



Cambridge International AS & A Level

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CHEMISTRY

9701/52

Paper 5 Planning, Analysis and Evaluation

May/June 2025

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. Any blank pages are indicated.



- 1 Activated carbon is a form of carbon with the ability to adsorb solutes from solutions. The adsorption of ethanedioic acid molecules, $(\text{COOH})_2$, from dilute ethanedioic acid, $(\text{COOH})_2(\text{aq})$, onto the surface of activated carbon is studied in a series of experiments.

Before beginning the experiment, 500.0 cm^3 of $0.139 \text{ mol dm}^{-3}$ $(\text{COOH})_2(\text{aq})$, solution **X**, is made. The activated carbon is placed in an oven at 120°C for three hours.

The experimental procedure involves the following steps.

- step 1** Prepare 100.0 cm^3 of $0.00556 \text{ mol dm}^{-3}$ $(\text{COOH})_2(\text{aq})$ from solution **X**.
- step 2** Transfer 50.0 cm^3 of the $0.00556 \text{ mol dm}^{-3}$ $(\text{COOH})_2(\text{aq})$ into a conical flask.
- step 3** Add 0.500 g of activated carbon to the conical flask and start a stopwatch.
- step 4** Shake the flask and immediately remove a 5.0 cm^3 sample from the flask. Determine the mass of non-adsorbed $(\text{COOH})_2$ in the sample using chromatography.
- step 5** Repeat step 4 at suitable time intervals until there is no further change in the mass of non-adsorbed $(\text{COOH})_2$ in the sample.

(a) Solid ethanedioic acid has the formula $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$.

- (i) Calculate the mass of $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}(\text{s})$ required to prepare 500.0 cm^3 of $0.139 \text{ mol dm}^{-3}$ $(\text{COOH})_2(\text{aq})$, solution **X**.

mass = g [1]

- (ii) The mass of $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}(\text{s})$ calculated in (a)(i) is placed into a 100 cm^3 beaker. Describe the steps taken to prepare 500.0 cm^3 of $0.139 \text{ mol dm}^{-3}$ $(\text{COOH})_2(\text{aq})$.

Give the name and capacity of any apparatus used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

.....

..... [3]



- (b) $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}(\text{s})$ is corrosive. Other than wearing eye protection and a lab coat, state **one** safety precaution that should be taken when using $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}(\text{s})$.

..... [1]

- (c) Suggest why the activated carbon is placed in the oven before use.

..... [1]

- (d) In step 1, solution **X** is diluted to a concentration of $0.00556 \text{ mol dm}^{-3}$.

Calculate the volume of solution **X** needed to make 100.0 cm^3 of $0.00556 \text{ mol dm}^{-3}$ $(\text{COOH})_2(\text{aq})$.

volume of solution **X** = cm^3 [1]

- (e) Identify the most appropriate piece of equipment to transfer 50.0 cm^3 of diluted $(\text{COOH})_2(\text{aq})$ in step 2.

..... [1]

- (f) Suggest a reason why the conical flask is shaken in step 4.

..... [1]





(g) The results of the experiment are shown in Table 1.1.

Table 1.1

time, t /min	mass of non-adsorbed (COOH) ₂ in 5.0 cm ³ sample /mg	mass of (COOH) ₂ adsorbed by activated carbon in 5.0 cm ³ sample /mg
0	2.50	0.00
5	1.90	
15	1.52	
30	1.43	
45	0.99	
60	0.88	
90	0.81	
120	0.80	
150	0.80	

(i) Complete Table 1.1. [1]

(ii) Plot a graph on the grid in Fig. 1.1 to show the relationship between mass of (COOH)₂ adsorbed by activated carbon in 5.0 cm³ sample and time, t . Use a cross (×) to plot each data point.

Draw a curved line of best fit.

[2]

(iii) Identify the independent variable.

..... [1]

(iv) Suggest **one** variable that needs to be controlled that is **not** stated in the experimental procedure.

..... [1]

(v) Circle the **one** point on the graph that you consider to be most anomalous.

Explain the error in timing that may have led to this anomalous point.

..... [1]





mass of $(\text{COOH})_2$
adsorbed by
activated carbon
in 5.0 cm^3
sample / mg

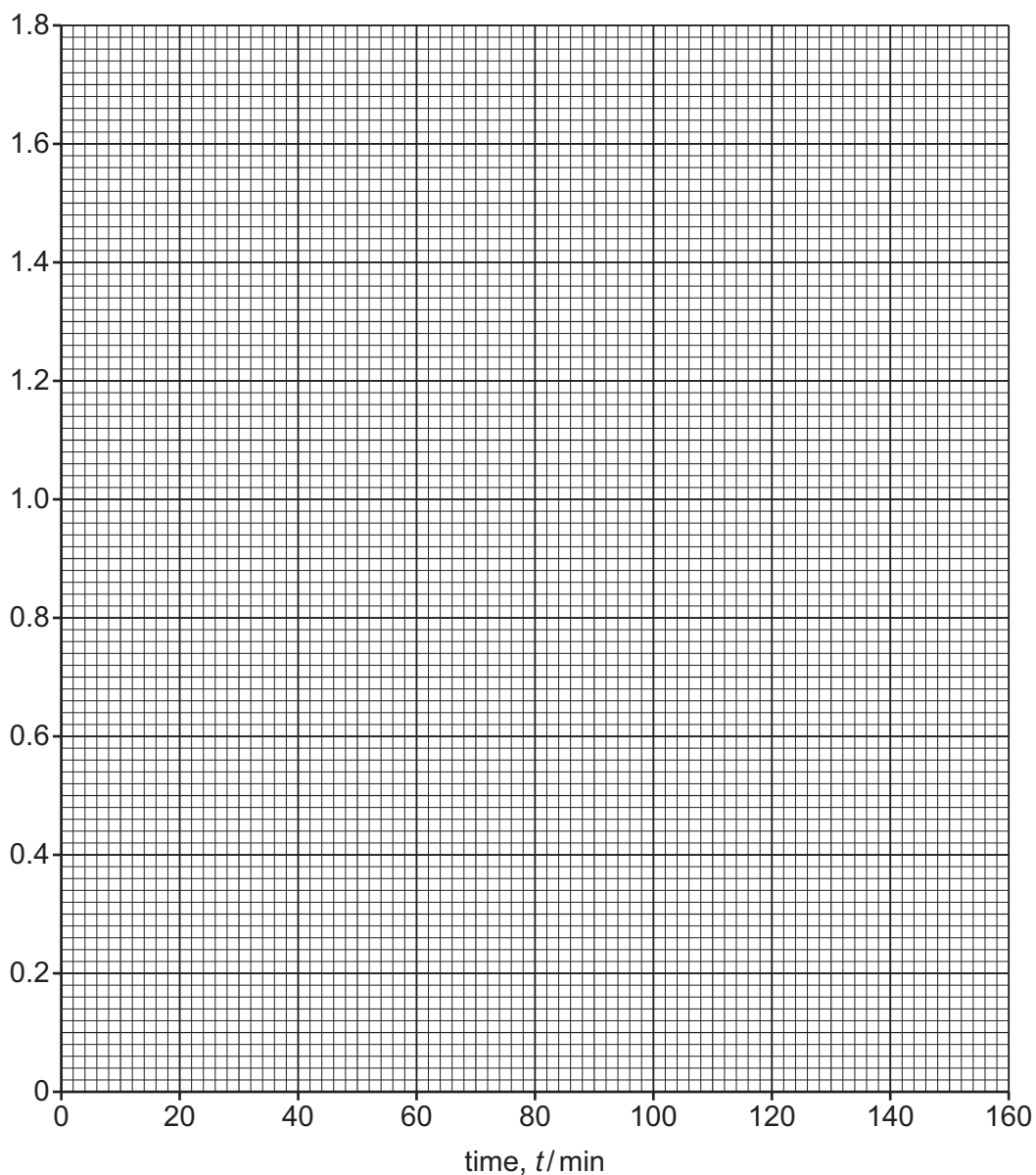


Fig. 1.1





- (h) The experiment is repeated using different concentrations of $(\text{COOH})_2(\text{aq})$ prepared in step 1. The results are shown in Table 1.2.

Table 1.2

1	2	3	4	5
m_i/mg	m_e/mg	$(m_i - m_e)/\text{mg}$	$q_e/\text{mg g}^{-1}$	$\frac{m_e}{q_e}/\text{g}$
2.5	0.80	1.70	34.0	0.0235
5.0	2.10	2.90	58.0	0.0362
7.5	4.03	3.47	69.4	0.0581
10.0	6.41	3.59	71.8	0.0893
12.5	8.87	3.63	72.6	0.1222

m_i is the initial mass of $(\text{COOH})_2$ in 5.0 cm^3 sample.

m_e is the mass of non-adsorbed $(\text{COOH})_2$ in the final 5.0 cm^3 sample at the end of step 5.

q_e is the mass of $(\text{COOH})_2$ adsorbed per gram of activated carbon.

- (i) A plot of $\frac{m_e}{q_e}$ against m_e gives the line of best fit shown in Fig. 1.2.

Use Fig. 1.2 to determine the gradient of the line of best fit.

State the coordinates of both points you used in your calculation.

coordinates 1 coordinates 2

Include units in your answer.

gradient =

units =

[3]

- (ii) The adsorption parameter, q_0 , is the maximum mass of $(\text{COOH})_2$ adsorbed per gram of activated carbon.

The equation of the line of best fit plotted in Fig. 1.2 is shown.

$$\frac{m_e}{q_e} = \frac{m_e}{q_0} + \text{constant}$$

Use the gradient determined in (h)(i) to calculate the adsorption parameter, q_0 .

[If you were unable to determine an answer to (h)(i), then use the value 0.0136 for the gradient. This is **not** the correct answer.]

$q_0 = \dots \text{mg g}^{-1}$ [1]



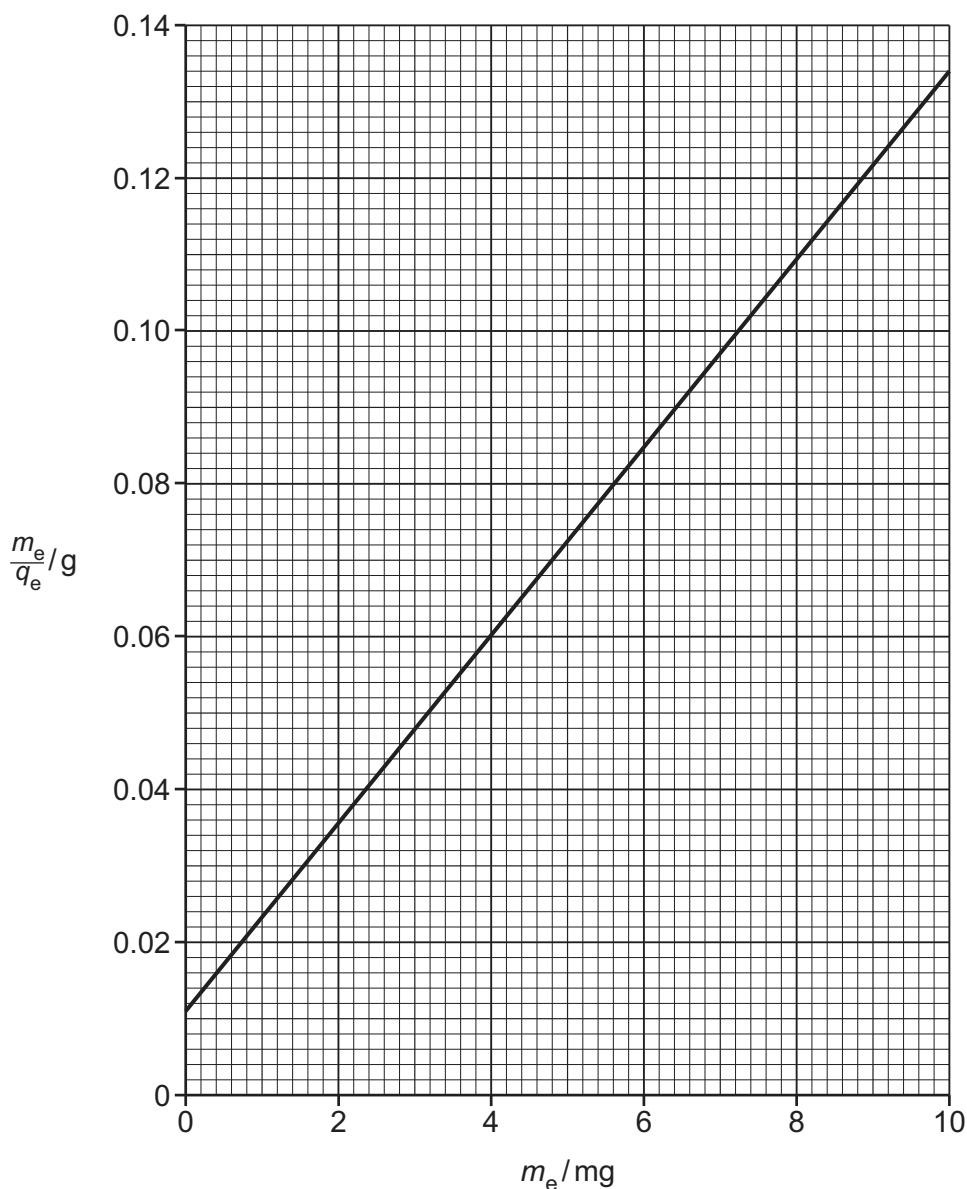


Fig. 1.2

- (i) The experiment is repeated and the value of q_0 is calculated to be 78.1 mg g^{-1} . The total percentage error from the experimental procedure is 6.5%.

The data book value of q_0 is 86.0 mg g^{-1} .

Use this information to determine whether the error in the repeated experiment could be accounted for by experimental errors or is caused by other factors.

Show your working.

..... [1]

[Total: 20]





- 2 The enthalpy change of combustion, ΔH_c , of butane, C_4H_{10} , can be determined using the apparatus shown in Fig. 2.1.

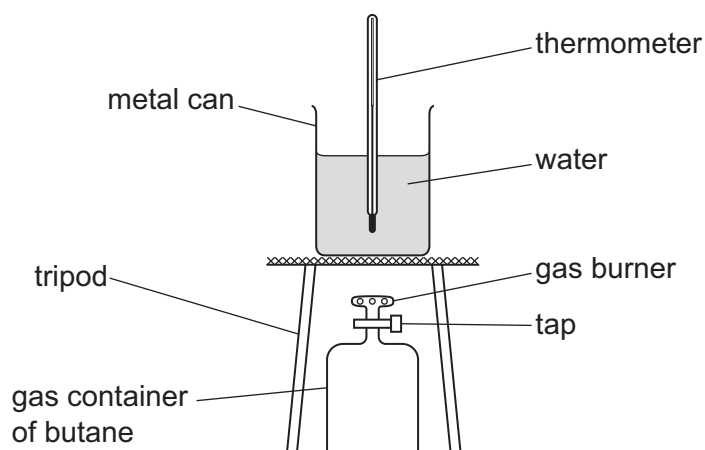


Fig. 2.1

The following steps are carried out.

- step 1** Use a 500 cm^3 measuring cylinder to transfer 320 cm^3 of water into a metal can.
- step 2** Place a thermometer into the water. Record the initial temperature of the water in the metal can.
- step 3** Weigh the gas container with burner and record the initial mass.
- step 4** Set up the apparatus as shown in Fig. 2.1.
- step 5** Light the burner and allow the flame to heat the water in the metal can for three minutes.
- step 6** Switch off the burner and record the maximum temperature reached.
- step 7** When cool, reweigh the gas container with burner and record the final mass.

The results are shown in Table 2.1.

Table 2.1

initial temperature of water / $^{\circ}\text{C}$	maximum temperature of water / $^{\circ}\text{C}$	change in temperature of water, ΔT / $^{\circ}\text{C}$	initial mass of gas container with burner / g	final mass of gas container with burner / g	mass of butane burned / g
19.3	76.6		183.56	181.46	

- (a) Complete Table 2.1. Record your answers to the appropriate number of decimal places. [2]





- (b) Use the relationship $q = mc\Delta T$ to calculate the energy, q , in J, gained by the water. 1.00 cm^3 of water has a mass of 1.00 g .

$q = \dots\dots\dots \text{ J [1]}$

- (c) Calculate the enthalpy change of combustion, ΔH_c , of butane, in kJ mol^{-1} .

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

$\Delta H_c = \dots\dots\dots \text{ kJ mol}^{-1} [2]$

- (d) Without changing the apparatus, suggest what should be done in step 6 before recording the maximum temperature reached to improve the experimental procedure.

$\dots\dots\dots [1]$

- (e) The 500 cm^3 measuring cylinder has graduations every 5 cm^3 .
Calculate the percentage error in the measurement of the volume of water.
Show your working.

percentage error = $\dots\dots\dots \% [1]$

- (f) A student suggests that the value calculated in (c) is different from the actual value of ΔH_c of butane because of heat lost during the experiment. Suggest **one** change to the apparatus that would reduce the heat lost.

$\dots\dots\dots [1]$

- (g) The experiment was repeated but the burner was switched off after only two minutes.

- (i) Suggest why this might contribute to a reduction in the accuracy of ΔH_c of butane.

$\dots\dots\dots [1]$

- (ii) Suggest why this might contribute to an increase in the accuracy of ΔH_c of butane.

$\dots\dots\dots [1]$

[Total: 10]







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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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 ⁻¹ K ⁻¹)





The Periodic Table of Elements

Group																									
1	2													13	14	15	16	17	18						
														1 H hydrogen 1.0								2 He helium 4.0			

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids																			
57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.2	61	Pm	promethium	—
89	Ac	actinium	—	90	Th	thorium	232.0	91	Pa	protactinium	231.0	92	U	uranium	238.0	93	Np	neptunium	—
actinoids																			
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
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
81	Tl	thallium	204.4	82	Pb	lead	207.2	83	Bi	bismuth	209.0	84	Po	polonium	—	85	At	astatine	—
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	—
98	Cf	californium	—	99	Es	einsteinium	—	100	Fm	fermium	—	101	Md	mendelevium	—	102	No	nobelium	—
104	Rf	rutherfordium	—	105	Db	dubnium	—	106	Sg	seaborgium	—	107	Bh	bohrium	—	108	Hs	hassium	—
110	Ds	darmstadtium	—	111	Rg	roentgenium	—	112	Cn	copernicium	—	113	Nh	nihonium	—	114	Fl	flerovium	—
116	Lv	livermorium	—	117	Ts	tennessine	—	118	Og	oganesson	—	119	Uut	unununium	—	120	Uuq	ununquadium	—
121	Uuh	ununhexium	—	122	Uub	ununbium	—	123	Uut	ununtrium	—	124	Uuq	ununquadium	—	125	Uuh	ununhexium	—
126	Uus	ununseptium	—	127	Uub	ununbium	—	128	Uut	ununtrium	—	129	Uuq	ununquadium	—	130	Uuh	ununhexium	—
131	Uus	ununseptium	—	132	Uub	ununbium	—	133	Uut	ununtrium	—	134	Uuq	ununquadium	—	135	Uuh	ununhexium	—
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146	Uus	ununseptium	—	147	Uub	ununbium	—	148	Uut	ununtrium	—	149	Uuq	ununquadium	—	150	Uuh	ununhexium	—
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294	Uus	ununseptium	—	295	Uub	ununbium	—	296	Uut	ununtrium	—	297	Uuq	ununquadium	—	298	Uuh	ununhexium	—
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419	Uus	ununseptium	—	420	Uub	ununbium	—	421	Uut	ununtrium	—	422	Uuq	ununquadium	—	423	Uuh	ununhexium	—
424	Uus	ununseptium	—	425	Uub	ununbium	—	426	Uut	ununtrium	—	427	Uuq	ununquadium	—	428	Uuh	ununhexium	—
429	Uus	ununseptium	—	430	Uub	ununbium	—	431	Uut	ununtrium	—	432	Uuq	ununquadium	—	433	Uuh	ununhexium	—
434	Uus	ununseptium	—	435	Uub	ununbium	—	436	Uut	ununtrium	—	437	Uuq	ununquadium	—	438	Uuh	ununhexium	—
439	Uus	ununseptium	—	440	Uub	ununbium	—	441	Uut	ununtrium	—	442	Uuq	ununquadium	—	443	Uuh	ununhexium	—
444	Uus	ununseptium	—	445	Uub	ununbium	—	446	Uut	ununtrium	—	447	Uuq	ununquadium	—	448	Uuh	ununhexium	—
449	Uus	ununseptium	—	450	Uub	ununbium	—	451	Uut	ununtrium	—	452	Uuq	ununquadium	—	453	Uuh	ununhexium	—
454	Uus	ununseptium	—	455	Uub	ununbium	—	456	Uut	ununtrium	—	457	Uuq	ununquadium	—	458	Uuh	ununhexium	—
459	Uus	ununseptium	—	460	Uub	ununbium	—	461	Uut	ununtrium	—	462	Uuq	ununquadium	—	463	Uuh	ununhexium	—
464	Uus	ununseptium	—	465	Uub	ununbium	—	466	Uut	ununtrium	—	467	Uuq	ununquadium	—	468	Uuh	ununhexium	—
469	Uus	ununseptium	—	470	Uub	ununbium	—	471	Uut	ununtrium	—	472	Uuq	ununquadium	—	473	Uuh	ununhexium	—
474	Uus	ununseptium	—	475	Uub	ununbium	—	476	Uut	ununtrium									