Name:		**Centre/Index Number:**		**Class:**	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 CHEMISTRY

9729/04

Paper 4 Practical

19 August 2024
2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class 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	**16**
2	**11**
3	**13**
4	**15**
Total	**55**

This question paper consists of **23** printed pages and **1** blank page.

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

1 Determination of the enthalpy change of decomposition of magnesium carbonate

The enthalpy change of decomposition of magnesium carbonate, ΔH_1, cannot be determined experimentally.

Reaction 1 $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$ ΔH_1

However, the enthalpy changes for **Reaction 2** and **Reaction 3** can be determined experimentally as ΔH_2 and ΔH_3 respectively.

Reaction 2 $MgCO_3(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l) + CO_2(g)$ ΔH_2

Reaction 3 $MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$ ΔH_3

You will carry out an experiment to determine the enthalpy change for **Reaction 3**, ΔH_3, and use this value, together with ΔH_2, to calculate the enthalpy change of decomposition of magnesium carbonate, ΔH_1.

FA 1 is solid magnesium oxide powder, MgO.
FA 2 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Determination of ΔH_3

In this experiment, you will be adding solid magnesium oxide powder to sulfuric acid in a Styrofoam cup. You will then measure the temperature of the reaction mixture over time. Plotting an appropriate graph using the data obtained will allow you to determine ΔH_3.

Prepare a table in the space provided on page 4 in which to record:

- 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.

Procedure

1. Weigh the capped bottle containing solid **FA 1**.
2. Place a clean and dry Styrofoam cup on the 250 cm^3 glass beaker.
3. Using a 25 cm^3 measuring cylinder, add 25 cm^3 of **FA 2** into the Styrofoam cup.
4. Stir the solution in the cup with the thermometer. Read and record its temperature, T (time, t = 0.0 min).
5. Continue to stir the solution. Read and record T every 0.5 min.
6. At exactly 2.0 minutes, transfer all the solid **FA 1** into the Styrofoam cup. Stir the mixture but do not read T.
7. Read and record T at t = 2.5 min and then every 0.5 min until t = 7.0 min.
8. Continue stirring occasionally throughout this time.
9. Reweigh the emptied bottle and its cap.

(i) Results

[3]

(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 = 2.0 min.

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

Extrapolate both lines to t = 2.0 min.

Fig. 1.1

[3]

(iii) From your graph, read the minimum temperature, T_{min}, and the maximum temperature T_{max}, at 2.0 min. Record these values in the spaces provided below.

Deduce the temperature change, ΔT, at t = 2.0 min.

T_{min} = …………………………

T_{max} = …………………………

ΔT = …………………………

[1]

(iv) In the reaction in **(a)**, the sulfuric acid was in excess. Without carrying out any additional tests, what observation could you have made during your experiment to confirm this?

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(v) Calculate the heat change, q, that occurred during the reaction in **(a)**.

You should assume that the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}, and that the density of the solution is 1.00 g cm^{-3}.

q = ………………………… [1]

(vi) Use your answer to **(a)(v)** to calculate ΔH_3, the enthalpy change for the reaction between magnesium oxide and sulfuric acid.

[A_r: Mg, 24.3; O, 16.0]

ΔH_3 = …………………… kJ mol^{-1} [1]

(b) **Determination of ΔH_2**

*Note: You do **not** need to perform this experiment.*

In this experiment, the initial temperature of 25 cm^3 of sulfuric acid in a Styrofoam cup is measured and recorded as 30 °C. After which, 2.00 g of solid magnesium carbonate powder is added to the sulfuric acid in the cup. The maximum temperature reached during the reaction is measured and recorded as 40 °C.

(i) Show, using suitable calculations, that sulfuric acid is in excess.

[A_r: Mg, 24.3; C, 12.0; O, 16.0]

[1]

(ii) Hence, calculate ΔH_2, the enthalpy change for the reaction between magnesium carbonate and sulfuric acid.

ΔH_2 = …………………… kJ mol^{-1} [2]

(c) Using your answers in **(a)(vi)** and **(b)(ii)**, construct an energy cycle to calculate ΔH_1, the enthalpy change for **Reaction 1**.

ΔH_1 = ………………………….. [2]

(d) The method used to determine ΔH_3 in **(a)** was more accurate than the method used to determine ΔH_2 in **(b)**. Suggest why the method used for **Reaction 2** was less accurate.

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[Total: 16]

2 Planning

Calcium hydroxide, $Ca(OH)_2$, is a white powder which is produced when calcium oxide is mixed with water. Calcium hydroxide is poorly soluble in water and its solubility is described by the following equilibrium.

$$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^{-}(aq)$$

(a) A 25.0 cm^3 saturated solution containing $Ca(OH)_2$ dissolved in 0.020 mol dm^{-3} NaOH at 25 °C was titrated with HC*l*.

Given the average titre volume of HC*l* is 20.00 cm^3 and the solubility of $Ca(OH)_2$ in 0.020 mol dm^{-3} NaOH at 25 ºC is approximately 5.00×10^{-3} mol dm^{-3}, show that a suitable concentration of HC*l* needed for this titration is 0.0375 mol dm^{-3}.

[2]

(b) Using the concentration of HC*l* from **(a)**, you are to plan an investigation to determine the solubility of $Ca(OH)_2$ in 0.020 mol dm^{-3} aqueous sodium hydroxide at 25 °C and hence, the solubility product of $Ca(OH)_2$ at 25 °C.

You may assume that you are provided with:
- solid calcium hydroxide, $Ca(OH)_2$
- 0.020 mol dm^{-3} aqueous sodium hydroxide, NaOH
- 0.0375 mol dm^{-3} aqueous hydrochloric acid, HC*l*
- methyl orange (yellow colour in alkaline medium and red colour in acidic medium)
- the equipment normally found in a school laboratory.

In your plan you should include brief details of:
- the procedure you would follow,
- the appropriate apparatus you would use,
- the measurements you would take.

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[5]

(c) **(i)** Calculate the solubility of $Ca(OH)_2$ in 0.020 mol dm^{-3} NaOH at 25 °C, assuming that the titre volume of HC*l* obtained in **(b)** is 19.80 cm^3.

[2]

(ii) Hence, calculate the solubility product of $Ca(OH)_2$ at 25 °C.

[1]

(iii) Predict and explain how your answer in **(c)(i)** would compare with the solubility of $Ca(OH)_2$ in water at 25 °C.

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[Total: 11]

Turn over for Question 3.

3 Determination of the basicity of an unknown acid X

The basicity of an acid is defined as the number of hydrogen ions (H^+) that can be produced when one molecule of the acid completely dissociates in water.

Monobasic acids produce one H^+ per molecule when completely dissociated in water while dibasic acids produce two H^+ per molecule when completely dissociated in water.

In this experiment, an acid-base titration is used to determine whether acid **X** is monobasic or dibasic.

FA 3 is a solid sample of acid **X**.
FA 4 is 0.100 mol dm^{-3} sodium hydroxide, NaOH.
Solution I is thymol blue indicator.

(a) Preparation of a dilute solution of acid X

1. Weigh between 1.2 g and 1.4 g of **FA 3** into a dry 100 cm^3 beaker. Record your mass readings to an appropriate level of precision in the space provided on the next page.

2. Use a measuring cylinder to add about 50 cm^3 of deionised water to the beaker. Stir with a glass rod until all the solid has dissolved completely.

3. Pour the solution from the beaker into a 100 cm^3 volumetric flask.

4. Wash out the beaker thoroughly with deionised water and transfer the washings to the volumetric flask.

5. Make the solution up to the mark with deionised water and shake well to mix. This solution is **FA 5**.

(b) (i) Titration of FA 5 against FA 4

1. Fill a burette with **FA 4**.

2. Pipette 10.0 cm^3 of **FA 5** into a 100 cm^3 conical flask.

3. Add five drops of **Solution I** to the conical flask. The solution should appear red in colour.

4. Titrate the solution in the conical flask with **FA 4**. The solution should gradually turn yellow. The end-point for this titration is reached when the solution changes colour from yellow to blue.

5. Record all burette readings, to an appropriate level of precision, in the space provided on the next page.

6. Repeat steps 1 to 5 until consistent results are obtained.

Results

[3]

(ii) From your titrations, obtain a suitable volume of **FA 4** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 4** = …………………………..cm^3 [3]

(c) **(i)** Calculate the amount of H$^+$ present in 10.0 cm^3 of **FA 5**.

amount of H$^+$ in 10.0 cm^3 of **FA 5** = ………………………….. mol [1]

(ii) Hence, determine the amount of H$^+$ present in the solid sample of **FA 3** you weighed out in **(a)**.

amount of H$^+$ in **FA 3** weighed out in **(a)** = …………………………..mol [1]

(iii) Given that the molecular mass of acid **X** is 126.0 g mol^{-1}, calculate the amount of acid **X** weighed out in **(a)**.

amount of acid **X** weighed out in **(a)** = ………………………….. mol [1]

(iv) Using your answers in **(c)(ii)** and **(c)(iii)**, deduce whether acid **X** is monobasic or dibasic.

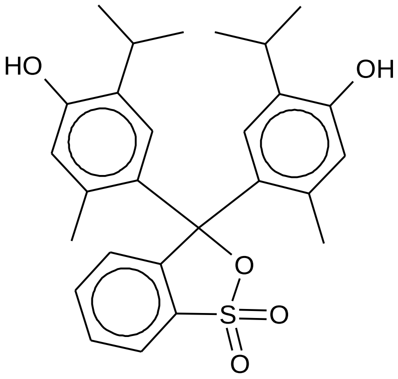
[1]

(d) The pipette used in this experiment is calibrated to ±0.02 cm^3.

Determine whether the pipette or burette used in this experiment would give a larger percentage error when used to measure 10 cm^3 of **FA 5** needed for the titration.

[1]

(e) The structure of the thymol blue indicator is shown below. The sulfur–containing functional group can be considered inert.



thymol blue

A student used much more thymol blue indicator in the titration than specified in the procedure. Suggest how this student's titre value will compare with the expected titre value. Explain your answer.

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……………………………………………………………………………………………………….… [2]

[Total: 13]

4 Analysis of Inorganic and Organic Compounds

(a) **FA 6** is an aqueous solution containing one cation.
FA 7 is an aqueous solution containing two cations.

You will perform tests to identify the cations in **FA 6** and **FA 7**.

You are **not** expected to identify the anions.

(i) Carry out the following tests. Record your observations in Table 4.1.

Unless otherwise stated, 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**.

Table 4.1

test		observations
1	Add 1 cm depth of **FA 6** into a boiling tube. Add all the sodium carbonate to this boiling tube.	
2	Add 1 cm depth of **FA 6** into a test-tube. Add aqueous ammonia slowly, with shaking, until no further change is seen.	
3	Add 2 cm depth of **FA 7** into a test-tube. Add aqueous ammonia, slowly with shaking, until 4 cm depth of aqueous ammonia has been added. Filter the mixture into a clean test-tube.	
4	Add 1 cm depth of the filtrate from test 3 into a test-tube. Add dilute nitric acid, slowly, with shaking, until no further change is seen.	

[5]

(ii) Identify the cation present in **FA 6**.

……………………………………………………………………………………………..................[1]

(iii) Explain your observations in Test 1 of Table 4.1.

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……………………………………………………………………………………………..................[2]

(iv) Identify the two cations in **FA 7** and state the evidence for each cation by completing Table 4.2.

Table 4.2

cation	evidence

[2]

(b) **FA 8** has the molecular formula C_8H_8O.
FA 9 has the molecular formula $C_8H_{10}O$.

Solution 1 is copper(II) sulfate solution.
Solution 2 is potassium sodium tartrate in sodium hydroxide solution.

You will perform tests to identify the functional groups present in **FA 8** and **FA 9**, and hence deduce their possible structures.

Half-fill a 250 cm^3 beaker with water and heat until the water is almost boiling. This is a hot water bath for use in **(b)(i)**. You should turn off the Bunsen burner but reheat the water if it cools excessively.

Note: Handle all hot apparatus with care and discard all unwanted mixtures in the waste bottle provided.

(i) Carry out the following tests. Some of the observations have been completed for you. There is no need to carry out those tests. Record your observations in Table 4.3.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

You do **not** need to test and identify any gases evolved.

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

Use a fresh sample of each solution in each test.

Table 4.3

	test	observations with **FA 8**, C_8H_8O	observations with **FA 9**, $C_8H_{10}O$
1	Add about 1 cm depth of the **FA** solution into a test-tube. To this test-tube add 1 cm depth of aqueous bromine.	no observable change	no observable change
2	Add about 1 cm depth of the **FA** solution into a test-tube. To this test-tube add 8 drops of sodium hydroxide solution followed by iodine solution, dropwise, until a permanent orange/red colour is present. Warm the mixture in the hot water bath for two minutes.	solution **FA 8** turns orange	pale yellow precipitate formed

	test	observations with **FA 8**, C_8H_8O	observations with **FA 9**, $C_8H_{10}O$
3	Add 1 cm depth of **Solution 1** into a test-tube. Then add 1 cm depth of **Solution 2** into the test-tube.		
	Add 1 cm depth of **FA 8** to the same test-tube. Shake the test-tube and warm the mixture in the hot water bath. Shake the test-tube occasionally. **Repeat test 3 using FA 9 instead of FA 8**.		
4	Add 1 cm depth of **FA 8** into a test-tube. Add 1 cm depth of 2,4-dinitrophenylhydrazine solution into the test-tube. **Repeat test 4 using FA 9 instead of FA 8**.		

[2]

(ii) Based on the observations for test 1 in Table 4.3, state **two** functional groups that are absent in **FA 8** and **FA 9**.

……………………………………………………………………………………………..............[1]

(iii) Using the observations in Table 4.3 and your answer in **(b)(ii)**, suggest the structures of **FA 8** and **FA 9**.

FA 8	**FA 9**

[2]

[Total: 15]

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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