Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

0123456789

CHEMISTRY **9701/05**

Paper 5 Planning, Analysis and Evaluation **For examination from 2022**

SPECIMEN PAPER **1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

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 30.
- 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.

This document has **12** pages. Blank pages are indicated.

1 Verdigris is a green pigment that contains both copper(II) carbonate, $CuCO_3$, and copper(II) hydroxide, $Cu(OH)_2$, in varying amounts.

Both copper compounds react with dilute hydrochloric acid.

$$CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + CO_2(g) + H_2O(l)$$

$$Cu(OH)_2(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + 2H_2O(l)$$

(a) You are to plan an experiment to determine the percentage of copper(II) carbonate in a sample of verdigris. Your method should involve the reaction of verdigris with excess dilute hydrochloric acid.

You are provided with the following:

- 0.494 g of verdigris
- 10.0 mol dm^{-3} hydrochloric acid, $HCl(aq)$
- commonly available laboratory reagents and equipment.

You may assume that any other material present in verdigris is unaffected by heating and is **not** acidic or basic.

(i) A student suggests that finding the volume of dilute hydrochloric acid required to react with a known mass of verdigris would be a suitable method to determine the percentage of copper(II) carbonate in a sample of verdigris.

Suggest why this method would **not** work.

....

....

.... [1]

(ii) The 10.0 mol dm^{-3} HCl is too concentrated for use in the experiment. Instead, a more dilute solution should be prepared.

Describe how you would accurately prepare 250.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid from the 10.0 mol dm^{-3} HCl provided.

Your answer should state the name and capacity in cm^3 of any apparatus you would use.

....

....

....

....

....

.... [3]

(iii) The percentage of copper(II) carbonate in a sample of verdigris can be determined by measuring the volume of gas produced when excess hydrochloric acid is added to the sample of verdigris.

Draw a diagram to show how you would set up the apparatus and chemicals to measure the total volume of gas produced in this reaction.

Label your diagram.

[2]

(iv) Sketch a graph on the axes to show how the volume of gas produced would change during your experiment. The independent variable should be on the *x*-axis.

- Label both axes.
- Extend the graph beyond the point at which the reaction is complete.

[2]

(v) A student thinks that their 0.494 g sample of verdigris only contains $CuCO_3$.

Calculate the minimum volume, in cm^3, of $0.500\ mol\ dm^{-3}$ HCl that is needed to completely react with this sample if the student is correct.
Show your working.
[M_r: $CuCO_3$ = 123.5]

volume of $0.500\ mol\ dm^{-3}$ HCl = ... cm^3 [2]

(b) Azurite is a blue copper-containing mineral. The copper compound in azurite has the formula $Cu_3(CO_3)_2(OH)_2$. This copper compound reacts with sulfuric acid according to the equation.

$$Cu_3(CO_3)_2(OH)_2(s) + 3H_2SO_4(aq) \rightarrow 3CuSO_4(aq) + 2CO_2(g) + 4H_2O(l)$$

A student carries out a series of titrations on 1.50 g samples of solid azurite using 0.400 mol dm^{-3} sulfuric acid.

Assume that any other material present in azurite does not react with sulfuric acid. Some titration data is given in Table 1.1.

Table 1.1

titration	rough	1	2	3
final reading / cm^3	25.55	23.90	48.30	28.10
initial reading / cm^3	0.00	0.00	23.90	3.95
titre / cm^3				

The indictor for the titration is bromophenol blue. Bromophenol blue is blue at pH 4.6 and yellow at pH 3.0.

(i) Complete Table 1.1. [1]

(ii) Calculate the percentage uncertainty in titre 1.

.... [1]

(iii) The student concludes that 24.15 cm^3 of 0.400 mol dm^{-3} sulfuric acid completely reacts with 1.50 g of azurite.

Calculate the percentage by mass of $Cu_3(CO_3)_2(OH)_2$ in the sample of azurite using the student's value of 24.15 cm^3 of 0.400 mol dm^{-3} sulfuric acid.

Write your answer to **three significant figures**.
Show your working.
[M_r: $Cu_3(CO_3)_2(OH)_2$ = 344.5]

percentage by mass of $Cu_3(CO_3)_2(OH)_2$ in the sample of azurite = ...% [3]

(iv) Identify **two** possible problems with the student's titration experiment **and** suggest improvements to it.

problem 1 ....

....

improvement 1 ....

....

problem 2 ....

....

improvement 2 ....

....
[4]

[Total: 19]

2 Activated charcoal is a form of carbon with a very high surface area. It can be used to remove impurities from mixtures. It does this by a process called *adsorption*, where particles of the impurity bond (adsorb) to the activated charcoal surface.

A student wants to determine the ability of activated charcoal to adsorb a blue dye (the impurity) from aqueous solution.

The equation that links the mass of activated charcoal with the amount of blue dye adsorbed is shown.

$$\log\left(\frac{D}{m}\right) = A + b\log[X]$$

D = difference in concentration of dye (in $g\,dm^{-3}$) before and after adsorption
m = mass of activated charcoal (in g)
$[X]$ = final concentration of dye (in $g\,dm^{-3}$) after adsorption
A and b are constants

The student uses the following procedure to investigate the ability of activated charcoal to adsorb a blue dye from an aqueous solution.

- Place a $50.0\,cm^3$ sample of a $25.00\,g\,dm^{-3}$ solution of blue dye in a conical flask.
- Add a weighed mass of activated charcoal to the flask.
- Stir the contents of the flask for three minutes and then leave for one hour.
- Filter the mixture.
- Determine the final concentration of the blue dye, $[X]$.
- Repeat the procedure using different masses of activated charcoal.

(a) The procedure is carried out. The final concentrations of blue dye, [*X*], are shown in Table 2.1.

(i) Process the results to complete Table 2.1.

Record your data to **two** decimal places.

Table 2.1

mass of activated charcoal, *m* / g	initial concentration of blue dye / g dm^{-3}	final concentration of blue dye, [*X*] / g dm^{-3}	difference in concentration of blue dye, *D* / g dm^{-3}	$\frac{D}{m}$	$\log\left(\frac{D}{m}\right)$	log [*X*]
0.20	25.00	0.96		120.20	2.08	
0.25	25.00	0.69		97.24	1.99	
0.30	25.00	0.60		81.33	1.91	
0.35	25.00	0.41		70.26	1.85	
0.40	25.00	0.33		61.68	1.79	
0.45	25.00	0.27		54.96	1.74	
0.50	25.00	0.23		49.54	1.69	
0.55	25.00	0.20		45.09	1.65	
0.60	25.00	0.17		41.38	1.62	

[2]

(ii) Identify the dependent variable in this experiment.

.... [1]

(iii) State and explain the effect, if any, of increasing the mass of activated charcoal, *m*, on the amount of adsorption that occurs.

....

....

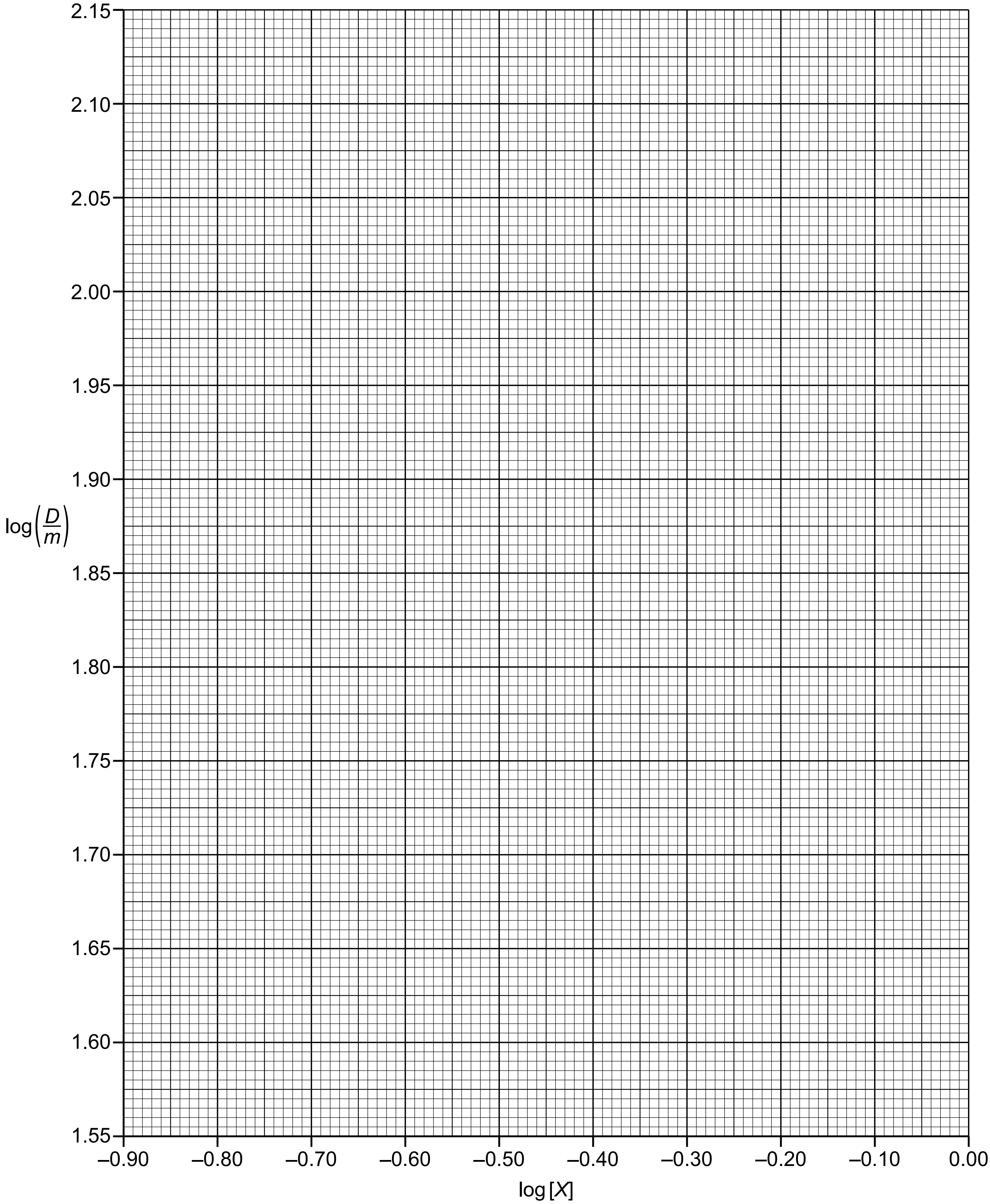
....

....

.... [2]

(b) Plot a graph on the grid to show the relationship between $\log\left(\frac{D}{m}\right)$ and $\log[X]$.

Use a cross (×) to plot each data point. Draw the straight line of best fit.



[2]

(c) Circle the most anomalous point on the graph.

Suggest why this anomaly may have happened during the experimental procedure.

....

....

.... [1]

(d) **(i)** Use the graph to determine the gradient of the line of best fit. State the coordinates of both points you used in your calculation. These must be selected from your line of best fit.

Write your answer to **three** significant figures

coordinates 1 .... coordinates 2 ....

gradient = ...

[2]

(ii) Use the graph to determine a value for *A*.

A = ... [1]

[Total: 11]

Important values, constants and standards

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

[Turn over

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 –