Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

* 0 4 7 2 8 2 6 5 3 2 *

CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1 **October/November 2020**

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions
Insert (enclosed)

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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

Session
Laboratory

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.
- Notes for use in qualitative analysis are provided in the question paper.
- The insert contains printed text for use in your practical.

For Examiner's Use	
1	
2	
3	
Total	

This document has **16** pages. Blank pages are indicated.

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

1 In this experiment you will determine the value of x in the formula of hydrated sodium thiosulfate, $Na_2S_2O_3•xH_2O$, where x is an integer. You will first prepare a solution of the salt and then use this solution in a titration with aqueous iodine. The thiosulfate ions react with iodine as shown.

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

FA 1 is hydrated sodium thiosulfate, $Na_2S_2O_3•xH_2O$.
FA 3 is 0.0500 mol dm^{-3} iodine, I_2.
starch indicator

(a) Method

Preparation of salt solution

- Weigh the container containing **FA 1**.
- Tip the contents of the container into the 250 cm^3 beaker.
- Weigh the container with any residue.
- Record all your readings in the space below.

- Add approximately 200 cm^3 of distilled water to the salt in the beaker and stir until the salt has dissolved.
- Pour the contents carefully into the 250 cm^3 volumetric flask.
- Rinse the beaker with a little distilled water and add these washings to the flask.
- Fill the flask to the mark with distilled water and shake to ensure thorough mixing.
- Label this solution **FA 2**.

Titration

- Fill a burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 3** into the conical flask.
- Add **FA 2** from the burette until the solution in the flask turns yellow.
- Add 10 drops of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FA 2** from the burette until the blue-black colour just disappears. This is the end-point of the titration.
- Carry out a rough titration and record your burette readings in the space below.

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

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure your recorded results show the precision of your practical work.
- Record, in a suitable form in the space below, all of your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) From your accurate titration results, obtain a value for the volume of **FA 2** to be used in your calculations. Show clearly how you obtained this value.

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

(c) Calculations

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

(ii) Calculate the number of moles of iodine in 25.0 cm^3 of **FA 3**.

moles of I_2 = ... mol [1]

(iii) Calculate the number of moles of thiosulfate ions in the volume recorded in **(b)**.

moles of $S_2O_3^{2-}$ = ... mol

Hence calculate the number of moles of hydrated sodium thiosulfate in the mass weighed in **(a)**.

moles of $Na_2S_2O_3{\bullet}xH_2O$ = ... mol [1]

(iv) Calculate the value for x in the formula of hydrated sodium thiosulfate, $Na_2S_2O_3{\bullet}xH_2O$. Show your working.

x = ...
[3]

(d) **(i)** State the maximum error in a single reading on the balance used in **(a)**.

maximum error = ± .... g

Calculate the maximum percentage error in the mass of **FA 1** used in **(a)**.
Show your working.

maximum percentage error = ± .... %
[1]

(ii) Assume that the uncertainty in the mass of **FA 1** is the only source of error in your experiment.

Calculate the minimum value for the relative formula mass of **FA 1**.
Show your working.

minimum value for the relative formula mass of **FA 1** = ... [1]

(e) A student prepares **FA 2** using anhydrous sodium thiosulfate salt and the same mass of salt that you used in **(a)**.

State how the student's titre would compare with the average titre value you obtained in **(b)**.
Explain your answer.

....

....

....

.... [1]

(f) In many titrations it is usual to fill the burette with the solution of known concentration.

Suggest why this was not done in **(a)**.

....

.... [1]

[Total: 19]

2 When a solution containing thiosulfate ions, $S_2O_3^{2-}$, is acidified the following reaction occurs.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(g) + H_2O(l)$$

The solid sulfur that is formed makes the mixture become cloudy. The rate of reaction can then be measured by timing how long it takes for the mixture to become too cloudy to see through.

You will investigate how changing the concentration of the thiosulfate ions affects the rate of reaction.

Throughout these experiments care must be taken to avoid inhaling the SO_2 that is produced. It is very important that as soon as each experiment is complete the contents of the beaker are emptied into the quenching bath.

FA 4 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.
FA 5 is a solution of sodium thiosulfate, $Na_2S_2O_3$.
distilled water

(a) Method

Experiment 1

- Use the 50 cm^3 measuring cylinder to transfer 40.0 cm^3 of **FA 5** into the 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to measure 20.0 cm^3 of **FA 4**.
- Add the 20.0 cm^3 of **FA 4** to **FA 5** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printed text on the insert from above through the mixture in the beaker.
- Note the time when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 2**.

Experiment 2

- Use the 50 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FA 5** into the 100 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 20.0 cm^3 of distilled water into the same beaker.
- Use the 25 cm^3 measuring cylinder to measure 20.0 cm^3 of **FA 4**.
- Add the 20.0 cm^3 of **FA 4** to **FA 5** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printed text on the insert from above through the mixture in the beaker.
- Note the time when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse the beaker thoroughly.

Keep FA 5 for use in Question 3.

Record all your results in a table. You should include the volume of **FA 5**, the volume of distilled water, the reaction time and the rate of reaction for both experiments.

The rate of reaction can be calculated using the following formula.

$$\text{rate of reaction} = \frac{1000}{\text{reaction time}}$$

I	
II	
III	
IV	

[4]

(b) A student suggested that the rate of the reaction is directly proportional to the concentration of the thiosulfate ions.

State whether your results support this suggestion.
Explain your answer.

....

....

.... [1]

(c) The student's suggestion in **(b)** could be made more reliable by carrying out further experiments.

Prepare a table to show three further experiments you could carry out. Show clearly the volumes of **FA 4**, **FA 5** and distilled water that you would use in each of these experiments. Do not suggest a volume of **FA 5** that is greater than 40.0 cm^3 or less than 20.0 cm^3.

DO <u>NOT</u> CARRY OUT THESE ADDITIONAL EXPERIMENTS.

[2]

[Total: 7]

Qualitative Analysis

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

At each stage of any test you are to record details of the following:

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

You should indicate clearly at what stage in a test a change occurs.

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

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

No additional tests for ions present should be attempted.

3 (a) **FA 6** is a salt containing one cation and one anion. The anion is listed in the Qualitative Analysis Notes.
Add all the sample of **FA 6** to the 100 cm^3 beaker. Dissolve the solid in approximately 50 cm^3 of distilled water.
Label this solution **FA 7**.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 7** in a test-tube, add a 3 cm depth of aqueous silver nitrate.	
Pour approximately half the contents of the test-tube into a clean test-tube.	
Test 2 To the first test-tube add aqueous ammonia.	
Test 3 To the second test-tube add **FA 5**, aqueous sodium thiosulfate.	

[2]

(ii) From the results of your tests in **(a)(i)** suggest which anion is present in **FA 6**.

.... [1]

(iii) It is suggested that **FA 6** could be sodium sulfite, Na_2SO_3, or sodium sulfate, Na_2SO_4.

Carry out tests using solution **FA 7** in order to decide whether **FA 6** is sodium sulfite or sodium sulfate.
Record the reagents selected, the results of your tests and your conclusions in the space below.

FA 6 is sodium .... [2]

(iv) Using your conclusion from **(a)(iii)**, write an ionic equation for the reaction between silver nitrate and **FA 7**.
Include state symbols.

.... [1]

(b) **FA 8** is a solution containing one of the cations listed in the Qualitative Analysis Notes.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add aqueous ammonia until there is no further change, then	
pour the contents into a boiling tube and add a few drops of aqueous hydrogen peroxide.	

[3]

(ii) Identify the cation in **FA 8**.

cation = ... [1]

(iii) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add a 1 cm depth of aqueous potassium iodide, then	
add **FA 5**, aqueous sodium thiosulfate.	

[2]

(iv) Explain your observations in **(b)(iii)**.

....

....

.... [2]

[Total: 14]

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Qualitative Analysis Notes

1 Reactions of aqueous cations

ion	*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 heating	–
barium, Ba^{2+}(aq)	faint white ppt. is nearly always observed unless 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	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

2 Reactions of anions

ion	*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 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
sulfate, $SO_4^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (soluble in excess dilute strong acids)

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 (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

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 –		114 Fl flerovium –		116 Lv livermorium –		

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 –