2 A student carries out an experiment to determine the concentration of aqueous sulfate ions, $SO_4^{2-}(aq)$, in a sample of lake water.

(a) The student uses the following method.

step 1 Transfer 25.00 cm^3 of the lake water sample to a beaker and record its conductivity as shown in Fig. 2.1.

step 2 Add 5.00 cm^3 of 0.100 $mol\,dm^{-3}$ aqueous barium hydroxide, $Ba(OH)_2(aq)$, to the beaker.

step 3 Stir the mixture and record the conductivity of the contents of the beaker as shown in Fig. 2.1.

step 4 Repeat steps 2 and 3 until a total of 40.00 cm^3 of 0.100 $mol\,dm^{-3}$ $Ba(OH)_2(aq)$ has been added to the beaker.

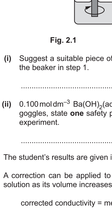

Fig. 2.1

(i) Suggest a suitable piece of apparatus to transfer 25.00 cm^3 of the lake water sample to the beaker in step 1.

.....

[1]

(ii) 0.100 $mol\,dm^{-3}$ $Ba(OH)_2(aq)$ is an irritant to skin and eyes. Other than wearing safety goggles, state **one** safety precaution that the student should take when conducting this experiment.

.....

[1]

(b) The student's results are given in Table 2.1.

A correction can be applied to the conductivity values to take into account dilution of the solution as its volume increases using the following equation.

$$\text{corrected conductivity} = \text{measured conductivity} \times \frac{\text{(total volume in beaker)}}{25.00}$$

Table 2.1

reading number	volume of 0.100 $mol\,dm^{-3}$ $Ba(OH)_2(aq)$ added to beaker / cm^3	total volume in beaker / cm^3	measured conductivity / $\mu S\,cm^{-1}$	corrected conductivity / $\mu S\,cm^{-1}$
1	0.00	25.00	37 000	37 000
2	5.00		23 000	27 600
3	10.00		12 000	16 800
4	15.00		2 300	3 680
5	20.00		5 000	
6	25.00		12 000	
7	30.00		18 000	
8	35.00		21 000	
9	40.00		24 500	

(i) Complete Table 2.1. [2]

(ii) Identify the independent variable in this experiment.

.....

[1]

(c) Plot a graph on the grid in Fig. 2.2 to show the relationship between corrected conductivity and volume of 0.100 $mol\,dm^{-3}$ $Ba(OH)_2$ added to beaker.

Use a cross (×) to plot each data point.

Draw a line of best fit using readings 1 to 4 and another line of best fit using readings 5 to 9. Extend the lines so that they intersect.

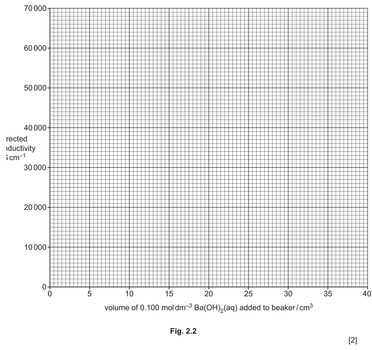

Fig. 2.2

[2]

(d) The point on the graph where the two lines intersect indicates the volume of 0.100 $mol\,dm^{-3}$ $Ba(OH)_2(aq)$ required to react exactly with the $SO_4^{2-}(aq)$ present in 25.00 cm^3 of lake water being tested.

(i) Use the graph in Fig. 2.2 to determine the volume of 0.100 $mol\,dm^{-3}$ $Ba(OH)_2(aq)$ required to react exactly with $SO_4^{2-}(aq)$ in the lake water sample.

volume required = ... cm^3 [1]

(ii) The equation for the reaction taking place in the beaker is shown.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

Use your answer in **(d)(i)** to calculate the concentration of $SO_4^{2-}(aq)$ in the lake water sample.

concentration of $SO_4^{2-}(aq)$ = ... $mol\,dm^{-3}$ [1]

(e) The concentration of $SO_4^{2-}(aq)$ in a sample of water can also be determined by measuring the mass of precipitate produced when excess $Ba(OH)_2(aq)$ is added to the sample.

The student suggests the following method.

step 1 Place 25.0 cm^3 of the water sample in a conical flask.

step 2 Add excess 0.100 $mol\,dm^{-3}$ $Ba(OH)_2(aq)$ to the flask.

step 3 Filter the contents of the flask.

step 4 Dry the residue in a warm oven.

step 5 Measure the mass of residue.

(i) Draw a labelled diagram to describe the arrangement of apparatus that would be needed to complete step 3.

[1]

(ii) Suggest a step that the student should add between steps 3 and 4 to improve this method.

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[1]

(iii) Describe what the student can do to ensure that the residue weighed in step 5 is completely dry.

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[1]

(iv) The mass of residue is used to calculate the concentration of $SO_4^{2-}(aq)$.

Suggest the effect, if any, on the concentration of $SO_4^{2-}(aq)$ that is calculated if the residue is **not** completely dried in step 4.

Explain your answer.

effect on concentration of $SO_4^{2-}(aq)$ calculated .....

explanation .....

.....

[1]

[Total: 13]

Important values, constants and standards

molar gas constant	$R = 8.31\,JK^{-1}mol^{-1}$
Faraday constant	$F = 9.65 \times 10^4\,C\,mol^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,dm^3\,mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,kJ\,kg^{-1}K^{-1}$ (4.18 $J\,g^{-1}K^{-1}$)