



Cambridge International AS & A Level

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

May/June 2020

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, 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.

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** 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 carry out a titration to determine the relative formula mass of a hydrated salt, **FA 1**.

FA 1 is a hydrated salt.

FA 2 is dilute sulfuric acid.

FA 3 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII).

(a) Method

Preparing a solution of **FA 1**

- Weigh the stoppered container of **FA 1**. Record the mass in the space below.
- Tip all the **FA 1** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FA 1** used.
- Add approximately 100 cm^3 of **FA 2** to the **FA 1** in the beaker.
- Stir the mixture until all the **FA 1** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Rinse the beaker and glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of the hydrated salt is **FA 4**. Label the flask **FA 4**.

Titration

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use the 25.0 cm^3 measuring cylinder to add 10 cm^3 of **FA 2** to the **FA 4** in the conical flask.
- Perform 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 any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

Keep FA 3 and FA 4 for use in Question 3.

[8]

- (b)** From your accurate titration results, obtain a suitable value for the volume of **FA 3** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm³ of **FA 4** required cm³ of **FA 3**. [1]

(c) Calculations

- (i)** Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 3** calculated in **(b)**.

moles of KMnO_4 = ... mol [1]

- (ii)** 1 mol of KMnO_4 reacts with 5 mol of the hydrated salt, **FA 1**.

Calculate the concentration of the hydrated salt, in mol dm⁻³, in **FA 4**.

concentration of **FA 4** = ... mol dm⁻³ [1]

- (iii)** Use your answer to **(c)(ii)**, and your data on page 2, to calculate an experimentally determined value for the relative formula mass of the hydrated salt, **FA 1**.
Show your working.

M_r of **FA 1** = ... [1]

[Total: 12]

- 2 In this experiment you will determine the enthalpy change of solution for anhydrous sodium carbonate.

FA 5 is anhydrous sodium carbonate, Na_2CO_3 . (You are given approximately 11 g.)

(a) Method

Experiment 1

- Weigh a cup. Record the mass.
- Transfer 4.0–4.2 g of **FA 5** from the container into the cup.
- Reweigh and record the mass of the cup with **FA 5**.
- Calculate and record the mass of **FA 5** used.
- Support the cup in the 250 cm³ beaker.
- Pour 30 cm³ of distilled water into the 50 cm³ measuring cylinder.
- Measure and record the temperature of the distilled water in the measuring cylinder.
- Add the 30 cm³ of distilled water to the **FA 5** in the cup.
- Stir constantly until the maximum temperature is reached.
- Measure and record the maximum temperature.
- Calculate and record the temperature rise.

Experiment 2

- Repeat **Experiment 1** but this time use 5.0–5.2 g of **FA 5** and the other cup.
- Record all data from **both** experiments in one table.

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Calculate the energy produced during **Experiment 1**.
(Assume that 4.2 J change the temperature of 1.0 cm³ of solution by 1.0 °C.)

energy produced = ... J [1]

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 hydrated salt. It contains two cations and one anion, all of which are listed in the Qualitative Analysis Notes.

(i) Describe and carry out tests to identify the cations in **FA 6**.

Record your tests and observations in the space below.

The cations in **FA 6** are and

[5]

- (ii) The anion in **FA 6** is a sulfite, sulfate or a halide.

Carry out a test to identify the anion in **FA 6**.

Record your tests and observations in the space below.

The anion in **FA 6** is [2]

- (iii) Give the ionic equation for **one** reaction you have carried out in (a)(i) or (a)(ii).
Include state symbols.

..... [1]

- (iv) The formula of **FA 6** is $\text{XY}_2\text{Z}_2 \cdot w\text{H}_2\text{O}$ where

- **X** and **Y** are the cations present and **Z** is the anion present
- **w** is the number of moles of water of crystallisation in the hydrated salt.

The relative formula mass of this compound is 392.0.

Using your conclusions from (a)(i) and (a)(ii), calculate the value of **w**, the number of moles of water of crystallisation.

w = ... [2]

(b) **FA 7** and **FA 8** are aqueous solutions of covalently bonded compounds.

Half fill the beaker with water and place it on a tripod and gauze. Heat until the water begins to boil and then turn off the Bunsen burner. This will be used as a hot water bath.

- (i) Complete the table by carrying out the tests described.
Use a 1 cm depth of **FA 7** or **FA 8** in a test-tube for each test.

test	observation(s)	
	FA 7	FA 8
Test 1 Add an equal volume of dilute sulfuric acid and a few drops of FA 3 , aqueous acidified potassium manganate(VII), then place in the hot water bath for several minutes.		
Test 2 Add an equal volume of dilute sulfuric acid and an equal volume of aqueous potassium iodide, then add a few drops of aqueous starch.		
Test 3 Add an equal volume of aqueous iodine, then add aqueous sodium hydroxide until no further change occurs. Leave the tube to stand.		
Test 4 Add a few drops of FA 4 , then add aqueous ammonia.		

[5]

- (ii) **FA 8** contains an organic compound.

From your observation(s), suggest one **possible** identity for this compound.
Explain your answer.

name

reason

.....

.....

[2]

- (iii) State the type of reagent **FA 7** acts as in its reaction with aqueous potassium iodide.
Explain your answer.

.....

.....

..... [1]

[Total: 18]

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

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests for gases

<i>gas</i>	<i>test and test result</i>
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

Group																		
1	2																17	18
		Key atomic number atomic symbol name relative atomic mass																
		1 H hydrogen 1.0																
3 Li lithium 6.9	4 Be beryllium 9.0																9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3																16 S sulfur 32.1	17 Cl chlorine 35.5
13 Al aluminium 27.0	14 Si silicon 28.1																31 Ga gallium 69.7	32 Ge germanium 72.6
15 P phosphorus 31.0	16 S sulfur 32.1																51 Sb antimony 121.8	52 Te tellurium 127.6
17 Cl chlorine 35.5	18 Ar argon 39.9																83 Bi bismuth 209.0	84 Po polonium —
19 K potassium 39.1	20 Ca calcium 40.1																114.8	115.7
37 Rb rubidium 85.5	38 Sr strontium 87.6																118.7	119.7
55 Cs caesium 132.9	56 Ba barium 137.3																207.2	208.9
87 Fr francium —	88 Ra radium —																116	117
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 —				

lanthanoids

actinoids



Cambridge International AS & A Level

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CHEMISTRY

9701/32

Paper 3 Advanced Practical Skills 2

May/June 2020

2 hours

You must answer on the question paper.

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

INSTRUCTIONS

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- 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.

INFORMATION

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- 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.

Session	
Laboratory	

For Examiner's Use	
1	
2	
3	
Total	

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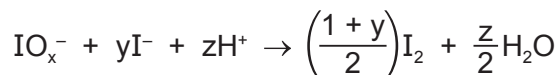
Quantitative Analysis

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

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

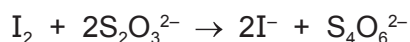
- 1 In this experiment you will determine the formula of the ion, IO_x^- . To do this you will first react IO_x^- ions with an excess of iodide ions, I^- , to form iodine, I_2 .

The equation for this reaction is:



where x, y and z are all integers.

The amount of iodine produced will then be determined by titration with thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$.



FB 1 is a solution containing $0.0150 \text{ mol dm}^{-3}$ IO_x^- ions.

FB 2 is dilute sulfuric acid, H_2SO_4 .

FB 3 is $0.500 \text{ mol dm}^{-3}$ potassium iodide, KI.

FB 4 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

starch indicator

(a) Method

- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Use the measuring cylinder to add 25 cm^3 of **FB 2** to the conical flask.
- Use the measuring cylinder to add 10 cm^3 of **FB 3** to the conical flask. The solution will turn brown as iodine is produced.
- Fill the burette with **FB 4**.
- Add **FB 4** from the burette until the solution in the conical flask turns yellow.
- Add 10–15 drops of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FB 4** 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 that 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 **FB 4** added in each accurate titration.

Keep FB 3 and FB 4 for use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a value for the volume of **FB 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm³ of **FB 1** required cm³ of **FB 4**. [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to the appropriate number of significant figures. [1]
- (ii) Use your answer to (b) and the relevant equation on page 2 to calculate the number of moles of iodine that form when 25.0 cm³ of **FB 1** react with 10 cm³ of **FB 3**.

moles of I₂ = ... mol [1]

- (iii) Calculate the number of moles of IO_x^- ions in 25.0 cm^3 of **FB 1**.

moles of IO_x^- ions = ... mol [1]

- (iv) Use the ratio of your answers to (c)(ii) and (c)(iii) along with the relevant equation given on page 2 to calculate the value of y . (Note that y is an odd integer such as 1, 3, 5, 7 etc.) Show your working.

y = ... [2]

- (v) Use your value of y to determine the formula of the IO_x^- ion.

formula = ... [1]

- (d) (i) The maximum error in the volume dispensed by the pipette is $\pm 0.06 \text{ cm}^3$.

Calculate the maximum percentage error in the volume of **FB 1** used.

maximum percentage error = ...% [1]

- (ii) A student suggested that a more accurate value of x could be obtained if a 10 cm^3 pipette is used to measure **FB 3** rather than the measuring cylinder.

State whether you agree with the student. Explain your answer.

.....

 [1]

[Total: 16]

- 2 In this experiment you will determine the enthalpy change of solution, ΔH_{sol} , for hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$. To do this you will measure the temperature change when a known mass of hydrated sodium thiosulfate is dissolved in a known volume of water.

FB 5 is hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$.

(a) Method

- Support the cup in the 250 cm³ beaker.
- Use the 25 cm³ measuring cylinder to transfer 20.0 cm³ of distilled water into the cup.
- Weigh the stoppered container of **FB 5** and record the mass.
- Measure and record the initial temperature of the water in the cup.
- Add all the **FB 5** to the water in the cup.
- Stir the mixture and record the minimum temperature that is reached.
- Reweigh the stoppered container. Record the mass.
- Calculate and record the mass of **FB 5** added to the water and the change in temperature.

I	
II	
III	
IV	
[4]	

(b) Calculations

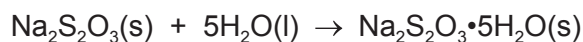
- (i) Calculate the energy change of the reaction.
(Assume that 4.2 J of heat energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.)
Show your working.

energy change = ... J [1]

- (ii) Calculate the enthalpy change of solution, ΔH_{sol} , for hydrated sodium thiosulfate.

ΔH_{sol} for $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ = ... kJ mol⁻¹
sign value [2]

- (iii) Assume that under the same conditions, the enthalpy change of solution, ΔH_{sol} , for anhydrous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, is -7.7 kJ mol^{-1} . Construct a Hess's cycle and determine the enthalpy change for the following reaction. (If you were unable to calculate an answer to (b)(ii), assume a value of $+32.2 \text{ kJ mol}^{-1}$. Note this is not the correct value.)


$$\Delta H = \text{.....} \text{ kJ mol}^{-1}$$

sign *value* [2]

- (c) How would your temperature change in (a) be affected if your sample of **FB 5** contained a small amount of anhydrous sodium thiosulfate? Explain your answer.

..... [1]

[Total: 10]

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) FB 6 is an aqueous solution containing one cation and one anion, both of which are listed in the Qualitative Analysis Notes.

- (i)** Carry out tests to identify the cation in **FB 6**.
Record your tests and observations in the space below.

[2]

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

<i>test</i>	<i>observations</i>
Test 1 To a 2 cm depth of FB 6 in a test-tube, add a few drops of nitric acid, followed by a few drops of aqueous silver nitrate.	
Pour approximately half the contents of the test-tube into a clean test-tube.	
Test 2 To one of the test-tubes add aqueous ammonia.	
Test 3 To the other test-tube add FB 4 , $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$.	

[2]

(iii) Deduce the formula of **FB 6**.

..... [1]

(b) **FB 7** is acidified aqueous iron(III) chloride, FeCl_3 .

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

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FB 7 in a test-tube, add a 1 cm depth of FB 3 , $\text{KI}(\text{aq})$, then	
add starch indicator.	

[1]

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

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FB 7 in a test-tube, add a 1 cm depth of FB 4 , $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$. Leave to stand until there is no further change, then	
add aqueous sodium hydroxide.	

[2]

(iii) Explain your observation in (b)(ii) when aqueous sodium hydroxide is added.

.....

.....

..... [2]

(c) **FB 8** is acidified aqueous iron(II) sulfate, FeSO_4 .

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

<i>test</i>	<i>observations</i>	<i>conclusions</i>
Test 1 To a 1 cm depth of FB 8 in a boiling tube , add a 1 cm depth of hydrogen peroxide, then		
add aqueous sodium hydroxide.		

[3]

(ii) Write an ionic equation for the reaction that occurs on addition of sodium hydroxide in (c)(i).

..... [1]

[Total: 14]

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

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests for gases

<i>gas</i>	<i>test and test result</i>
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

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

lanthanoids

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

actinoids



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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

May/June 2020

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, 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.

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.

Session

Laboratory

For Examiner's Use

1

2

3

Total

This document has 12 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 **FA 1** is an aqueous solution of a monoprotic organic acid. You will investigate the identity of **FA 1** by using a titration method to find its relative molecular mass, M_r .

FA 1 is an aqueous solution containing 6.20 g dm^{-3} of a monoprotic organic acid.

FA 2 is $0.105 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH.

thymol blue indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Fill the burette with **FA 2**.
- Add several drops of thymol blue indicator to the conical flask.
- 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 any recorded results show the accuracy of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you obtained this value.

25.0 cm³ of **FA 1** required cm³ of **FA 2**. [1]

(c) Calculations

- (i) Calculate the number of moles of sodium hydroxide present in the volume of **FA 2** calculated in (b).

moles of NaOH = ... mol [1]

- (ii) Deduce the number of moles of the organic acid present in 25.0 cm³ of **FA 1**.

moles of organic acid = ... mol

Hence calculate the concentration, in mol dm⁻³, of the organic acid in **FA 1**.
Show your working.

concentration of the organic acid = ... mol dm⁻³ [1]

- (iii) Calculate the relative molecular mass, M_r , of the organic acid in **FA 1**.

M_r of the organic acid = ... [1]

- (iv) From another experiment it is found that **FA 1** contains one of the following.

CH₃COOH HCOOH C₂H₄ClCOOH CH₂CHCOOH

NaOH(aq) reacts only with the COOH group in the acid.

Deduce which of these acids is present in **FA 1**. Explain your answer.

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

- (d) This method of investigation uses the relative molecular mass of the acid. The relative molecular masses of $\text{C}_2\text{H}_5\text{COOH}$ and CH_2CHCOOH are similar so that any inaccuracy in the practical procedure could lead to an incorrect conclusion.

Suggest a chemical test that would enable you to distinguish between $\text{C}_2\text{H}_5\text{COOH}$ and CH_2CHCOOH . Include the test and the results expected but do **not** carry out this test.

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

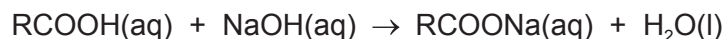
- (e) A student is given a solution of another organic acid containing the same concentration, in mol dm^{-3} , as that used in (a). The student assumes this acid is monoprotic but it is diprotic.

Explain the effect the student's assumption has on the value of the relative molecular mass that the student calculates.

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

[Total 15]

- 2 When an organic acid, RCOOH, is neutralised by an alkali an exothermic reaction takes place. You will determine the enthalpy change of neutralisation, ΔH , for the following reaction.



In this equation R is an alkyl group.

FA 3 is a solution containing 120.1 g dm^{-3} of RCOOH.

FA 4 is aqueous sodium hydroxide, NaOH.

(a) Method

Experiment 1

- Support the cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 3** into the cup.
- Measure and record the temperature of this **FA 3**. Rinse the thermometer.
- Place 25.0 cm^3 of **FA 4** into the 50 cm^3 measuring cylinder.
- Measure and record the temperature of the **FA 4** in the measuring cylinder. Rinse the thermometer.
- Tip the **FA 4** from the measuring cylinder into the cup. Stir, then measure and record the highest temperature reached.
- Calculate and record the average initial temperature of **FA 3** and **FA 4**.
- Calculate and record the difference between the average initial temperature and the highest temperature reached.
- Rinse and dry the cup for use in **Experiment 2**.

Experiment 2

- Repeat **Experiment 1** using 50.0 cm^3 of **FA 3** and **FA 4**. You will need to use the 25 cm^3 measuring cylinder twice to measure the **FA 3**.
- Calculate and record the average initial temperature of **FA 3** and **FA 4**.
- Calculate and record the difference between the average initial temperature and the highest temperature reached.

[4]

- (d) A student repeated both experiments in (a) using hydrochloric acid in place of RCOOH.

Suggest how the temperature rise when using HCl would compare to the temperature rise recorded in (a). Assume all volumes and concentrations of solutions, in mol dm^{-3} , are the same.

Explain your answer by considering the chemical bonds involved.

.....

.....

..... [2]

[Total: 12]

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** Half fill the beaker with water and place it on a tripod and gauze. Heat until the water begins to boil then switch off your Bunsen burner. This is the hot water bath.

For a test in **(a)(i)** you will need Tollens' reagent. Place a 2–3 cm depth of silver nitrate in a test-tube, add aqueous sodium hydroxide drop by drop until a small amount of brown precipitate is formed and then add aqueous ammonia drop by drop with shaking until the precipitate just dissolves. This is Tollens' reagent. When Tollens' reagent is used, ensure that all test-tubes are thoroughly rinsed immediately after use.

(a) FA 5, FA 6 and FA 7 are organic compounds each of which contains carbon, hydrogen and oxygen only.

- (i)** Carry out the following tests on **FA 5, FA 6 and FA 7**. Use a 1 cm depth of organic compound in a test-tube for each test. One test has been done for you.

<i>test</i>	<i>observations</i>		
	FA 5	FA 6	FA 7
Test 1 Add 2,4-dinitrophenylhydrazine.	no visible reaction	orange precipitate formed	orange precipitate formed
Test 2 Add a 1 cm length of magnesium ribbon.			
Test 3 Add a 1 cm depth of Tollens' reagent, place the tube in the hot water bath and leave for a few minutes.			
Test 4 Add a few drops of acidified potassium manganate(VII), place the tube in the hot water bath and leave for a few minutes.			

[5]

- (ii) Identify the organic functional group present in each of **FA 5**, **FA 6** and **FA 7**.

FA 5 contains the functional group

FA 6 contains the functional group

FA 7 contains the functional group

[3]

- (b) **FA 8** contains one anion and one cation from those listed in the Qualitative Analysis Notes.

- (i) In a hard-glass test-tube heat a spatula measure of **FA 8** gently at first and then more strongly. Record all your observations.

.....

.....

..... [1]

- (ii) Describe tests that will allow you to identify the cation in **FA 8**.
Carry out these tests and record the tests and your observations in the space below.

[3]

- (iii) Give the formula of the cation present in **FA 8**.

.....

[1]

[Total: 13]

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

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests for gases

<i>gas</i>	<i>test and test result</i>
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

CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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9701/34

May/June 2020

2 hours

You must answer on the question paper.

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

- 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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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

- 1 **FB 1** is a solution of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, where x is an integer. You will determine the value of x in this compound by a titration method.

You will add **FB 1** to a known volume and concentration of hydrochloric acid, **FB 2**. The hydrochloric acid is in excess. You will then titrate the remaining acid with aqueous sodium hydroxide, **FB 3**.

FB 1 is a solution containing 37.5 g dm^{-3} hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

FB 2 is $0.200 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FB 3 is $0.100 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH .
bromophenol blue indicator

(a) Method

- Fill the burette with **FB 3**.
- For each titration:
Use the **25 cm³** pipette to place 25.0 cm^3 of **FB 2** into a conical flask.
Use the **10 cm³** pipette to place 10.0 cm^3 of **FB 1** into the same conical flask.
- Add a few drops of bromophenol blue indicator.
- Titrate the contents of the conical flask with **FB 3** from the burette.
- Perform 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 any recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FB 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your titration results, obtain a suitable value to be used in your calculations. Show clearly how you obtained this value.

volume of **FB 3** used in titration = ... cm^3 [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to an appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of sodium hydroxide present in the volume of **FB 3** calculated in (b).

moles of NaOH = ... mol

This number of moles of sodium hydroxide neutralises the remaining hydrochloric acid. Deduce the number of moles of remaining hydrochloric acid.

moles of remaining HCl = ... mol [1]

- (iii) Calculate the initial number of moles of hydrochloric acid in each 25.0 cm^3 sample of **FB 2** pipetted into the conical flask.

initial moles of HCl in each sample of **FB 2** = ... mol

You have calculated

- the number of moles of remaining HCl
- the initial number of moles of HCl in each sample of **FB 2**.

Calculate the number of moles of hydrochloric acid neutralised by the $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ in **FB 1** in each titration.

number of moles of HCl neutralised by the $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ = ... mol [1]

(iv) Complete the equation. Include state symbols.



Deduce the number of moles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ present in each 10.0 cm^3 sample of **FB 1**.

number of moles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ present = ... mol [1]

(v) **FB 1** contains 37.5 g dm^{-3} $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

Use your answer to (c)(iv) to calculate the relative formula mass, M_r , of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.
Show your working.

relative formula mass of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ = ... [2]

(vi) Determine the value of x in the formula $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

x = ... [1]

(d) A student suggested a different method.

- To 250 cm^3 of **FB 2**, add 100 cm^3 of **FB 1**.
- Pipette 25.0 cm^3 of this mixture of solutions into a conical flask.
- Titrate this mixture of solutions with **FB 3**.
- Repeat titrations until concordant results are achieved.

Comment on one disadvantage **or** one advantage of using this method rather than the method you used in (a).

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

[Total: 16]

- 2 You will now investigate a different hydrated salt with the formula $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$, where **M** is a Group 2 metal. By heating a sample of $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$ to produce anhydrous MSO_4 you will determine its relative formula mass and hence identify **M**.

FB 4 is the hydrated salt $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Place between 1.80 g and 2.20 g of **FB 4** in the crucible.
- Reweigh the crucible, its lid and contents and record the mass.
- Without the lid, place the crucible on the pipe-clay triangle and heat gently for approximately 1 minute and then strongly for approximately 4 minutes.
- Place the lid on the crucible and leave it to cool.
- You may wish to start **Question 3** while you are waiting for the crucible to cool.
- Reweigh the crucible, its lid and contents and record the mass.
- Calculate, and record, the mass of **FB 4**, the mass of residue after heating and the mass of water lost.

[4]

(b) Calculations

- (i) Calculate the number of moles of water lost when your sample of $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$ was heated.

moles of water = ... mol [1]

- (ii) Write the equation for the reaction that occurs when $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$ is heated. Include state symbols.

.....

Deduce the number of moles of anhydrous salt, MSO_4 , left after the heating.

moles of MSO_4 = ... mol
[1]

- (iii) Calculate the relative formula mass, M_r , of $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$.

$$M_r \text{ of } \text{MSO}_4 \cdot 7\text{H}_2\text{O} = \dots\dots\dots [1]$$

- (iv) Determine the relative atomic mass, A_r , of **M** and hence identify **M**.
Show your working.

$$A_r = \dots\dots\dots$$

$$\text{M is } \dots\dots\dots [2]$$

- (c) (i) In the method used above, the lid was placed on the crucible when the crucible was left to cool.

Explain why the lid was placed on the crucible.

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

- (ii) Suggest and explain the effect on the calculated value of the relative atomic mass of **M** if the lid had not been placed on the crucible during cooling.

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

[Total: 11]

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** In this question you may need Tollens' reagent. To prepare this, place a 2–3 cm depth of aqueous silver nitrate in a test-tube, add aqueous sodium hydroxide drop by drop until a small amount of brown precipitate is formed and then add aqueous ammonia drop by drop with shaking until the precipitate just dissolves. This is Tollens' reagent. If Tollens' reagent is used, ensure that all test-tubes are thoroughly rinsed immediately after use.

Half fill the 250 cm³ beaker with water and heat to boiling. Then turn off the Bunsen burner. This will be used as a hot water bath.

- (a) (i)** You are to investigate some reactions of solid **FB 5**.

To a 2 cm depth of aqueous ammonium vanadate(V) in a test-tube add a small spatula measure of **FB 5**. Leave for approximately 4 minutes with occasional shaking.

Record all the changes that you observe.

Keep the test-tube and its contents for use in the next test.

.....

.....

.....

..... [2]

- (ii) Transfer a 1 cm depth of the **solution** from (a)(i) into a test-tube and add acidified potassium manganate(VII) a few drops at a time until no further reaction occurs. At this stage the solution is pink because unreacted KMnO_4 is present.

Record all the changes that you observe.

.....

 [1]

- (iii) State the type of reaction occurring in the test in (a)(ii).

..... [1]

- (iv) To a 1 cm depth of dilute sulfuric acid in a test-tube add a small spatula measure of **FB 5**. Record your observations. Place the test-tube in the hot water bath if necessary to start the reaction.

.....
 [2]

- (b) **FB 6** is an aqueous solution that has been made by reacting solid **FB 5** with dilute sulfuric acid.

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

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FB 6 in a test-tube add aqueous sodium hydroxide.	
Test 2 To a 1 cm depth of FB 6 in a test-tube add aqueous ammonia.	

[2]

- (ii) Identify **FB 5**.

FB 5 is [1]

- (iii) Give the equation for the reaction of **FB 5** with sulfuric acid to make **FB 6**. Include state symbols.

..... [1]

(c) **FB 7** is either ethanal, CH_3CHO , or propanone, CH_3COCH_3 .

- (i) Describe a test that would enable you to identify which of these compounds is present in **FB 7**. You should state the observation expected for ethanal and propanone.

test

.....

expected observations

ethanal

propanone

[2]

- (ii) Carry out this test on **FB 7**. Record the result of the test and hence identify **FB 7**.

result

FB 7 is

[1]

[Total: 13]

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

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests for gases

<i>gas</i>	<i>test and test result</i>
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

Group																						
1	2											1 H hydrogen 1.0		13	14	15	16	17	18			
		Key																				
		atomic number atomic symbol name relative atomic mass																				
3	4																					
Li lithium 6.9	Be beryllium 9.0																					
11	12																					
Na sodium 23.0	Mg magnesium 24.3																					
		3	4	5	6	7	8	9	10	11	12						13	14	15	16	17	18
19	20	K potassium 39.1	Ca calcium 40.1	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8					
37	38	Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3					
55	56	lanthanoids		73	74	75	76	77	78	79	80	81	82	83	84	85	86					
Cs caesium 132.9	Ba barium 137.3			Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —					
87	88	actinoids		104	105	107	108	109	110	111	112											
Fr francium —	Ra radium —			Rf rutherfordium —	Db dubnium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Flerovium Flerovium —	Livermorium Livermorium —									

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	europlum	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
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	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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CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

May/June 2020

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, 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.

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.

Session

Laboratory

For Examiner's Use

1

2

3

Total

This document has 12 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 Ethanedioic acid forms salts with Group 1 metals. In this experiment you will identify the Group 1 metal ion, Z^+ , present in an ethanedioate salt, $(\text{COO})_2Z_2$. You will titrate a solution of the salt with acidified aqueous potassium manganate(VII). The equation for the reaction between manganate(VII) ions and ethanedioate ions in acidic solution is shown.



FA 1 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 2 is a solution containing 8.06 g dm^{-3} of an ethanedioate salt, $(\text{COO})_2Z_2$.

FA 3 is dilute sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 2** into a conical flask.
- Use the measuring cylinder to transfer 25 cm^3 of **FA 3** into the same conical flask.
- Place the conical flask on the tripod and gauze and heat the conical flask until the temperature of the solution is approximately 70°C .
- **Carefully** remove the hot conical flask and place it on the white tile under the burette.
- During titrations, add **FA 1**, **slowly at first**, until a permanent pale pink colour is formed. (The pink colour on initial addition may take several seconds to disappear.) If the reaction mixture turns brown, reheat it to approximately 70°C . If the brown colour disappears, continue with the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- Perform a rough titration (the end-point is a permanent pale pink colour) 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 any recorded results show the precision of your practical work.
- Record all of your burette readings and the volume of **FA 1** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm³ of **FA 2** required cm³ of **FA 1**. [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii), (c)(iv) and (c)(v) to the appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of manganate(VII) ions in the volume of **FA 1** calculated in (b).

moles of MnO_4^- = ... mol [1]

- (iii) Use the equation on page 2 to calculate the number of moles of ethanedioate ions in 25.0 cm³ of **FA 2**.

moles of $(\text{COO})_2^{2-}$ = ... mol [1]

- (iv) Calculate the relative formula mass, M_r , of the ethanedioate salt, $(\text{COO})_2\text{Z}_2$.

M_r of ethanedioate salt = ... [1]

- (v) Calculate the relative atomic mass, A_r , of the Group 1 metal, Z, in the ethanedioate salt.
Show your working.

A_r of Z = ...

Hence identify Z.

Z is [2]

[Total: 14]

- 2 In this experiment you will determine the value of x in the formula for hydrated manganese(II) sulfate, $\text{MnSO}_4 \cdot x\text{H}_2\text{O}$, where x is an integer. You will do this by measuring the mass lost when a sample of hydrated manganese(II) sulfate is heated.



FA 4 is hydrated manganese(II) sulfate, $\text{MnSO}_4 \cdot x\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with a lid and record the mass.
- Add all the **FA 4** to the crucible.
- Reweigh the crucible with the lid and **FA 4**. Record the mass. Describe the appearance of **FA 4**.

appearance of **FA 4**

- Place the crucible in the pipe-clay triangle on top of the tripod.
- Heat the crucible **gently** with the lid on for approximately 1 minute.
- Remove the lid and then heat more strongly for a further 4 minutes.
- Replace the lid and allow the crucible to cool.
- **While the crucible is cooling you may wish to begin work on Question 3.**
- Once the crucible has cooled, reweigh the crucible with the lid and contents. Record the mass.
- Calculate and record the mass of **FA 4** added to the crucible, the mass of the residue and the mass of water lost.
- Describe the appearance of the residue.

appearance of the residue

I	
II	
III	
IV	
V	
VI	

[6]

(b) Calculations

- (i) Calculate the number of moles of manganese(II) sulfate present in the residue. You may assume all the water of crystallisation has been removed.

moles of MnSO_4 = ... mol [1]

- (ii) Calculate the number of moles of water lost.

moles of water lost = ... mol [1]

- (iii) Calculate the value of x in $\text{MnSO}_4 \cdot x\text{H}_2\text{O}$.

x = ... [1]

- (c) It is possible that **FA 4** did not lose all of the water of crystallisation in your experiment.

- (i) Explain how you could modify the experiment to ensure all water has been removed.

.....
 [1]

- (ii) Explain why your calculated value of x might not change if a small amount of water of crystallisation remained in the residue.

.....

 [1]

[Total: 11]

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** Half fill the 250 cm³ beaker with water and place it on a tripod and gauze. Heat until the water begins to boil then switch off your Bunsen burner. This is the hot water bath for part **(b)**.

- (a)** **FA 5** is a solution of a salt which contains one cation and at least one anion, all of which are listed in the Qualitative Analysis Notes.
Sulfur is not present in **FA 5**.

- (i)** To a 1 cm depth of **FA 5** in a test-tube add aqueous sodium hydroxide.

observation

..... [1]

- (ii)** You are to carry out tests to allow you to determine the anion present in **FA 5**.

Identify reagents for these tests, carry out these tests and record these tests and observations in a table.

[3]

- (iii) Use your results to identify the ions present in **FA 5**.

formulae of ions present in **FA 5** [1]

- (iv) Write an ionic equation for the expected reaction between **FA 5** and aqueous ammonia. Include state symbols.

..... [1]

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

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FA 5 in a test-tube, add a 1 cm depth of hydrogen peroxide, then	
add aqueous sodium hydroxide.	

[2]

- (vi) Suggest what type of reaction occurred when hydrogen peroxide was added to **FA 5**.

..... [1]

(b) **FA 6**, **FA 7** and **FA 8** are butan-1-ol, butan-2-ol and methylpropan-2-ol, but not necessarily in that order.

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

<i>test</i>	<i>observations</i>		
	FA 6	FA 7	FA 8
Test 1 To a 1 cm depth of dilute sulfuric acid in a test-tube, add 2 or 3 drops of FA 1 , KMnO_4 , then add a few drops of the alcohol. Shake the tube and place it in the hot water bath. Shake the tube occasionally until there is no further change.			
Test 2 To a 1 cm depth of aqueous iodine in a test-tube, add a few drops of the alcohol, then add drops of aqueous sodium hydroxide until the iodine colour just disappears or remains unchanged. Place the test-tube in the hot water bath.			

[3]

(ii) Use your observations from (b)(i) to identify the alcohols.

alcohol	FA....
butan-1-ol	FA.....
butan-2-ol	FA.....
methylpropan-2-ol	FA.....

[2]

(iii) Write an equation for the oxidation of one of these alcohols with acidified KMnO_4 . Use [O] to represent the oxidising agent.

..... [1]

[Total: 15]

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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

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests for gases

<i>gas</i>	<i>test and test result</i>
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

Group																				
1	2										13	14	15	16	17	18				
Key											1 H hydrogen 1.0							2 He helium 4.0		
	atomic number atomic symbol name relative atomic mass																			
	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

actinoids

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