of reaction, ΔH, for the reaction between zinc and copper(II) ions.

Include the sign of ΔH in your answer.

[A_r: Zn, 65.4, Cu, 63.5]

ΔH = ... [3]

(b) A student followed the procedure in **(a)(i)** to perform the experiment, except that he used 60 cm^3 of 0.40 mol dm^{-3} copper(II) ions.

State and explain the effect on the temperature change as compared to the value in **(a)(iii)**.

.....

.....

..... [2]

[Total: 14]

2 Qualitative analysis

FA 2, which you used in Question 1, contains one anion.
FA 3 is a solid metal oxide.
FA 4 is an aqueous solution of an organic compound, $C_6H_{12}O_6$, containing a functional group which is either an alcohol, an aldehyde or a carboxylic acid.

You will carry out tests to identify the anion in **FA 2**, cation in **FA 3** and whether an alcohol, an aldehyde or a carboxylic acid functional group is present in **FA 4**.

You will also carry out some reactions involving **FA 2**.

Carefully record your observations in Table 2.1 and 2.2.

Unless otherwise stated, the volumes given in Table 2.1 and 2.2 are approximate and should be estimated rather than measured.

Test any gases evolved during the tests.

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

(a) (i) Half-fill the 250 cm^3 beaker with water and place it on a tripod and gauze. Heat the water until boiling then switch off your Bunsen burner. This will be your hot water bath.

Table 2.1

	test	observations
1	Add 1 cm depth of **FA 2** to a test-tube. Add 1 cm depth of dilute nitric acid followed by 1 cm depth of aqueous barium nitrate.	
2	Add about 3 cm depth of dilute sulfuric acid to the boiling tube containing **FA 3**. Gently shake the boiling tube for one minute. Leave to settle, then decant the liquid into a clean test-tube. This solution is **FB 1** to be used for Test 3.	
3	Add 1 cm depth of **FB 1** to a test-tube. Add aqueous ammonia, slowly with shaking, until no further change is seen.	
4	Place a ½ cm depth of aqueous silver nitrate in a test-tube. Add 1 or 2 drops of aqueous sodium hydroxide to form a brown precipitate. Add aqueous ammonia dropwise with shaking until the precipitate just dissolves. Add 1 cm depth of **FA 4** to this mixture and place the test-tube in the hot water bath.	
	When you have completed Test 4 pour the contents in the test-tube down the sink with plenty of water and rinse the test-tube.	
5	Add 1 cm depth of **FA 4** to a test-tube. Add 10 drops of dilute sulfuric acid, then 1 or 2 drops of **FA 5** (potassium manganate(VII)) and place the test-tube in the hot water bath.	
6	Add 1 cm depth of **FA 4** to a test-tube. Add 1 cm depth of aqueous sodium carbonate.	

[6]

(ii) State the anion present in **FA 2**.

…….. [1]

(iii) In Test 2, a disproportionation reaction occurred. The cation in **FA 3** is both reduced and oxidised.

Consider the observations you made in Test 2 and 3, deduce the identity of the cation. Write an overall equation for the reaction that occurred when you added dilute sulfuric acid to **FA 3** in Test 2.

cation present in **FA 3** ……

…….. [2]

(iv) State which functional group is present in **FA 4**. Explain your answer.

…….....

…….....

…….. [1]

(b) (i) Reheat your water bath to boiling then switch off your Bunsen burner.

Table 2.2

	test	observations
7	Add 1 cm depth of **FA 2** to a test-tube. Add 2 cm depth of aqueous EDTA, followed by a few drops of aqueous sodium hydroxide. To the same test-tube, add a 1 cm depth of **FA 4** and place the test-tube in the hot water bath.	

[3]

The following questions are on the reactions in Test 7 on page 10.

Fig. 2.1 shows the structure of EDTA. It is a hexadentate ligand and forms very stable water-soluble octahedral complexes with many metal ions. These complexes have the general formula $[M(edta)]^{(n-4)}$, where n is the charge of the metal ion M.

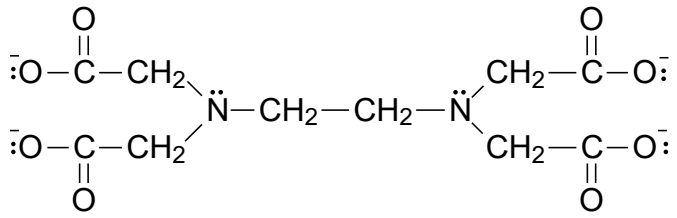

Fig. 2.1

(ii) Suggest an explanation, in terms of the copper-containing complexes present, for the observation when EDTA was added to **FA 2**.

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…… [1]

(iii) When certain conditions are met, hydroxide ions react with some metal ions, causing them to precipitate out as metal hydroxides. In qualitative analysis, this process is useful to identify the presence of certain metal ions.

Use your knowledge in solubility equilibria and the information given about EDTA complexes, explain the observation when sodium hydroxide was added.

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…… [2]

(iv) Consider the nature of the functional group present in **FA 4**, suggest an explanation for the observation(s) when **FA 4** was added.

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…… [1]

[Total: 17]

3 Investigation of reaction between iron(III) ions and hydroxylamine

A redox reaction takes place between hydroxylamine, NH_2OH, and iron(III) ion, Fe^{3+}, in acidic conditions. The iron(III) ion is reduced to an iron(II) ion, Fe^{2+}. The reaction is slow at room temperature but is complete in a few minutes at 100 °C. The reaction is shown by one of the following equations.

equation 1 $NH_2OH(aq) + Fe^{3+}(aq) \rightarrow Fe^{2+}(aq) + ½N_2(g) + H^+(aq) + H_2O(l)$

equation 2 $NH_2OH(aq) + 2Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + ½N_2O(g) + 2H^+(aq) + ½H_2O(l)$

equation 3 $NH_2OH(aq) + 3Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq) + NO(g) + 3H^+(aq)$

You will carry out a titration to determine which of equations 1, 2 or 3 best represents the reaction. The iron(II) ions formed in the reaction with the hydroxylamine are oxidised by manganate(VII) ions.

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

FA 5 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 6 is a solution prepared by boiling a 1.00 dm^3 aqueous mixture consisting 3.30 g of hydroxylamine hydrochloride, $NH_2OH{\cdot}HCl$, excess iron(III) chloride, $FeCl_3$, and excess sulfuric acid. Any water lost by evaporation was replaced after cooling.
FA 7 is 1.0 mol dm^{-3} dilute sulfuric acid.

Assume that one mole of hydroxylamine hydrochloride gives one mole of hydroxylamine in solution.

(a) (i) Titration of FA 6 against FA 5

1. Fill the burette with **FA 5**.
2. Pipette 25.0 cm^3 of **FA 6** into a conical flask.
3. Use a 25 cm^3 measuring cylinder to add 10 cm^3 of **FA 7** to the same conical flask.
4. Run **FA 5** from the burette into the flask. The end-point is reached when the solution changes from yellow to permanent pale pink.
5. Record your titration results, to an appropriate level of precision in Table 3.1.
6. Repeat steps 2 to 5 until consistent titre values are obtained.

Table 3.1

final burette reading / cm^3					
initial burette reading / cm^3					
volume of **FA 5** added / cm^3					

[5]

(ii) From your titrations, obtain a suitable volume of **FA 5** to be used in your calculations. Show clearly how you obtained this volume.

Volume of **FA 5** = ... cm^3 [1]

(b) (i) Calculate the amount, in mol, of potassium manganate(VII) present in the volume of **FA 5** in **(a)(ii)**.

amount of $KMnO_4$ =..... mol [1]

(ii) Use your answer to **(b)(i)** to calculate the amount, in mol, of iron(II) ions in 25.0 cm^3 of solution **FA 6**.

amount of Fe^{2+} = ... mol [1]

(iii) Calculate the amount, in mol, of hydroxylamine hydrochloride that has reacted in 25.0 cm^3 of solution **FA 6.**
[A_r: H, 1.0; N, 14.0; O, 16.0; C*l*, 35.5]

Amount of $NH_2OH{\cdot}HCl$ = ... mol [3]

(iv) Use your answers in **(b)(ii) and (iii)** to deduce which of the three suggested equations corresponds to your results. Show your working.

The correct equation number is …… [1]

[Total: 12]

4 Planning

Benzenediazonium chloride, $C_6H_5N_2Cl$, an aromatic diazonium compound, decomposes in solution at a temperature higher than 45 °C to produce phenol and nitrogen gas.

$$C_6H_5N_2Cl(aq) + H_2O(l) \rightarrow C_6H_5OH(aq) + N_2(g) + HCl(aq)$$

The rate equation for this reaction is

$$\text{Rate} = k[C_6H_5N_2Cl]$$

where k is the rate constant.

The order with respect to $C_6H_5N_2Cl$ may be confirmed to be first order by warming the solution at 50 °C and recording the volume of nitrogen evolved over time.

In this experiment, there is no need to calculate $[C_6H_5N_2Cl]$ as $V_{final} - V_t$ is proportional to the concentration of the $C_6H_5N_2Cl$, where

- V_{final} is the final volume of nitrogen gas measured once the decomposition is complete
- V_t is the volume collected at time = t.

You may assume that you are provided with:

- 1.5 g of solid benzenediazonium chloride
- 200 cm^3 gas syringe
- the equipment normally found in a school or college laboratory

(a) Describe how you would make a standard solution of 0.100 mol dm^{-3} of benzenediazonium chloride (M_r = 140.5) for your experiment.

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…… [4]

(b) Plan an experiment to collect sufficient data for a graph of $V_{final} - V_t$ against *time* to be plotted.

In your plan, you should use the standard solution of benzenediazonium chloride made in **(a)** and include brief details of:

- justification of volume of benzenediazonium chloride solution you would use,
- the apparatus you would use,
- the procedure you would follow,
- the measurements you would make.

You should assume that all gases are measured at r.t.p. with molar gas volume of 24 dm^3 mol^{-1}.

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…… [6]

(c) The order of reaction with respect to benzenediazonium chloride is expected to be first order.

Sketch, on Fig. 4.1, the graph of $V_{final} - V_t$ against *time* you would expect to obtain.

Explain how the order of reaction with respect to benzenediazonium chloride may be determined from your graph.

Fig. 4.1

explanation ……

…….

…….

…….

…….

……. [2]
[Total: 12]

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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

anion	***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) Tests for gases

gas	***test and test result***
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

Preparation List:

Label	Per candidate	Identity	Preparation
FA 1	2.0 ± 0.1 g	zinc metal powder	Provide in a stoppered container.
FA 2	60 cm^3	0.32 mol dm^{-3} copper(II) sulfate	Dissolve 79.9 g of $CuSO_4.5H_2O$ in 1 dm^3 solution.
FA 3	0.45 g to 0.50 g	powdered solid copper(I) oxide	Provide in a stoppered dry boiling tube.
FA 4	15 cm^3	0.20 mol dm^{-3} glucose	Dissolve 36.0 g of $C_6H_{12}O_6$ in 1 dm^3 solution.
EDTA	10 cm^3	0.20 mol dm^{-3} EDTA	Dissolve 74.5 g of $[CH_2N(CH_2CO_2H)CH_2CO_2Na]_2.2H_2O$ in 1 dm^3 solution.
aq sodium carbonate	5 cm^3	1 mol dm^{-3} sodium carbonate	Dissolve 286 g of $Na_2CO_3.10H_2O$ or 106 g of Na_2CO_3 in 1 dm^3 solution.
FA 5	120 cm^3	0.0200 mol dm^{-3} $KMnO_4$	Dissolve 3.16 of $KMnO_4$ in 1 dm^3 solution
FA 6	120 cm^3	0.0950 mol dm^{-3} $(NH_4)_2Fe(SO_4)_2$	Dissolve 14.43g of $FeSO_4$ OR 26.40 g of $FeSO_4.7H_2O$ in 1 dm^3 of 1.0 mol dm^{-3} $H_2SO_4(aq)$ This solution must be freshly prepared.
FA 7	120 cm^3	1 mol dm^{-3} sulfuric acid	

Apparatus and chemicals for each student:

(1) 8 x clean and dry test-tube
(2) 5 x teat pipette (dropper)
(3) 2 x wooden splint
(4) Red and blue litmus papers
(5) 2 x filter paper
(6) Paper towels
(7) 2 x clean and dry Styrofoam cup
(8) 1 x thermometer (0.2°C gradation)
(9) 1 x glass rod
(10) 1 x burette clamp and stand
(11) 1 x burette
(12) 1 x 25 cm^3 pipette
(13) 1 x pipette filler
(14) 1 x 50 cm^3 measuring cylinder
(15) 1 x 25 cm^3 measuring cylinder
(16) 2 x 250 cm^3 conical flask
(17) 1 x 250 cm^3 beaker
(18) 1 x delivery tube
(19) 1 x test-tube rack
(20) 1 x test-tube holder
(21) 1 x white tile
(22) 1 x heat-proof mat
(23) 1 x small brush
(24) 1 x filter funnel
(25) 1 x lighter
(26) 1 x Bunsen burner
(27) 1 x stopwatch
(28) 1 pair of safety goggles
(29) 1 x marker pen
(30) 1 x wash bottle of deionised water
(31) Chemicals:
- **FA 1**
- **FA 2**
- **FA 3**
- **FA 4**
- **FA 5**
- **FA 6**
- **FA 7**
- EDTA
- aqueous sodium carbonate

You are also provided with the following bench reagents.

1) dilute nitric acid
2) dilute sulfuric acid
3) dilute hydrochloric acid
4) aqueous ammonia
5) aqueous sodium hydroxide
6) aqueous barium nitrate
7) limewater
8) aqueous silver nitrate
9) aluminium foil

Communal equipment:

Weighing balance