



## Cambridge International AS & A Level

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NAME

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**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.

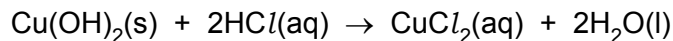
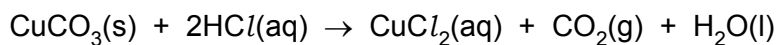
### INFORMATION

- 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,  $\text{CuCO}_3$ , and copper(II) hydroxide,  $\text{Cu}(\text{OH})_2$ , in varying amounts.

Both copper compounds react with dilute hydrochloric acid.



- (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
- $10.0 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}(\text{aq})$
- 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  $10.0 \text{ mol dm}^{-3}$   $\text{HCl}$  is too concentrated for use in the experiment. Instead, a more dilute solution should be prepared.

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

Your answer should state the name and capacity in  $\text{cm}^3$  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  $\text{CuCO}_3$ .

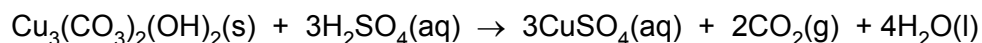
Calculate the minimum volume, in  $\text{cm}^3$ , of  $0.500 \text{ mol dm}^{-3} \text{ HCl}$  that is needed to completely react with this sample if the student is correct.

Show your working.

[ $M_r$ :  $\text{CuCO}_3 = 123.5$ ]

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

- (b) Azurite is a blue copper-containing mineral. The copper compound in azurite has the formula  $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$ . This copper compound reacts with sulfuric acid according to the equation.



A student carries out a series of titrations on 1.50 g samples of solid azurite using  $0.400 \text{ mol dm}^{-3}$  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 / $\text{cm}^3$	25.55	23.90	48.30	28.10
initial reading / $\text{cm}^3$	0.00	0.00	23.90	3.95
titre / $\text{cm}^3$				

The indicator 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  $24.15 \text{ cm}^3$  of  $0.400 \text{ mol dm}^{-3}$  sulfuric acid completely reacts with 1.50 g of azurite.

Calculate the percentage by mass of  $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$  in the sample of azurite using the student's value of  $24.15 \text{ cm}^3$  of  $0.400 \text{ mol dm}^{-3}$  sulfuric acid.

Write your answer to **three significant figures**.

Show your working.

$[M_r: \text{Cu}_3(\text{CO}_3)_2(\text{OH})_2 = 344.5]$

percentage by mass of  $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$  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  $\text{g dm}^{-3}$ ) before and after adsorption

$m$  = mass of activated charcoal (in g)

$[X]$  = final concentration of dye (in  $\text{g dm}^{-3}$ ) 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  $50.0 \text{ cm}^3$  sample of a  $25.00 \text{ g dm}^{-3}$  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, $m / \text{g}$	initial concentration of blue dye / $\text{g dm}^{-3}$	final concentration of blue dye, $[X] / \text{g dm}^{-3}$	difference in concentration of blue dye, $D / \text{g dm}^{-3}$	$\frac{D}{m}$	$\log\left(\frac{D}{m}\right)$	$\log [X]$
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]

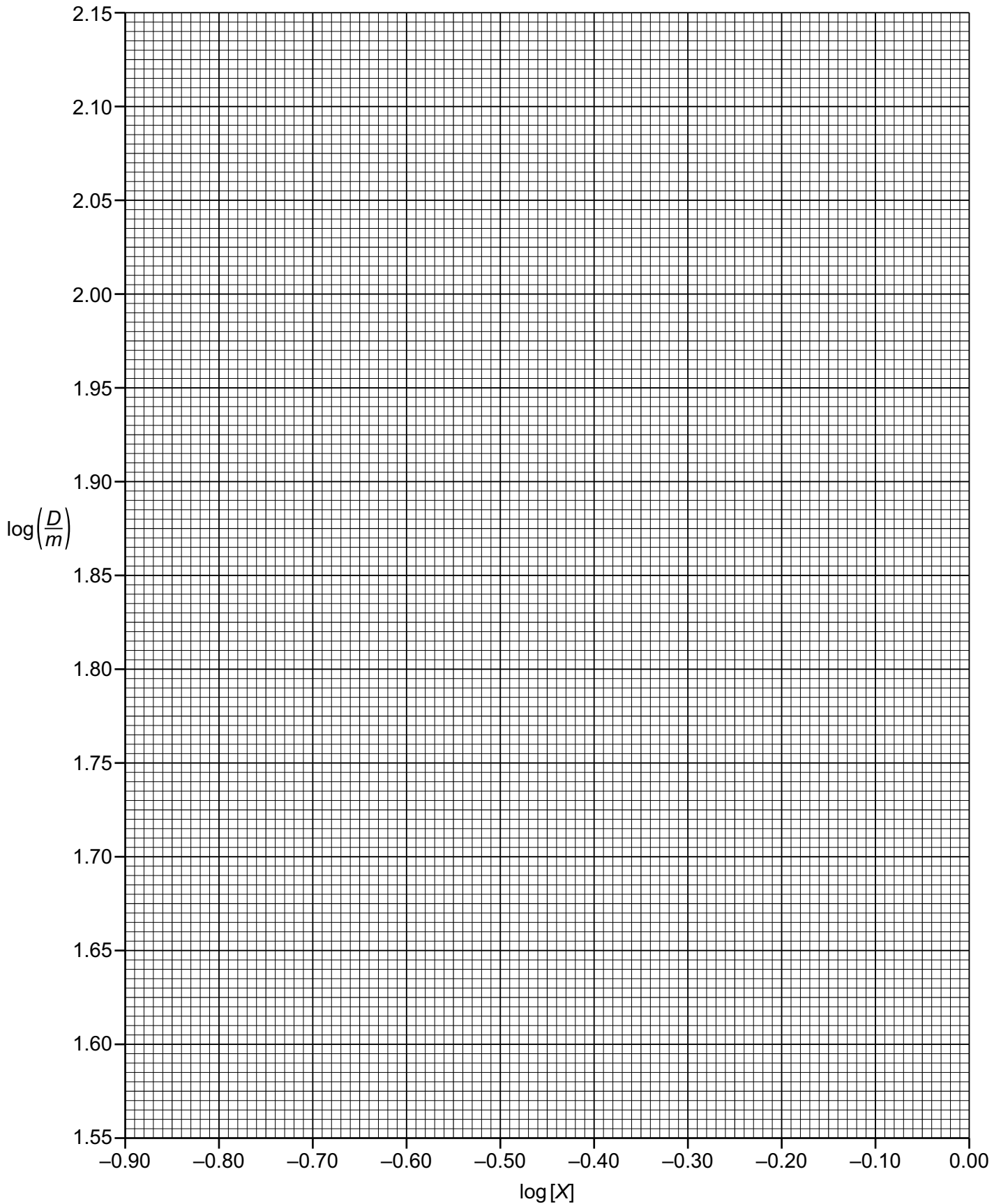
(iii) State and explain the effect, if any, of increasing the mass of activated charcoal,  $m$ , on the amount of adsorption that occurs.

.....  
 .....  
 .....  
 .....  
 ..... [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	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
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	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g <sup>-1</sup> K <sup>-1</sup> )

## The Periodic Table of Elements

Group																			
1	2	Key										13	14	15	16	17	18		
		1																	2
		H																	He
		hydrogen																	helium
		1.0																	4.0
		atomic number																	
		atomic symbol																	
		name																	
		relative atomic mass																	
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca		
lithium	beryllium	boron	carbon	nitrogen	oxygen	fluorine	neon	sodium	magnesium	aluminium	silicon	phosphorus	sulfur	chlorine	argon	potassium	calcium		
6.9	9.0	10.8	12.0	14.0	16.0	19.0	20.2	23.0	24.3	27.0	28.1	31.0	32.1	35.5	39.9	39.1	40.1		
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28		
Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni		
sodium	magnesium	aluminium	silicon	phosphorus	sulfur	chlorine	argon	potassium	calcium	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel		
23.0	24.3	27.0	28.1	31.0	32.1	35.5	39.9	39.1	40.1	45.0	47.9	50.9	52.0	54.9	55.8	58.9	58.7		
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
rubidium	strontium	yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	silver	cadmium	indium	tin	antimony	tellurium	iodine	xenon		
85.5	87.6	88.9	91.2	92.9	95.9	—	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3		
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86		
Cs	Ba	lanthanoids	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
caesium	barium		hafnium	tantalum	tungsten	rhenium	osmium	iridium	platinum	gold	mercury	thallium	lead	bismuth	polonium	astatine	radon		
132.9	137.3		178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	—	—	—		
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118		
Fr	Ra	actinoids	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og		
francium	radium		rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	darmstadtium	roentgenium	coppernium	nihonium	flerovium	moscovium	livermorium	tennessine	oganesson		
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		

lanthanoids	57	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	lanthanum	cerium	praseodymium	neodymium	promethium	samarium	europium	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium	
	138.9	140.1	140.9	144.4	—	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0	
actinoids	89	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium	lawrencium	
	—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—	—

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