Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME											
CENTRE NUMBER							CANDIDATE NUMBER				

CHEMISTRY **9701/33**

Paper 3 Advanced Practical Skills 1 **February/March 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 You will determine the concentration of sulfuric acid by reaction with a known concentration of sodium hydroxide using a thermometric method. The equation for the reaction is shown.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

FA 1 is 1.90 mol dm^{-3} sodium hydroxide, NaOH.
FA 2 is dilute sulfuric acid, H_2SO_4.

(a) Method

- Place the cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 1** into the cup.
- Place the thermometer into the solution in the cup and record its temperature in the table of results.
- Fill a burette with **FA 2**.
- Run 5.00 cm^3 of **FA 2** into the solution in the cup.
- Stir the mixture and record the highest temperature reached.
- Repeat adding 5.00 cm^3 volumes of **FA 2** into the solution in the cup until 45.00 cm^3 has been added. Record the highest temperature reached after each addition.

Results

volume of **FA 2** added / cm^3	0.00	5.00	10.00	15.00	20.00
temperature of solution / °C					

volume of **FA 2** added / cm^3	25.00	30.00	35.00	40.00	45.00
temperature of solution / °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 4.0 °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 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, **FA 2**, required to neutralise 25.0 cm^3 of sodium hydroxide, **FA 1**.

volume of H_2SO_4 = ... cm^3 [1]

(iii) Calculate the concentration of sulfuric acid in **FA 2**.

concentration of H_2SO_4 = ... $mol\,dm^{-3}$ [1]

(c) A student carrying out the same procedure used the results from their graph to determine the enthalpy of neutralisation for the reaction.

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

(i) State how the student used their graph to determine the value of ΔT for use in the equation $q = mc\Delta T$.

....

.... [1]

(ii) The student correctly calculated the value of ΔH for the reaction as ΔH = –55.2 kJ mol^{-1}. The theoretical value for $\Delta H^{\ominus}_{neut}$ given in the student's textbook is –57.6 kJ mol^{-1}.

Calculate the percentage error in the student's result compared with the theoretical value.

percentage error = ... % [1]

(iii) Suggest why the student's result was less negative than the theoretical value. Explain your answer.

....

.... [1]

[Total: 12]

2 Solid sodium sulfite is often provided as the hydrated salt, $Na_2SO_3{\bullet}xH_2O$, where *x* is an integer. You will determine *x* by using a solution of this sodium sulfite and reacting it with an excess of aqueous iodine.

$$Na_2SO_3(aq) + I_2(aq) + H_2O(l) \rightarrow Na_2SO_4(aq) + 2I^-(aq) + 2H^+(aq)$$

The amount of iodine remaining will be determined by titration using a known concentration of sodium thiosulfate, $Na_2S_2O_3$.

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

FA 3 is a solution containing 31.50 g dm^{-3} of hydrated sodium sulfite, $Na_2SO_3{\bullet}xH_2O$.
FA 4 is 0.100 mol dm^{-3} iodine, I_2.
FA 5 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 6 is starch indicator.

(a) Method

- Pipette **10.0** cm^3 of **FA 3** into a conical flask.
- Pipette **25.0** cm^3 of **FA 4** into the same flask.
- Swirl the flask to mix the contents.
- Fill the second burette with **FA 5**.
- Add **FA 5** to the flask until the mixture is yellow.
- Add approximately 10 drops of **FA 6**.
- Complete the rough titration by adding **FA 5** until the mixture is colourless.
- 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 5** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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

10.0 cm^3 of **FA 3** plus 25.0 cm^3 of **FA 4** required .... cm^3 of **FA 5**. [1]

(c) Calculations

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

(ii) Use your answer to **(b)** to calculate the amount, in mol, of sodium thiosulfate, **FA 5**, required to react with the excess iodine which remained in the conical flask.

amount of $Na_2S_2O_3$ = ... mol

Hence calculate the amount, in mol, of iodine, **FA 4**, remaining in the conical flask.

amount of I_2 remaining = ... mol [1]

(iii) Calculate the amount, in mol, of iodine, **FA 4**, added to the conical flask.

amount of I_2 added = ... mol

Hence calculate the amount, in mol, of iodine that reacted with the 10.0 cm^3 of sodium sulfite, **FA 3**.

amount of I_2 that reacted with Na_2SO_3 = ... mol [1]

(iv) Use your final answer to **(c)(iii)** and the information on page 5 to calculate the amount, in mol, of sodium sulfite present in 1.00 dm^3 of **FA 3**.

amount of Na_2SO_3 in 1.00 dm^3 = ... mol [1]

(v) Use your answer to **(c)(iv)** to calculate the value of *x* in $Na_2SO_3{\bullet}xH_2O$.

x = ... [2]

(d) A student suggests that sodium carbonate should be added to each mixture of sodium sulfite and iodine in the conical flask before titrating with sodium thiosulfate.

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

....

.... [1]

[Total: 15]

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 **FA 7** and **FA 8** are solutions containing a total of three cations and two anions. Two of the cations and both of the anions are listed in the Qualitative analysis notes.

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

test	*observations*	
	FA 7	**FA 8**
Test 1 Add a 1 cm depth of dilute nitric or hydrochloric acid and allow to stand for 2 minutes, then		
add a few drops of aqueous barium nitrate or aqueous barium chloride.		
Test 2 Add a few drops of acidified aqueous potassium manganate(VII).		
Test 3 Add a few drops of aqueous iron(III) chloride and allow to stand for 1 minute.		

[4]

(ii) From your test results, give the formulae of the anions present in **FA 7** and **FA 8**. If the tests do not allow you to positively identify an anion, write 'unknown'.

anion in **FA 7** = ...

anion in **FA 8** = ...

[2]

(b) (i) Select reagents for tests to identify as many of the cations as possible in **FA 7** and **FA 8**. Carry out your tests and record your reagents, conditions and observations.

[4]

(ii) From your test results, give the formulae of as many cations as possible in **FA 7** and **FA 8**. If the tests do not allow you to positively identify a cation, write 'unknown'.

FA 7 contains ....

FA 8 contains ....

[2]

(iii) Write an ionic equation for **one** reaction you observed in **(b)(i)**. Include state symbols.

.... [1]

[Total: 13]

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^+

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

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 –