Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

1086226346

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **May/June 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **11** printed pages and **1** blank page.

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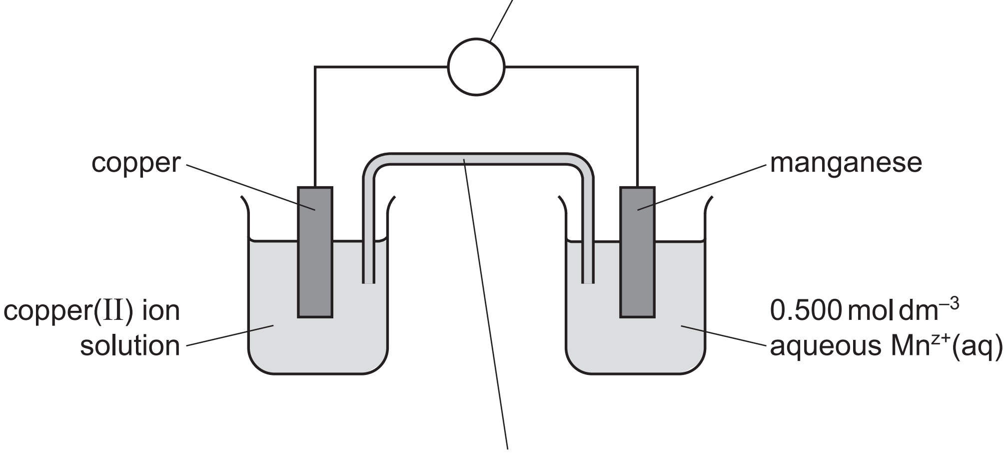
1 A student investigates the charge (z+) carried by aqueous manganese ions, $Mn^{z+}(aq)$. The electrochemical cell shown is set up for this investigation with the following two half-cells:

- a standard copper(II) ion / copper half-cell ($E^{\ominus}$ = +0.340 V)
- a half-cell made from manganese and 0.500 mol dm^{-3} $Mn^{z+}(aq)$.

(a) Label the items **P** and **Q** and state the concentration of the copper(II) ion solution in the copper half-cell.

P ....



Q ....

concentration of the copper(II) ion solution in the copper half-cell = ...

[1]

(b) During the investigation the student plans to use solutions of $Mn^{z+}(aq)$ of lower concentration than 0.500 mol dm^{-3}.

(i) Calculate the volume of 0.500 mol dm^{-3} $Mn^{z+}(aq)$ needed to prepare 100.0 cm^3 of 0.200 mol dm^{-3} $Mn^{z+}(aq)$.

volume = ... cm^3 [1]

(ii) Describe how, using a 100 cm^3 volumetric flask, the student should prepare exactly 100.0 cm^3 of 0.200 mol dm^{-3} Mn^{z+}(aq) using the volume of 0.500 mol dm^{-3} Mn^{z+}(aq) calculated in **(b)(i)** and standard school or college apparatus.

....

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....

.... [2]

The cell potential of the electrochemical cell in **(a)** is measured. The 0.500 mol dm^{-3} Mn^{z+}(aq) is then replaced by the 0.200 mol dm^{-3} solution and the cell potential is measured again. This is repeated for other lower concentrations of Mn^{z+}(aq). All measurements are made at 25 °C.

(iii) The results of the experiment are shown in the table.

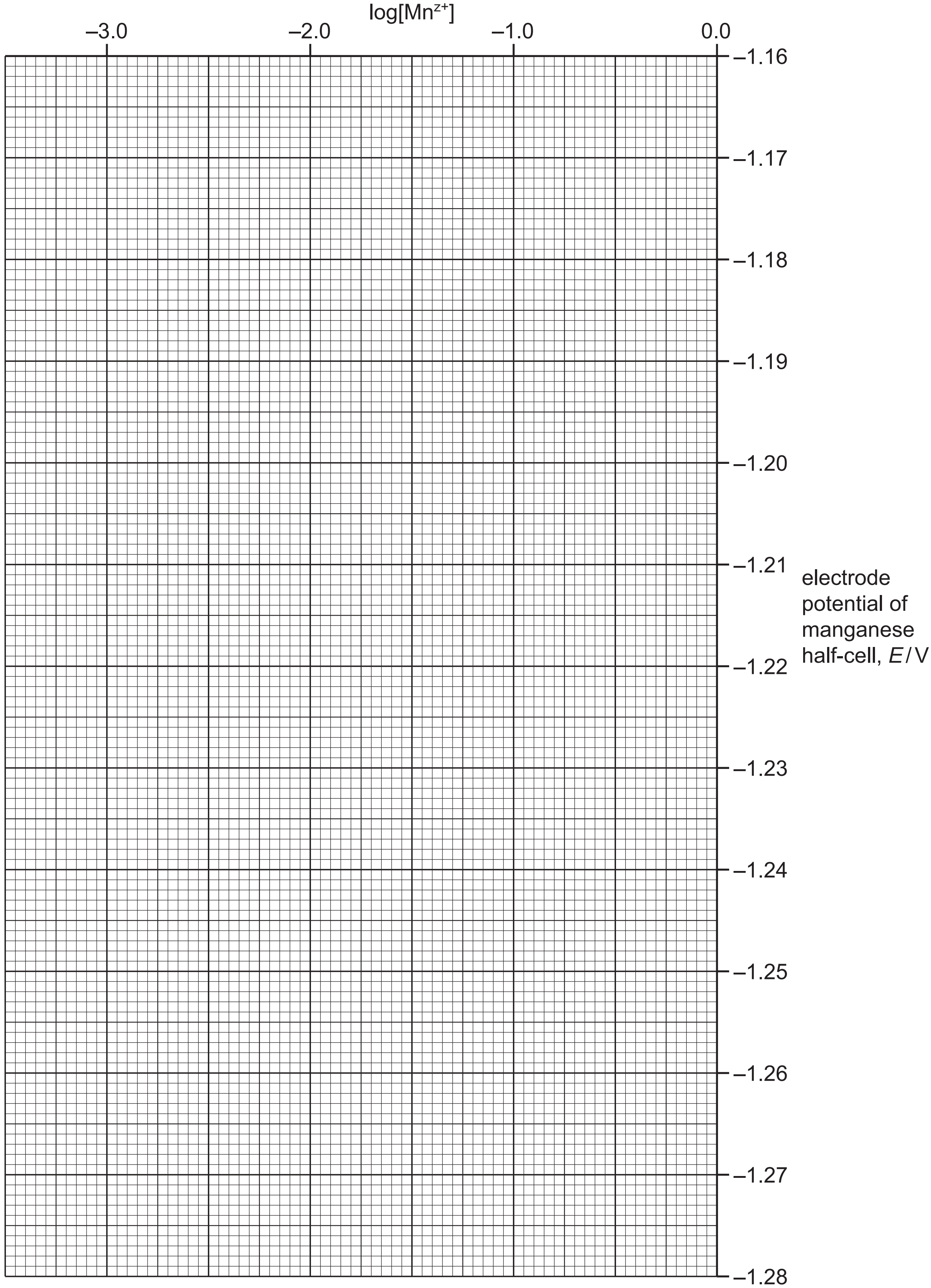
Complete column three of the table, calculating log[Mn^{z+}] to **two decimal places**.
Complete column four of the table, calculating E, the electrode potential of each manganese half-cell, to **three decimal places**, using the equation shown.

$$E\text{(manganese half-cell)} = E_{cell} + 0.340\,V$$

[Mn^{z+}] / mol dm^{-3}	cell potential, E_{cell} / V	log[Mn^{z+}]	electrode potential of each manganese half-cell, E / V
5.0×10^{-1}	–1.529	–0.30	–1.189
2.0×10^{-1}	–1.541		
1.0×10^{-1}	–1.550		
7.5×10^{-2}	–1.553		
2.5×10^{-2}	–1.567		
8.0×10^{-3}	–1.582		
6.0×10^{-3}	–1.590		
4.0×10^{-3}	–1.591		
3.0×10^{-3}	–1.594		
5.0×10^{-4}	–1.617		

[2]

(c) Plot a graph of electrode potential of manganese half-cell (y-axis) against $\log[Mn^{z+}]$ (x-axis). Use a cross (×) to plot each data point. Draw a line of best fit.



[2]

(d) **(i)** Circle the most anomalous point on your graph. [1]

(ii) The student is careful to ensure that all solutions used are at the same temperature in all experiments.

Suggest a possible explanation for the position of the anomalous point circled in **(d)(i)** relative to the line of best fit.

....

....

.... [1]

(e) Your graph is a plot of E against $\log[Mn^{z+}]$ and can be analysed using the Nernst equation at 25 °C.

$$E = E^{\ominus} + \frac{0.059}{z} \log[Mn^{z+}]$$

z is the value of the charge carried by the manganese ion
E is the electrode potential / V
$E^{\ominus}$ is the standard electrode potential / V

Use the Nernst equation and your graph to find the standard electrode potential, $E^{\ominus}$, of the manganese half-cell.

$E^{\ominus}$ = ... V [1]

(f) **(i)** Determine the gradient of the graph.
State the co-ordinates of both points you used for your calculation.
Record the value of the gradient to **three significant figures**.

co-ordinates 1 .... co-ordinates 2 ....

gradient = ...
[2]

(ii) Use your answer to **(f)(i)** and the Nernst equation to calculate the value of z to three significant figures and give the formula of the manganese ion.
Your calculation **must** show the use of the Nernst equation.

(If you were unable to calculate an answer to **(f)(i)** you may use the value 0.0197. This is **not** the correct value.)

z = ...

formula of manganese ion = ...
[2]

(g) Lowering $[Mn^{z+}]$ causes the value of the electrode potential of the manganese half-cell to become more negative.

Suggest why this happens.

....

.... [1]

[Total: 16]

2 A student plans to prepare propanone from propan-2-ol and test the product. Reagents provided to the student and some of their hazards are shown in the table.

reagent	hazard
propan-2-ol	flammable
concentrated sulfuric acid	corrosive
potassium dichromate(VI)	oxidising
distilled water	non-hazardous

(a) (i) The full equation for the reaction between propan-2-ol and acidified potassium dichromate(VI) is shown.

$$3CH_3CH(OH)CH_3 + K_2Cr_2O_7 + 4H_2SO_4 \rightarrow 3(CH_3)_2CO + K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O$$

Calculate the minimum mass of potassium dichromate(VI) that is needed for complete oxidation of 5.00 g of propan-2-ol to propanone. Give your answer to **three significant figures**.

[A_r: K, 39.1; Cr, 52.0; O, 16.0; C, 12.0; H, 1.0]

mass $K_2Cr_2O_7$ = ... g
[2]

(ii) The student is provided with a set of instructions to prepare the propanone.

step 1 Add concentrated sulfuric acid to 5.0 g of propan-2-ol in a round-bottomed flask, a few drops at a time.

step 2 Dissolve the mass of potassium dichromate(VI) calculated in **(a)(i)** in a few cm^3 of distilled water.

step 3 Add this aqueous potassium dichromate(VI) slowly to the mixture in the round-bottomed flask.

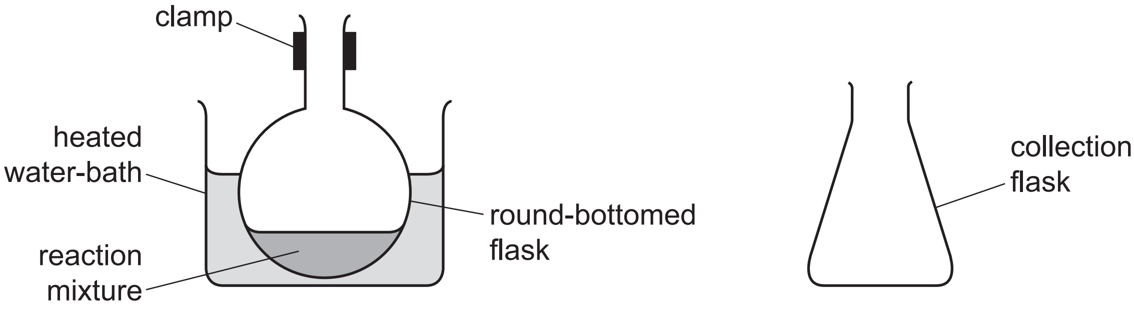
step 4 Heat the mixture under reflux.

step 5 Separate the propanone from the reaction mixture using distillation.

The student is also provided with the boiling points of propan-2-ol and propanone.

compound	boiling point / °C
propan-2-ol	82.5
propanone	56.5

Complete the diagram to show how the propanone is separated from the reaction mixture in step 5.
Label your diagram fully including the location of propan-2-ol and propanone after distillation has taken place. There is no need to include clamps.



[3]

(iii) The reaction mixture needs heating for reflux to take place.

Explain why a water-bath is used to heat the mixture.

....

....

.... [1]

(iv) The propanone separated from the mixture in step 5 contains sulfuric acid as an impurity which needs to be removed.

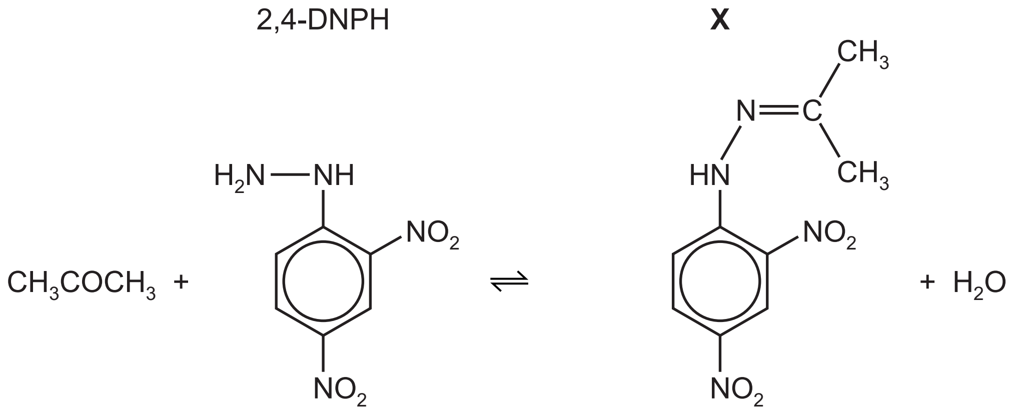
Name a reagent that could be added to remove the sulfuric acid and explain how the student would ensure that all of the acid is no longer present.

reagent ....

explanation ....

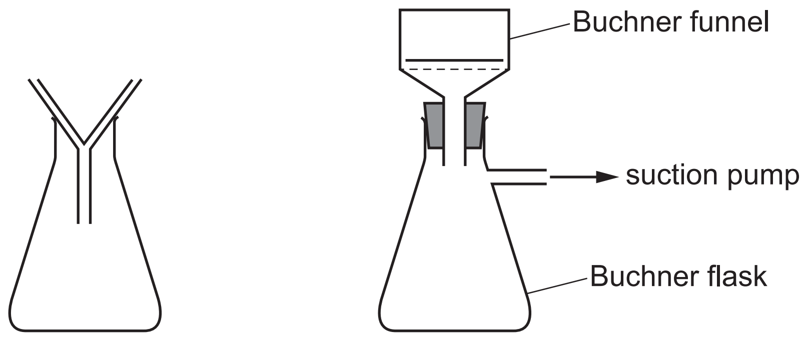
.... [2]

(b) (i) When propanone reacts with a solution of 2,4-DNPH an insoluble compound, **X**, is produced according to the following equation.



The melting point of **X** can be used to confirm the identity of the carbonyl compound that has reacted with 2,4-DNPH. To do this, solid **X** must be separated from the mixture.

This can be done using method **A** or method **B**.



A **B**

method **A**: gravity filtration using a filter funnel, filter paper and a conical flask

method **B**: filtration under reduced pressure using a Buchner funnel and Buchner flask, filter paper and a suction pump to reduce the pressure in the Buchner flask

Suggest **one** major advantage of using method **B** rather than method **A**.

....

.... [1]

(ii) The student places a washed sample of **X** in a drying oven for an hour. The student records the mass of **X**. The student wants to ensure that **X** is completely dry.

Describe what the student should do to ensure that **X** is completely dry.

....

.... [1]

(iii) 5.00 cm^3 of propanone reacts with an excess of 2,4-DNPH. The mass of dry **X** produced is 11.84 g.

Calculate the percentage yield of **X** in this reaction.

M_r **X** = 238
M_r CH_3COCH_3 = 58
density CH_3COCH_3 = 0.789 g cm^{-3}

percentage yield of **X** = ... %
[3]

(iv) Explain why a 100% yield in the preparation of a pure sample of **X** is not possible.

....

....

.... [1]

[Total: 14]