11.2 Synoptic Data Handling & Graphical Skills

Question Paper

Course	DP IB Chemistry
Section	11. Measurements & Data Processes
Topic	11.2 Synoptic Data Handling & Graphical Skills
Difficulty	Medium

Time allowed: 70

Score: /55

Percentage: /100

Question 1a

a) Aluminium will react with copper(II) sulfate solution according to the following equation:

$$2Al\ (s) + 3CuSO_4\ (aq) \rightarrow\ 3Cu\ (s) + Al_2(SO_4)_3\ (aq)$$

The reaction is quite slow at room temperature, but when chloride ions in the form of hydrochloric acid are added, the rate increases significantly. The chloride ions catalyse the reaction.

An experiment was carried out to determine the yield of the reaction. A student made a solution of aqueous copper(II) sulfate by dissolving 2.00 g of copper(II) sulfate pentahydrate, $CuSO_4.5H_2O$ (M_r 249.72 $gmol^{-1}$) in 10.0 mL of distilled water in a small beaker.

To this solution she added 0.25 g of aluminium foil followed by 2.0 mL of 6.0 $moldm^{-3}$ hydrochloric acid.

After the reaction was complete, she collected, dried, and weighed the copper that was produced.

She recorded the measurements in **Table 1** below.

Table 1

	Mass / ± 0.01 g
Initial mass of copper sulfate	2.00
Mass of aluminium foil used	0.25
Mass of empty beaker	42.18
Mass of beaker with dry copper	42.61

Use the data to show that the copper sulfate is the limiting reagent in the experiment and calculate the mass of aluminium in excess.

[4 marks]

Question 1b

b) Calculate the actual yield and the percentage yield of copper in the experiment.

[3 marks]

Question 1c

c) Determine the percentage uncertainty in the mass of copper produced, and the overall percentage error for the experiment.

[2 marks]

Question 1d

d) Discuss the impact on the percentage yield of copper from the following systematic errors:

i) The copper collected is not fully dried out before the beaker is weighed.

ii) The student misread the instructions and used 1.0 mL of hydrochloric acid.

[2 marks]

Question 2a

a) A student carried out a metal displacement reaction between zinc powder and copper(II) sulfate solution. The equation for the reaction is

$$Zn\ (s) + CuSO_4\ (aq) \rightarrow ZnSO_4\ (aq) + Cu\ (s)$$

3.78 g of zinc powder was added to 50.0 cm^3 of 0.250 $moldm^{-3}$ copper(II) sulfate solution.

Determine the limiting reagent showing your working.

[3 marks]

Question 2b

b) The reaction between the zinc and copper sulfate was carried out in a polystyrene cup and the temperature change was measured using a temperature probe. The maximum temperature rise the student recorded was 8.5 °C.

Using section 1 and 2 of the data booklet, calculate the enthalpy change, ΔH, for the reaction, in kJ.

Assume that all the heat evolved was absorbed by the solution, and that the density and specific heat capacity of the copper(II) sulfate solution are the same as pure water.

[2 marks]

Question 2c

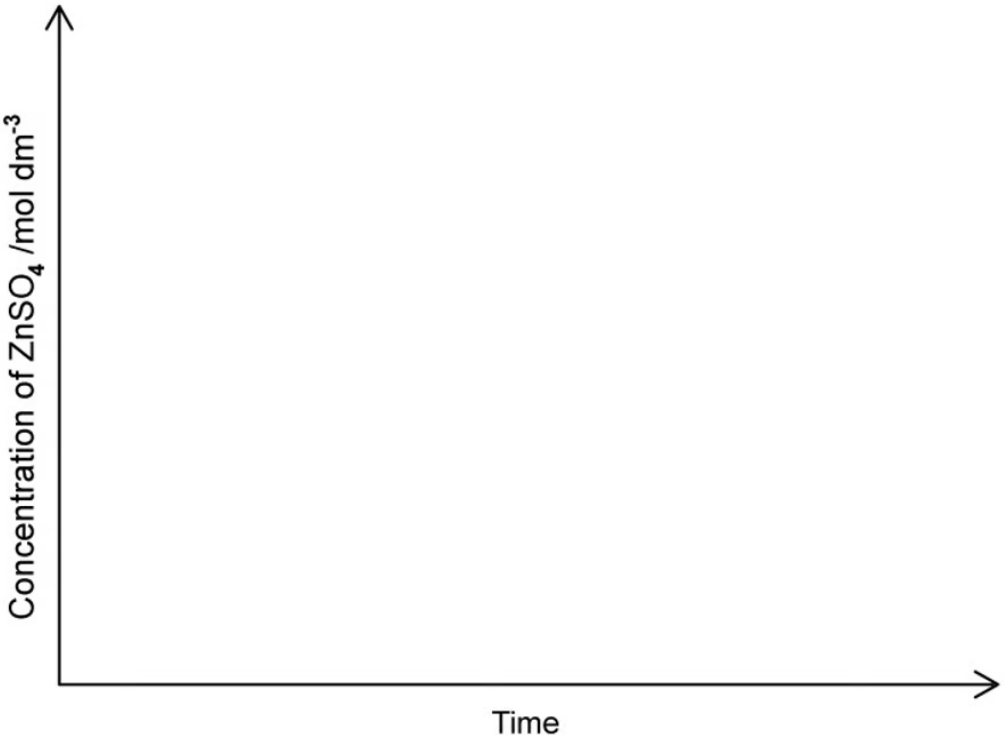
c) State **two** further assumptions made in the calculation of ΔH.

[2 marks]

Question 2d

d) Using **Figure 1**, sketch a graph of the concentration of zinc sulfate, $ZnSO_4$ (aq), versus time and show how the graph may be used to find the initial rate of reaction.

Figure 1



[4 marks]

Question 3a

a) The concentration of coloured metal ions in a solution can be determined by spectroscopic methods, such as colorimetry. A colorimeter is used to measure relative absorbance of a number of standard solutions and a calibration graph is drawn.

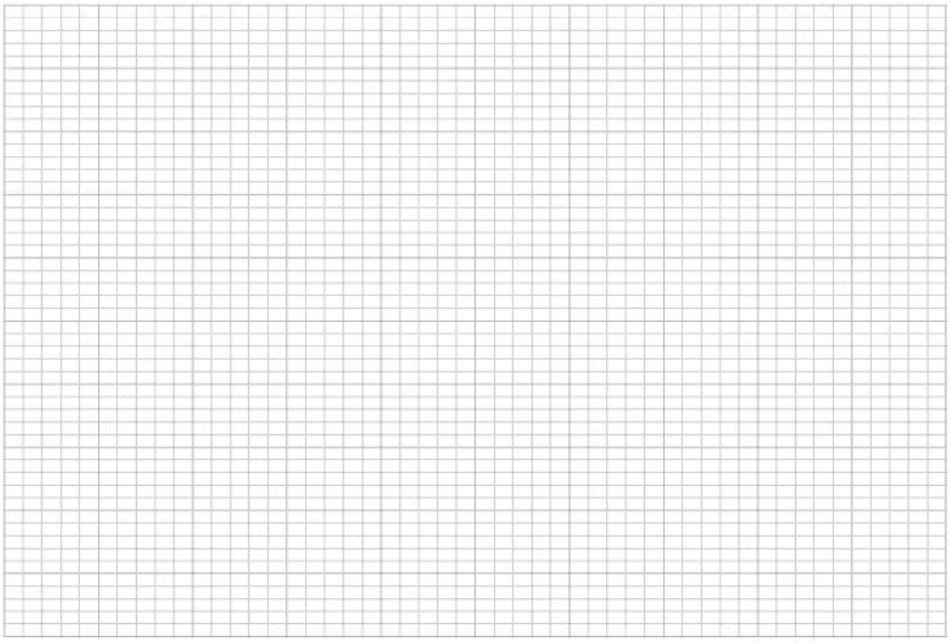
Table 1 shows the concentration of nickel(II) ions and the relative absorbance of light at 635 nm wavelength.

Table 1

Concentration of Ni(II) ions / moldm^{-3}	Relative absorbance
1.0	0.890
0.8	0.717
0.5	0.450
0.3	0.270
0.1	0.089

Using **Figure 1**, draw a labelled a graph of concentration against relative absorbance and draw a line of best fit through the points.

Figure 1



[4 marks]

Question 3b

b) Identify the dependent and independent variables and use the graph in part (a) to determine the concentration of a solution of Ni(II) ions whose relative absorbance is 0.560. Show how you arrive at your answer.

[3 marks]

Question 3c

c) Use your graph from part (a) to answer the following questions.

i) State the type of relationship shown between the variables.

ii) Determine the value of m in the formula: $y = mx + c$.

iii) Use the formula and your answer in (ii) to calculate the concentration of the Ni(II) ions when the relative absorbance in 0.560 and comment on your result compared to the value found graphically in part (b).

[4 marks]

Question 3d

d) The relationship between concentration and absorbance is only linear at low concentrations. Suggest a possible reason for this.

[1 mark]

Question 4a

a) The Winkler method is a chemical technique used to measure the concentration of dissolved oxygen in water samples. The method involves treating the samples to convert the dissolved oxygen into iodine which is then titrated against standard sodium thiosulfate solution as shown below:

Step 1: $2Mn^{2+}(aq) + O_2(aq) + 4OH^-(aq) \rightarrow 2MnO_2(s) + 2H_2O(l)$

Step 2: $MnO_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2H_2O(l)$

Step 3: $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

A student wanted to check if the water in a fish tank was sufficiently oxygenated and analysed two 500 cm^3 samples, five days apart.

The following results in **Table 1** were obtained when the resulting iodine was titrated against 0.0120 $moldm^{-3}$ $Na_2S_2O_3$ (aq).

Table 1
Oxygen analysis in fish tank water on day 0

Initial burette reading / cm^3 ± 0.1cm^3	0.20
Final burette reading / cm^3 ± 0.1cm^3	26.0
Titre / cm^3	

i) Determine the reacting ratio by moles of $S_2O_3^{2-}$ to O_2, using the balanced equations in steps 1-3.

ii) Calculate the titre and determine the percentage uncertainty in the reading.

[3 marks]

Question 4b

b) Determine the number of moles of oxygen in the 500 cm^3 sample and hence the concentration in ppm.

[3 marks]

Question 4c

c) It is generally considered that dissolved oxygen levels of at least 4-5 ppm are sufficient for most aquatic life. The day 5 sample contained 5.03×10^{-5} moles of oxygen.

Discuss whether the student should be concerned about the oxygen levels in the fish tank over the 5-day period.

[2 marks]

Question 4d

d) Suggest a modification to the procedure which would make the result more reliable.

[1 mark]

Question 5a

a) A student investigated the rate of decomposition of hydrogen peroxide, H_2O_2, at a temperature of 45 °C. The decomposition reaction occurs in the presence of a catalyst, MnO_2.

$$2H_2O_2\,(aq) \xrightarrow{MnO_2} O_2\,(g) + 2H_2O\,(l)$$

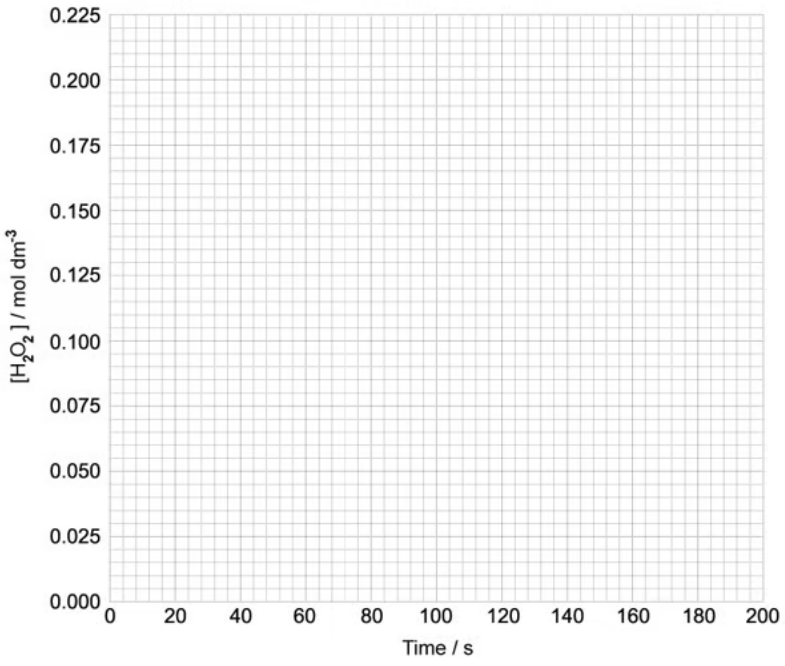
The results she obtained are shown in **Table 1** below.

Table 1

Time / s	Concentration of H_2O_2 / moldm^{-3}	Time / s	Concentration of H_2O_2 / moldm^{-3}
0	0.200	120	0.068
20	0.155	140	0.063
40	0.124	160	0.058
60	0.102	180	0.055
80	0.085	200	0.052
100	0.075		

Plot a graph on the axes below in **Figure 1** and from it determine the rate of reaction after 60 s.

Figure 1



[4 marks]

Question 5b

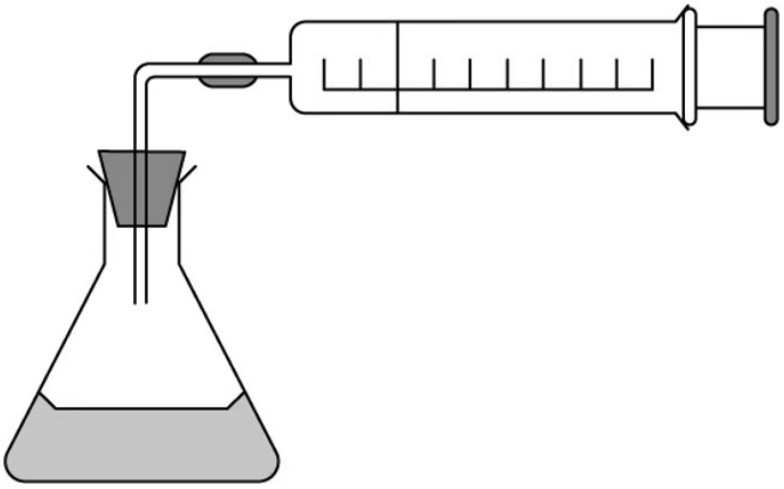
b) On the same graph sketch the shape obtained if the student had carried out the same reaction at 60 °C. Explain the shape of the graph at 60 °C.

[3 marks]

Question 5c

c) The decomposition of hydrogen peroxide can be investigated by measuring the volume of oxygen given off using the apparatus shown in **Figure 2**.

Figure 2



i) Explain why the volume of oxygen given off can be used as a measure of the concentration of hydrogen peroxide.

ii) Suggest one limitation of using the apparatus used in **Figure 2**.

iii) Suggest an alternative method of measuring the rate of reaction.

[3 marks]

Question 5d

d) Two students decide to measure the rate of decomposition for H_2O_2 using the change in mass as oxygen escapes from the reaction container.

One student says that they should use a three decimal place rather than two decimal place balance because it will make their results more accurate. The second student disagrees and says it will make their results more precise, but not more accurate.

Which student is correct?

[2 marks]