Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER | CANDIDATE NUMBER

2105320516

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **February/March 2017**

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.

IB17 03_9701_52/4RP

1 The enthalpy change of reaction, ΔH_r, for the decomposition of sodium hydrogencarbonate, $NaHCO_3(s)$, cannot be measured directly.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

A student must carry out **two** separate experiments and use the results of these experiments to determine the enthalpy change of reaction for the decomposition of sodium hydrogencarbonate.

(a) Suggest why the enthalpy change of reaction, ΔH_r, for the decomposition of sodium hydrogencarbonate cannot be measured directly.

....

.... [1]

In both experiments the student used a weighing boat. A weighing boat is a small vessel used to contain solid samples when they are weighed.

Experiment 1 Reaction between sodium carbonate, $Na_2CO_3(s)$, and dilute hydrochloric acid, $HCl(aq)$

step 1 The student added approximately 3 g of $Na_2CO_3(s)$ to a weighing boat and accurately measured the combined mass of the weighing boat and $Na_2CO_3(s)$. This mass was recorded in Table 1.1.

step 2 The student used a measuring cylinder to measure 50 cm^3 of 2 $mol\,dm^{-3}$ $HCl(aq)$.

step 3 The experiment was carried out and the results were recorded in Table 1.2.

step 4 The student reweighed the empty weighing boat and recorded the mass in Table 1.1.

Table 1.1 mass results from Experiment 1

mass of weighing boat and $Na_2CO_3(s)$ / g	4.15
mass of empty weighing boat after addition of $Na_2CO_3(s)$ to $HCl(aq)$ / g	0.97
mass of $Na_2CO_3(s)$ added / g	

Table 1.2 temperature results from Experiment 1

time / minutes	0	1	2	3		5	6	7	8	9	10
temperature of mixture / °C	20.0	19.8	19.8	19.8		24.6	24.7	24.5	24.3	24.1	23.9

(b) Outline how the student carried out **step 3** of the experiment.
You may find it helpful to write your answer as a series of smaller steps.

....

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....

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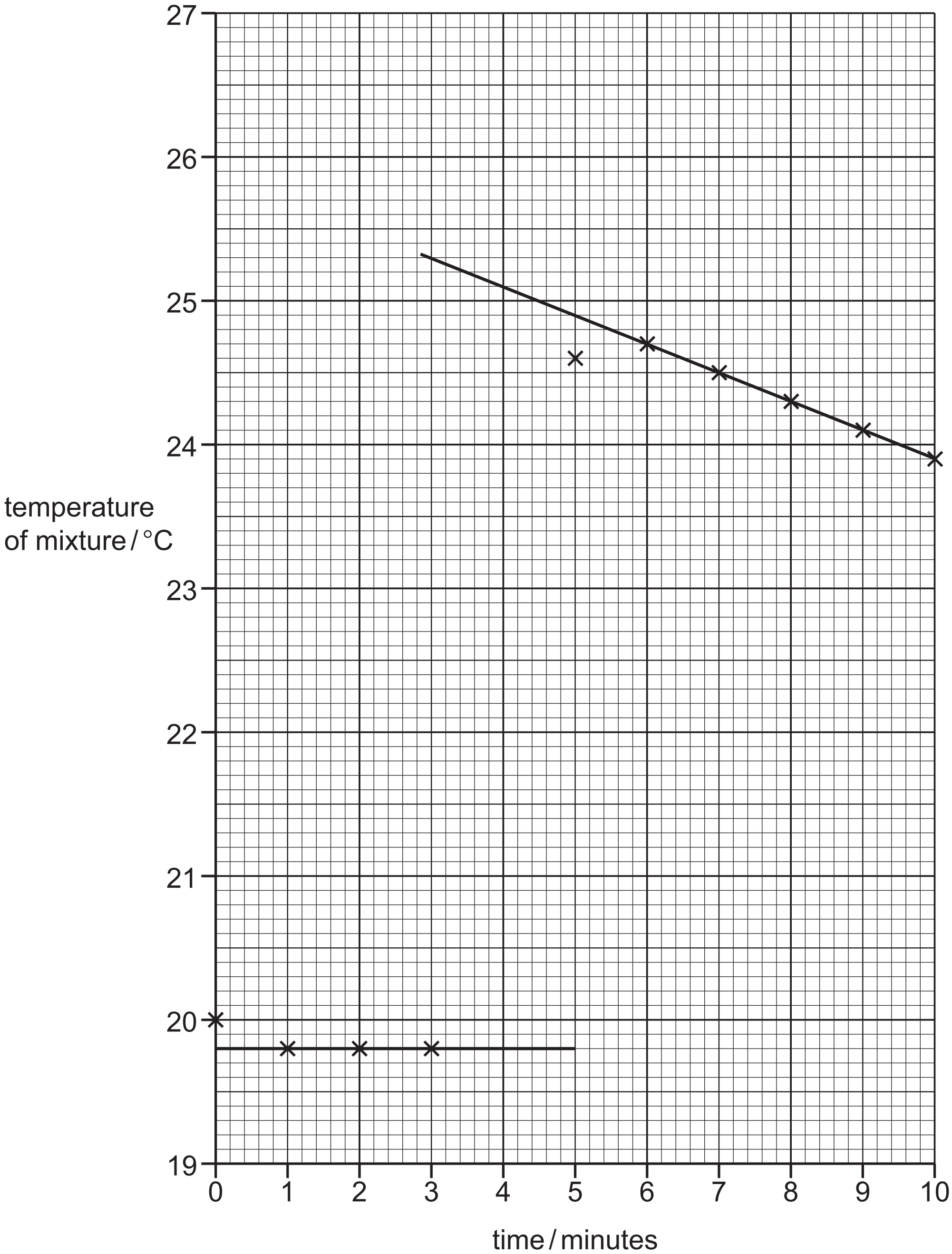
....

....

Draw a labelled diagram of the apparatus.

[3]

The student plotted a graph of the results and drew **two** lines of best fit which were both extrapolated as shown.



(c) Use the graph to determine the theoretical temperature increase at 4 minutes.

theoretical temperature increase = ... °C [1]

(d) Use Table 1.1 on page 2 to determine the mass of $Na_2CO_3(s)$ which was added to the $HCl(aq)$. Use this value and your answer to **(c)** to determine the enthalpy change, ΔH_1, for the reaction shown.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

Give your answer to **three** significant figures.
[Assume that the specific heat capacity of the solution is $4.18\,J\,g^{-1}\,K^{-1}$.]
[A_r: Na, 23.0; C, 12.0; O, 16.0]

ΔH_1 = ... $kJ\,mol^{-1}$ [3]

(e) **(i)** Explain why the student did **not** add the $Na_2CO_3(s)$ to the $HCl(aq)$ at 0 minutes.

....

.... [1]

(ii) Suggest why the temperature measured at 5 minutes was lower than the temperature measured at 6 minutes.

....

.... [1]

Experiment 2 Reaction between sodium hydrogencarbonate, $NaHCO_3$(s), and dilute hydrochloric acid, HCl(aq)

step 1 The student weighed an empty weighing boat and recorded the mass in Table 1.3.

step 2 The student added exactly 4.20 g of $NaHCO_3$(s) to the weighing boat and recorded the mass in Table 1.3.

step 3 The student carried out the same experimental procedure as in **steps 2** and **3** of Experiment 1.

Table 1.3 mass results from Experiment 2

mass of empty weighing boat / g	0.95
mass of weighing boat and $NaHCO_3$(s) / g	5.15
mass of $NaHCO_3$(s) added / g	

(f) Explain why the method of determining the mass of solid added in Experiment 2 is less accurate than the method of determining the mass of solid added in Experiment 1.

....

.... [1]

(g) **(i)** In Experiment 2 a 50 cm^3 measuring cylinder was used to measure the 50 cm^3 of HCl(aq). The 50 cm^3 measuring cylinder had 1 cm^3 graduations.

Calculate the maximum percentage error in measuring 50 cm^3 of HCl(aq) with this 50 cm^3 measuring cylinder.

maximum percentage error = ... % [1]

(ii) Explain why measuring the concentration of the 2 mol dm^{-3} HCl more precisely would **not** affect the result of the experiment.

....

.... [1]

(iii) Suggest what the student should change to reduce the percentage error associated with the temperature readings **without** changing the apparatus.

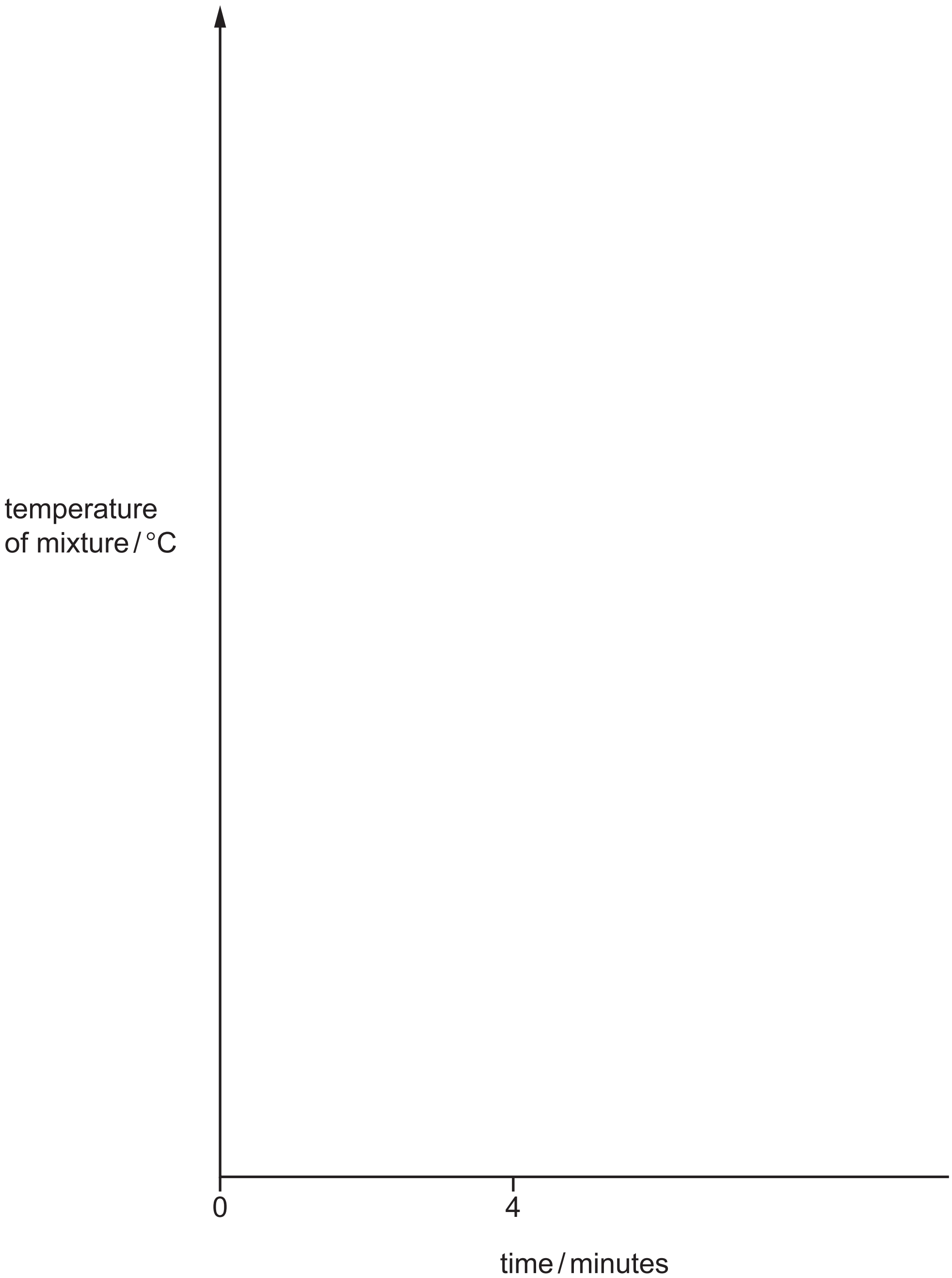
....

.... [1]

(h) The student used the results from Experiment 2 and correctly determined the enthalpy change for the reaction between $NaHCO_3$(s) and HCl(aq), ΔH_2, to be +24.2 kJ mol^{-1}.

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g) \qquad \Delta H_2 = +24.2\,kJ\,mol^{-1}$$

Use the axes to draw a sketch graph of the expected results of Experiment 2.

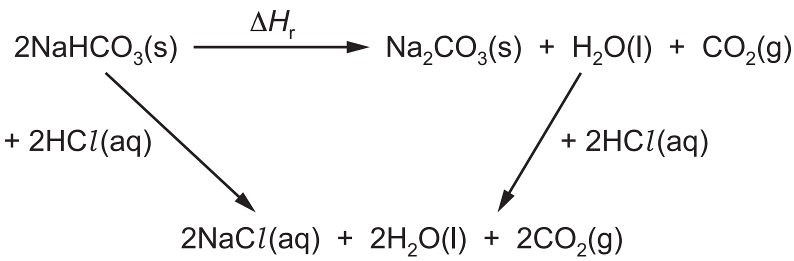


[2]

(i) Use ΔH_1 from **(d)** and ΔH_2 from **(h)** to determine the enthalpy change of reaction, ΔH_r, for the decomposition of $NaHCO_3(s)$.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

An energy cycle has been drawn for you.



If you were unable to calculate ΔH_1 in **(d)**, assume $\Delta H_1 = -26.7\,kJ\,mol^{-1}$. This is **not** the correct value of ΔH_1.

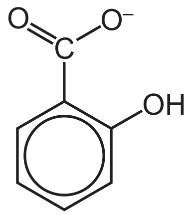
ΔH_r = ... $kJ\,mol^{-1}$ [2]

[Total: 18]

2 Transition metal complex ions are coloured. The formula of a complex ion can be determined using colorimetry.

In colorimetry, light of a certain wavelength is passed through a complex ion solution. The absorbance of the light is proportional to the intensity of the colour of the solution. The more concentrated the complex ion solution, the more intense its colour and so the higher the absorbance.

A student carried out an experiment to determine the formula of the complex ion formed between aqueous iron(III) ions, $Fe^{3+}(aq)$, and aqueous 2-hydroxybenzoate ions, $C_6H_4(OH)CO_2^-$, which have the structure shown.



(a) In the first step of the experiment the student prepared 100.0 cm^3 of 0.0500 mol dm^{-3} aqueous iron(III) nitrate.

(i) Determine the mass, in g, of solid hydrated iron(III) nitrate, $Fe(NO_3)_3.9H_2O$, needed to prepare 100.0 cm^3 of a 0.0500 mol dm^{-3} solution.
[A_r: Fe, 55.8; N, 14.0; O, 16.0; H, 1.0]

mass of $Fe(NO_3)_3.9H_2O$ = ... g [2]

(ii) Describe how, after weighing the mass determined in **(i)**, the student should prepare 100.0 cm^3 of 0.0500 mol dm^{-3} aqueous iron(III) nitrate.

In your answer you must give the name and capacity, in cm^3, of any apparatus used.

....

....

....

....

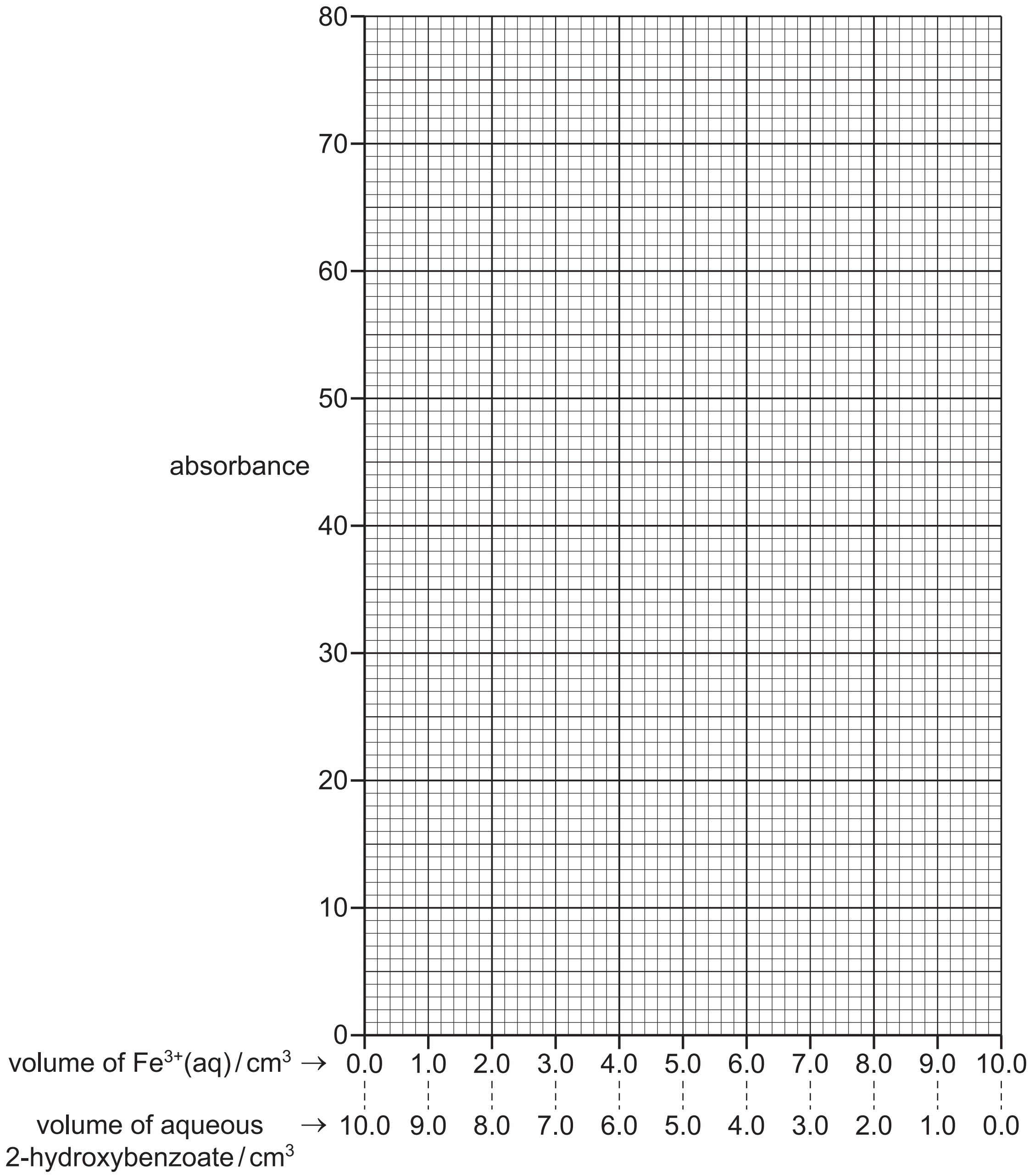
.... [2]

(b) The student prepared solutions containing various combinations of 0.0500 mol dm^{-3} Fe^{3+}(aq) and 0.0500 mol dm^{-3} aqueous 2-hydroxybenzoate, as shown in the table.

The student placed a small sample of each solution into a colorimeter and measured the absorbance. The student made a mistake in test number **9** and did **not** measure the result.

test number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
volume of Fe^{3+}(aq) / cm^3	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0		9.0	10.0
volume of aqueous 2-hydroxybenzoate / cm^3	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0		1.0	0.0
absorbance	0	23	46	69	70	58	47	35		13	0

(i) Plot a graph on the grid to show the relationship between absorbance and the volumes of Fe^{3+}(aq) and aqueous 2-hydroxybenzoate used.
Use a cross (×) to represent each data point. Draw **two** lines of best fit. [2]



(ii) Use the graph in **(i)** to determine the volumes of $Fe^{3+}(aq)$ and aqueous 2-hydroxybenzoate which would give the maximum absorbance.

volume of $Fe^{3+}(aq)$ = ... cm^3

volume of aqueous 2-hydroxybenzoate = ... cm^3
[1]

(iii) The point of maximum absorbance shows where all of the ions are combined in the complex.

Use the volumes in **(ii)** to determine the number of moles of 2-hydroxybenzoate ions that form a complex with 1 mole of Fe^{3+} ions.

moles of 2-hydroxybenzoate ions = ... [1]

(iv) $Fe^{3+}(aq)$ ions exist in aqueous solution as complex ions with the formula $[Fe(H_2O)_6]^{3+}(aq)$. 2-hydroxybenzoate ions, $C_6H_4(OH)CO_2^-$, are bidentate ligands.

Use this information and your answer to **(iii)** to suggest the formula of the complex ion formed between $Fe^{3+}(aq)$ ions and 2-hydroxybenzoate ions.

.... [1]

(v) Name the apparatus that should be used to measure the volumes of the solutions given in the table accurately.

.... [1]

(c) In test **9**, instead of mixing 8.0 cm^3 of $Fe^{3+}(aq)$ and 2.0 cm^3 of aqueous 2-hydroxybenzoate, the student mixed 16.0 cm^3 of $Fe^{3+}(aq)$ and 4.0 cm^3 of aqueous 2-hydroxybenzoate.

Use your graph in **(b)(i)** to suggest the absorbance that would have been measured if a sample of this solution had been analysed in the colorimeter.

absorbance = ... % [1]

(d) In a colorimetry experiment, the absorbance of the solution follows the relationship shown.

$$A = \varepsilon c l$$

A is the absorbance (no units).
c is the concentration in mol dm^{-3}.
l is the path length of the light travelling through the solution in cm.
ε is the molar absorption coefficient (a constant).

Determine the unit of ε.

unit = ... [1]

[Total: 12]