Experimental investigation

39

Experimental investigation /Equilibrium

Reading time: 5 minutes

Writing time: 40 minutes

Student's Name: ______________________________

Teacher: ____________________________________

Structure of booklet

Section	Number of Questions	Number of questions to be answered	Marks
Short Answer	2	2	39
		Total:	**39**

Directions to students

Materials
- Students **are permitted** to use pens/pencils, highlighters, erasers, sharpeners, rulers, and an approved scientific calculator.
- Students are **NOT permitted** to use white out liquid/tape, phones or electronic devices, including smart watches.
- Students are provided with the following: Question and answer booklet of **10 pages, not including the front cover** and students are permitted to use the VCAA Data booklet provided.

The task
- Please ensure that you write your name and teacher's name on this booklet. This paper consists of short answer questions only.
- There are a total of **39** marks available.
- Be sure to include states with all chemical equations.
- All numerical answers need to be quoted to the correct number of significant figures and appropriate units.
- All working out must be shown in the space provided.

For his extended VCE Chemistry experimental investigation project, Chris decided to investigate whether there is a relationship between the rate of the reaction between magnesium, Mg, and hydrochloric acid, HCl, and the concentration of the acid. The following is an extract from the scientific poster that Chris produced.

Question under investigation:
Is there a relationship between the rate of the reaction between magnesium, Mg, and different concentrations of hydrochloric acid, HCl?

Equation for the reaction:

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

Experimental design:
Four different concentrations of HCl were tested. The rate of each reaction was investigated by measuring the volume of hydrogen, H_2, gas produced at 60-second intervals.

Hypothesis:
The greater the concentration of the acid, the faster the reaction will be. I expect this because, for a reaction to occur, H^+ ions must collide with Mg atoms. The greater the concentration of the acid, the more frequently the H^+ ions will collide with the surface of the Mg and so the greater the amount of H_2 gas that will be produced.

a. In his hypothesis, does Chris demonstrate an understanding of the chemistry that is relevant to this experimental investigation? Explain your reasoning. 2 marks

In his poster, Chris outlined how the experimental investigation was conducted. An extract from his methodology is shown in the table below, diagram 1.

Methodology: First, the variables were identified. The decisions I made are shown in Table 1.

Table 1. The variables identified

Variable	Classification	Details
mass of Mg	controlled variable	The first piece of Mg ribbon was weighed and measured, then the same length of Mg was used for each concentration of HCl tested.
concentration of HCl	dependent variable	0.5 M, 1.0 M, 1.5 M and 2.0 M solutions of HCl were tested.
volume of HCl	controlled variable	50.0 mL was used for each test, measured using a graduated measuring cylinder.

b. Is Chris's identification of the concentration of HCl as the dependent variable correct? Give a reason for your answer. 2 marks

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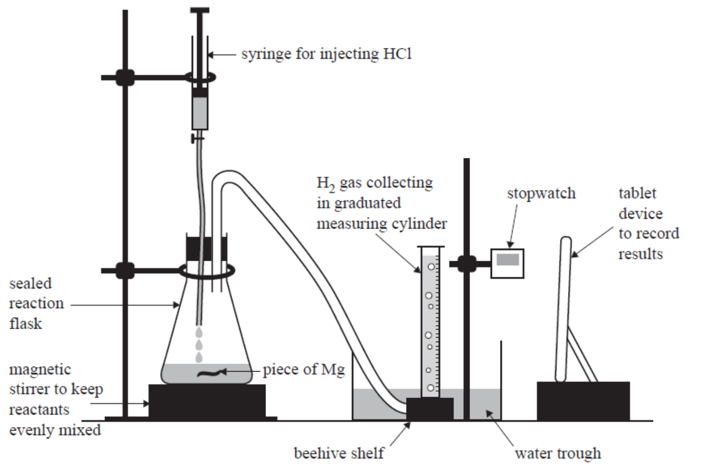
The experimental set-up:



Notes:

- Timing began the instant I started injecting the acid from the syringe above the flask onto the piece of Mg.
- The stopwatch was mounted next to the graduated measuring cylinder, and the volume and time were recorded using a video app on a tablet device and replayed in slow motion to allow the results to be obtained.
- The injection of 20.0 mL HCl into the sealed reaction flask immediately pushed 20.0 mL of air out of the flask and into the measuring cylinder. I recorded only the net volume of H_2 gas produced.

Diagram 1

c. Chris's poster included a diagram of the experimental set-up supported by short notes, as shown above in diagram 1. Identify **one** feature of Chris's experimental set-up and notes above that was designed to improve the accuracy of the results. Explain how this feature could improve accuracy. ` 3 marks

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Chris also recorded his observations on his poster.

Observations: *For the 2.0 M HCl, initially there was very rapid bubbling in the flask. The bubbling slowed over time. All Mg appeared to have dissolved. The flask became very hot. For the 1.5 M and 1.0 M HCl solutions, the bubbling was not as rapid as for the 2.0 M HCl and for the 0.5 M HCl it was much slower. The solutions were still bubbling when timing stopped. The flasks became hot, although not as hot as the flask containing 2.0 M HCl.*

d. Comment on Chris's observations, including the differences in the rate of bubbling and how well the experiment had been controlled. 3 marks

Chris replayed his video in slow motion, recorded his experimental results in his logbook and produced a graph for his poster. The graph is shown below in diagram 2.

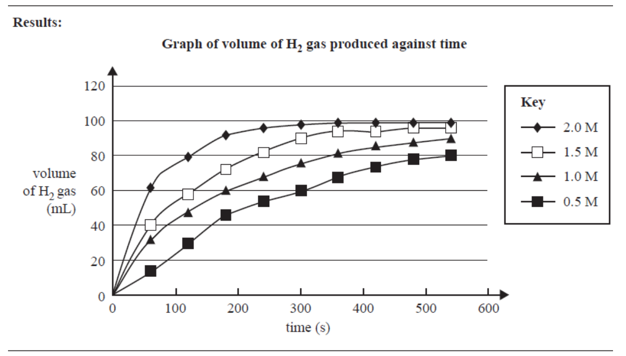

Diagram 2

e. With reference to the data in diagram 2 and Chris' hypothesis give two conclusions that Chris may have stated. 2 marks

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f. Suggest **one** other question Chris could ask to extend this experimental investigation and briefly outline an experimental design that would enable Chris to answer this question. You may present your answer as a list of main steps. Include a step that minimises the impact of random errors and step that test for repeatability. 4 marks

g. In your procedure identify which steps:

i. test for repeatability ___________________________________1 mark

Explain ____

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____1 mark

ii. lead to results with high validity . Provide a step other than the one given to question i. above. __________________ 1 mark

Explain____

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____1 mark

iii. use equipment prone to producing systematic errors _________1 mark

Explain____

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____1 mark

h. What must the method have in order to give results with high validity? 1 mark

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2. A laboratory wished to study the impact of an equilibrium system, shown below, as stresses are applied at constant temperature.

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

The procedure is shown below.

1. Prepare a series of four equilibrium mixtures:
   - In a set of test tubes, mix different volumes of Fe^{3+} and SCN^{-} solutions with water to maintain a constant total volume of 10.00 mL.

   - Keep the initial concentration of one ion constant (Fe^{3+}) and vary the concentration of SCN^{-} to observe how equilibrium shifts.

2. Allow the mixtures to reach equilibrium:
   - Let the solutions stand at constant room temperature, for at least 10 minutes until equilibrium is established.

3. Measure absorbance:
   - Use a spectrophotometer to measure the absorbance of each equilibrium mixture at 447 nm, where $FeSCN^{2+}$ forms a deep red ion complex that strongly absorbs light at 447 nm.

4. Prepare a calibration curve:
   - Make a standard solution containing a known concentration of $FeSCN^{2+}$ by mixing excess Fe^{3+} and a known amount of SCN^{-} .

   - Measure its absorbance and prepare a calibration curve, fig 4, (absorbance vs. [$FeSCN^{2+}$]).

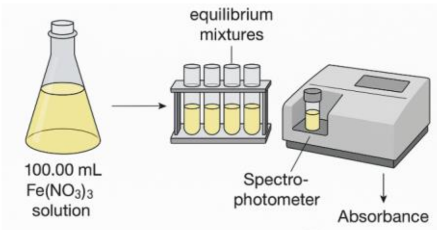

Diagram 3

5. Calculate [Fe^{3+}] at equilibrium:
   Use initial concentrations and the amount of Fe^{3+} consumed (based on [$FeSCN^{2+}$]) to calculate the free Fe^{3+} concentration at equilibrium.

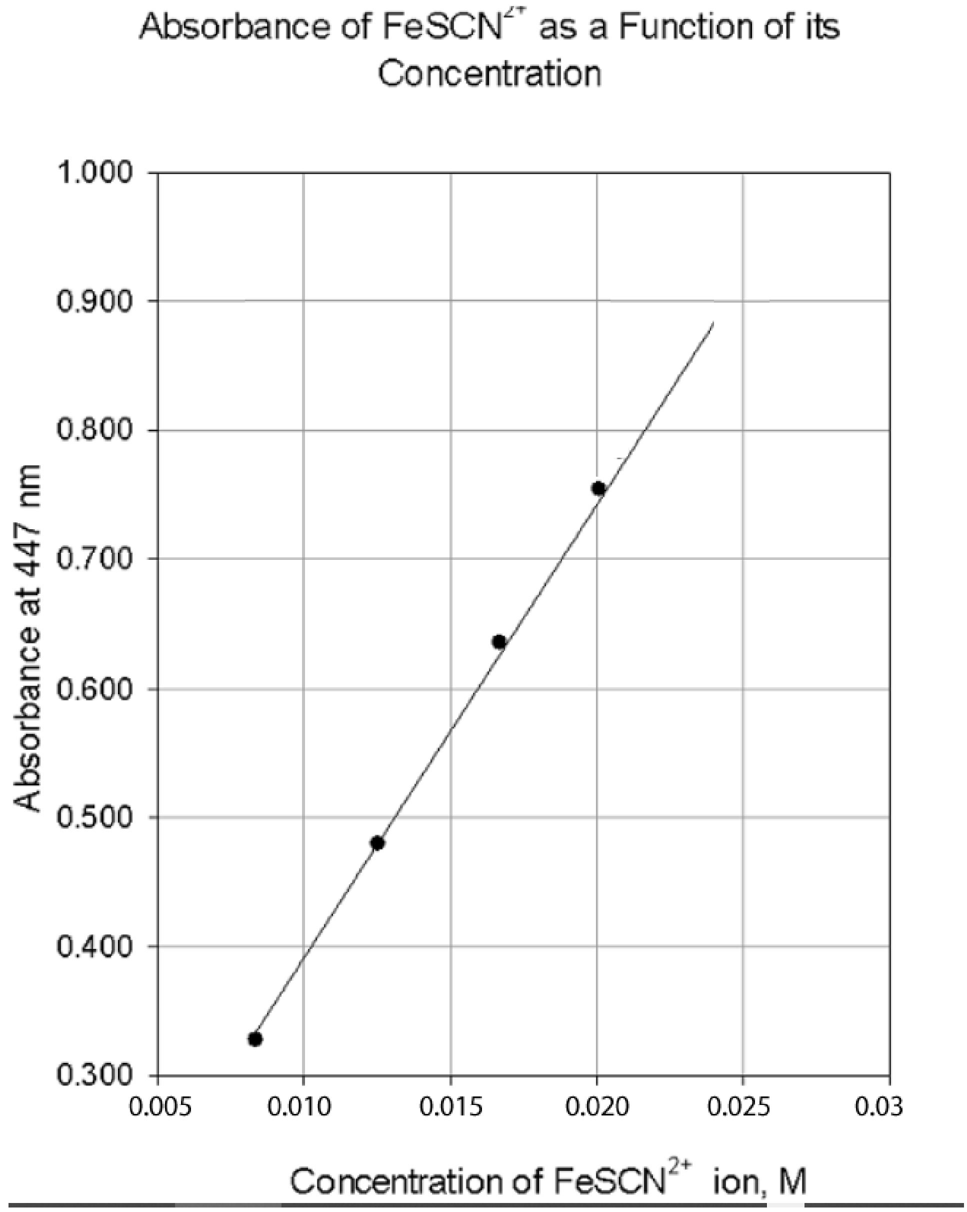

Diagram 4

a. What are the:

DV ____ 1 mark

and

IV ____ 1 mark

b. Name three controlled variables: 3 marks

i. ____

ii. ____

iii. ____

c. One sample had an initial [Fe^{3+}] of 0.035 M. It was allowed to reach equilibrium at which point the absorbance due to [$FeSCN^{2+}$] was 0.9 absorbance units (au).

   i. Using the calibration curve, shown in fig. 4, state the concentration of [Fe^{3+}]. Clearly indicate on the graph how you arrived at the value. 2 marks

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   ii. Discuss the degree of accuracy of this result and justify your answer.

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j. In step 4 of the procedure above, it states, " Make a standard solution containing a known concentration of $FeSCN^{2+}$ by mixing excess Fe^{3+} and a known amount of SCN^{-}. A student questioned whether it was possible to make a solution with a known concentration of $FeSCN^{2+}$ as the equilibrium concentration of SCN^{-} is unknown. Using Le Chatelier's principle discuss the validity of this approach. 3 marks

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k. Another student opted to use a different method of finding the [Fe^{3+}] at equilibrium. They added excess Na_3PO_4 (aq) to the equilibrium mixture to precipitate out the Fe^{3+} (aq) from solution as $FePO_4$ (s). They then filtered, dried and weighed the precipitate. Compare the validity of the two methods.

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____ 4 marks

Solutions