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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

4290061779

CHEMISTRY **9701/32**

Paper 3 Advanced Practical Skills 2 **May/June 2022**

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION
- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages.

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Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 A bottle containing the acid salt sodium hydrogen sulfate, $NaHSO_4$, has been contaminated. You will determine the percentage purity by mass of the sodium hydrogen sulfate by titrating a solution of the acid salt against a known concentration of sodium hydroxide.

$$NaHSO_4(aq) + NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$$

The impurity in the sodium hydrogen sulfate does not react with aqueous sodium hydroxide under the conditions of the titration.

FB 1 is 0.100 mol dm^{-3} sodium hydroxide, NaOH.
FB 2 is 12.53 g dm^{-3} impure sodium hydrogen sulfate.
FB 3 is thymol blue indicator.

(a) Method

- Fill a burette with **FB 1**.
- Pipette 25.0 cm^3 of **FB 2** into a conical flask.
- Add approximately 10 drops of **FB 3**.
- Perform a rough titration and record your burette readings in the space below. The end-point is shown by the appearance of a permanent blue colour.

The rough titre is .... cm^3.

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record, in a suitable form below, all your burette readings and the volume of **FB 1** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FB 2** required .... cm^3 of **FB 1**. [1]

(c) Calculations

(i) Give **all** your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to an appropriate number of significant figures. [1]

(ii) Use your answer to **(b)** to calculate the amount, in mol, of sodium hydroxide, **FB 1**, titrated.

amount of NaOH = ... mol

Hence, deduce the amount, in mol, of sodium hydrogen sulfate present in 25.0 cm^3 of **FB 2**.

amount of $NaHSO_4$ = ... mol [1]

(iii) Use your final answer to **(c)(ii)** to calculate the mass of sodium hydrogen sulfate present in 1.00 dm^3 of **FB 2**.

mass of $NaHSO_4$ = ... g [1]

(iv) Use your answer to **(c)(iii)** and the information on page 2 to calculate the percentage purity by mass of the sodium hydrogen sulfate.

percentage purity = ... % [1]

[Total: 12]

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2 In **Question 1** you carried out a neutralisation reaction involving sodium hydroxide.

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

In **Question 2** you are to determine the enthalpy of neutralisation, ΔH_{neut}, as shown by the equation above. You will use a solution of sodium hydroxide and the diprotic acid, sulfuric acid.

FB 4 is approximately 2 mol dm^{-3} sodium hydroxide, NaOH.
FB 5 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Method

- Place the cup in the 250 cm^3 beaker.
- Use the 25.0 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FB 4** into the cup.
- Place the thermometer in the solution. Record the temperature.
- Fill the clean burette with **FB 5**.
- Run 5.00 cm^3 of **FB 5** into the same cup.
- Stir the mixture and record the highest temperature observed.
- Repeat adding 5.00 cm^3 volumes of **FB 5** into the same cup until 45.00 cm^3 has been added. Record the highest temperature after each addition.

Results

Table 2.1

volume of **FB 5** / cm^3	0.00	5.00	10.00	15.00	20.00
temperature / °C					

volume of **FB 5** / cm^3	25.00	30.00	35.00	40.00	45.00
temperature / °C					

[3]

(b) (i) Plot a graph of temperature (*y*-axis) against volume of acid added (*x*-axis) on the grid provided. Select a scale on the *y*-axis to include a temperature 2.0 °C above the highest temperature you recorded.

Label any points you consider to be anomalous. Draw two lines of best fit, one for the rise in temperature and one for the temperature change after the maximum temperature has been reached.
Extrapolate the two lines so they intersect. [4]

(ii) Use your graph to:
- determine the volume of sulfuric acid, **FB 5**, required to neutralise 25.0 cm^3 of sodium hydroxide, **FB 4**
- determine the maximum change in temperature, ΔT.

volume of H_2SO_4 = ... cm^3

maximum ΔT = ... °C
[1]

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(c) **(i)** Use your answer to **(b)(ii)** to calculate the amount, in mol, of sulfuric acid, **FB 5**, neutralised in your reaction.

amount of H_2SO_4 = ... mol [1]

(ii) Calculate the heat energy evolved in the neutralisation reaction in **(a)**.
(Assume that 4.18 J are required to change the temperature of $1.0\,cm^3$ of solution by 1.0 °C.)

heat energy evolved = ... J [1]

(iii) Use your answers to **(c)(i)** and **(c)(ii)** to calculate the enthalpy of neutralisation, ΔH_{neut}, for the reaction given in **(a)**.

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

ΔH_{neut} = ... [1]
sign *value* *unit*

(d) **(i)** The value for $\Delta H^{\ominus}_{neut}$ quoted in a textbook is $-57.6\,kJ\,mol^{-1}$.

Calculate the percentage error in your answer to **(c)(iii)** compared with the theoretical value.
(If you were unable to answer **(c)(iii)** then assume the value was $-49.2\,kJ\,mol^{-1}$.)

percentage error = ... % [1]

(ii) Without changing the apparatus, suggest **one** improvement that could be made to the method in **(a)**.
Explain your answer.

improvement ....

....

explanation ....

....
[1]

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(e) **(i)** Use your graph and the information on page 4 to calculate the concentration, in mol dm^{-3}, of sodium hydroxide in **FB 4**.

concentration of NaOH = ... mol dm^{-3} [1]

(ii) A student repeats **Question 1** with a new solution of **FB 1**.

The student decides to dilute **FB 4** by a factor of 20 to make the new **FB 1** solution.

The student incorrectly assumes the concentration of the new **FB 1** solution is 0.100 mol dm^{-3}.

Calculate the **actual** concentration of NaOH in the new **FB 1** solution.

(If you were unable to answer **(e)(i)** then assume the concentration of sodium hydroxide in **FB 4** was 1.93 mol dm^{-3}. This is not the correct value.)

concentration of NaOH in the new **FB 1** solution = ... mol dm^{-3}

Predict the effect that using the new **FB 1** solution has on the value for the percentage purity of the sodium hydrogen sulfate you calculated in **1(c)(iv)**.

The percentage purity of $NaHSO_4$ would be larger than calculated.	
The percentage purity of $NaHSO_4$ would be the same as calculated.	
The percentage purity of $NaHSO_4$ would be smaller than calculated.	

Tick the appropriate box and explain your answer.

....

....

.... [2]

[Total: 16]

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Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **(a)** **FB 6** is the solid impurity found in the bottle of solid used to prepare **FB 2**. It is a compound of a Group 1 metal and does **not** contain sulfur. The anion in **FB 6** is listed in the Qualitative analysis notes.

Select a reagent, or reagents, and carry out **one** test on **FB 6** to collect more information about the anion present.

reagent or reagents ....

apparatus and conditions ....

....

observations ....

....

From your observations give the formula of the anion present.
If you are unable to identify the anion positively from your test and observations, then write 'unknown'.

formula of anion ....

[4]

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(b) **(i)** **FB 7** and **FB 8** are solutions containing a total of three cations. All of the cations are listed in the Qualitative analysis notes.

Carry out the following tests and record your observations. Use a fresh 1 cm depth of solution in a test-tube for each test.

Table 3.1

test	*observations*	
	FB 7	**FB 8**
Test 1 Add a few drops of acidified aqueous potassium manganate(VII).		
Test 2 Add aqueous ammonia.		
Test 3 Add aqueous sodium hydroxide, then		
decant the mixture into a boiling tube and warm gently.		

[4]

(ii) Using your observations in **(b)(i)**, identify the cations present in **FB 7** and **FB 8**.
Write the formula of each cation identified. If the tests do not allow you to positively identify the cations, write 'unknown'.

cation or cations in **FB 7** ....

cation or cations in **FB 8** ....

[2]

(iii) Construct the ionic equation for **one** reaction observed on addition of aqueous ammonia in **Test 2**. Include state symbols.

.... [1]

(iv) Deduce the type of reaction which occurs when acidified aqueous potassium manganate(VII) is added to **FB 7** in **Test 1** in **(b)(i)**.

.... [1]

[Total: 12]

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Qualitative analysis notes

1 Reactions of 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)	no ppt. ammonia produced on warming	–
barium, Ba^{2+}(aq)	faint white ppt. is observed unless $[Ba^{2+}(aq)]$ is very low	no ppt.
calcium, Ca^{2+}(aq)	white ppt. unless $[Ca^{2+}(aq)]$ is very low	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	pale 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

2 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 cream / off-white ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives pale 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; decolourises acidified aqueous $KMnO_4$
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids); gives white ppt. with high $[Ca^{2+}(aq)]$
sulfite, SO_3^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids); decolourises acidified aqueous $KMnO_4$
thiosulfate, $S_2O_3^{2-}$(aq)	gives off-white / pale yellow ppt. slowly with H^+

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3 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
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^4\,C\,mol^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,dm^3\,mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

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The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

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