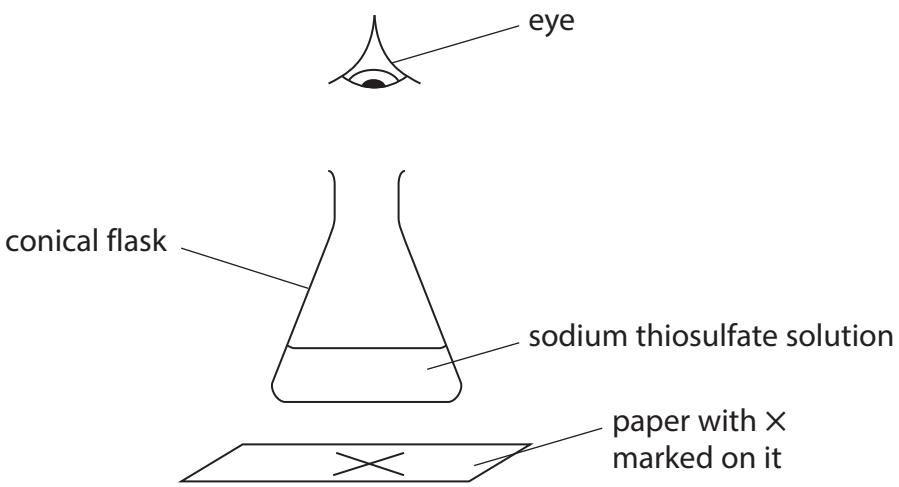
1 Sodium thiosulfate solution and dilute hydrochloric acid react together slowly to form a precipitate of sulfur. This precipitate eventually makes the mixture go cloudy.

A student uses this method.

- place 20 cm^3 of sodium thiosulfate solution and 20 cm^3 of water in a conical flask
- add 10 cm^3 of dilute hydrochloric acid to the flask
- place the flask on a piece of paper marked with a black ×
- time how long it takes before the × can no longer be seen



(a) The equation for the reaction is

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + S(s) + SO_2(g)$$

Before starting her experiments, the student considers the risk to her of sulfur dioxide escaping from the flask. She uses this information.

concentration of sodium thiosulfate solution = 0.300 mol/dm^3

volume of sodium thiosulfate solution = 20 cm^3

volume of water = 20 cm^3

volume of hydrochloric acid = 10 cm^3

(i) Calculate the mass of sulfur dioxide formed in this experiment.
The hydrochloric acid is in excess.

(3)

mass of sulfur dioxide formed = ... g

(ii) The solubility of sulfur dioxide at room temperature is 100 g/dm^3.

Use this additional information to explain whether any sulfur dioxide gas escapes from the flask.

(2)

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(b) At what point in the experiment should the student have started a timer?

(1)

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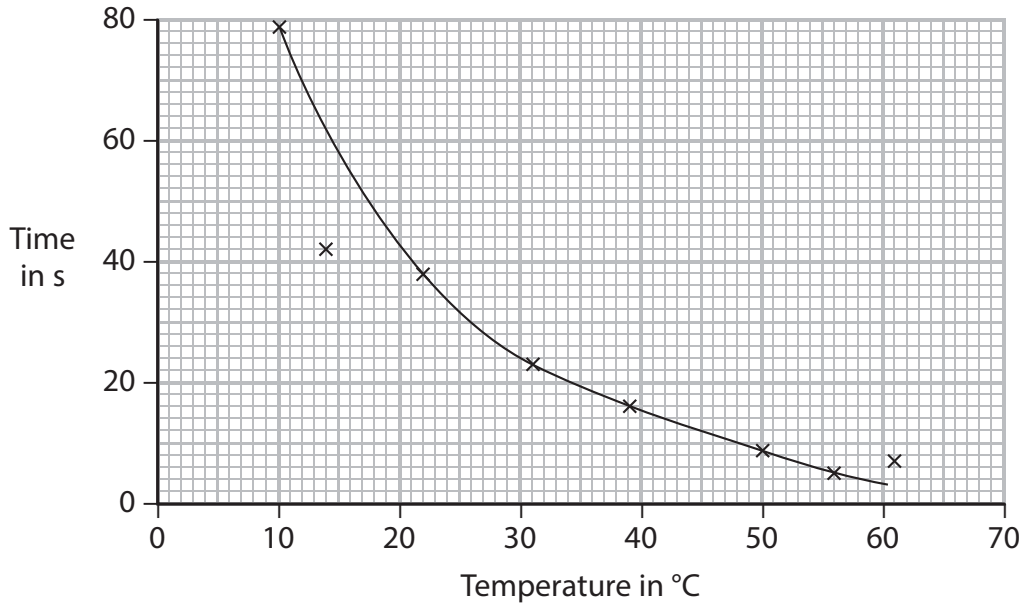
(c) She repeats the experiment using the same volumes and concentrations of solutions, but at different temperatures. The graph shows her results.



(i) The result at (14, 42) is anomalous.

Explain one mistake the student may have made to cause this anomalous result.

(1)

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(ii) Use the graph to find the time taken for the × to be no longer seen at 35 °C.

(1)

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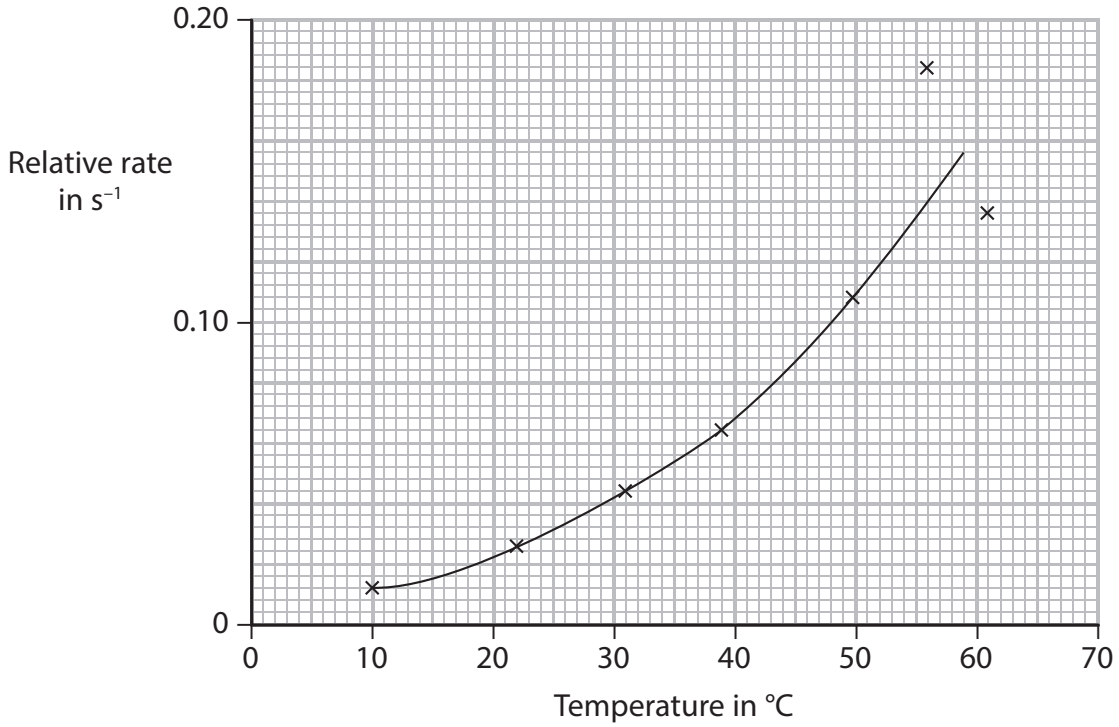
(d) The student repeats the experiments using nitric acid in place of hydrochloric acid. She records the times for the × to no longer be seen, then uses the times to calculate the rate of reaction at each temperature.
The graph shows the results she plots.



(i) Suggest two reasons why the results are least accurate at higher temperatures.

(2)

1 .....

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2 .....

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(ii) The student wrote this explanation for the shape of the graph.

As the temperature increases, the rate of reaction increases. This is because there are more frequent collisions between particles of reactants.

Use the particle collision theory to explain another more important reason for the increase in reaction rate.

(2)

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(e) Another student uses the same reaction to investigate the effect of changing the concentration of the sodium thiosulfate solution on the rate of reaction.

Give three variables that the student must control in this investigation to obtain valid results.

(3)

1 .....

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2 .....

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3 .....

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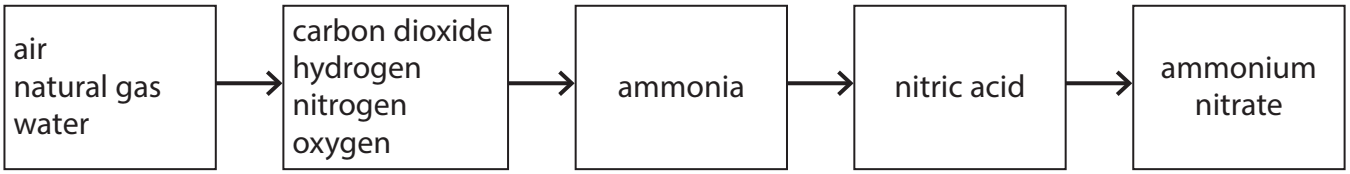
(Total for Question 1 = 15 marks)

2 The flow diagram shows how a fertiliser is manufactured from raw materials.



The hydrogen needed is formed in two reactions.

(a) Reaction 1 occurs between steam and methane in natural gas.

Balance the equation for this reaction.

(1)

$$\ldots\ldots CH_4 + \ldots\ldots H_2O \rightarrow \ldots\ldots CO + \ldots\ldots H_2$$

(b) The equation for reaction 2 is

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -41 \text{ kJ/mol}$$

(i) Assuming that this reaction reaches equilibrium, explain what happens to the yield of hydrogen if the reaction is carried out at a higher pressure but at the same temperature.

(2)

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(ii) Assuming that this reaction reaches equilibrium, explain what happens to the yield of hydrogen if the reaction is carried out at a higher temperature but at the same pressure.

(2)

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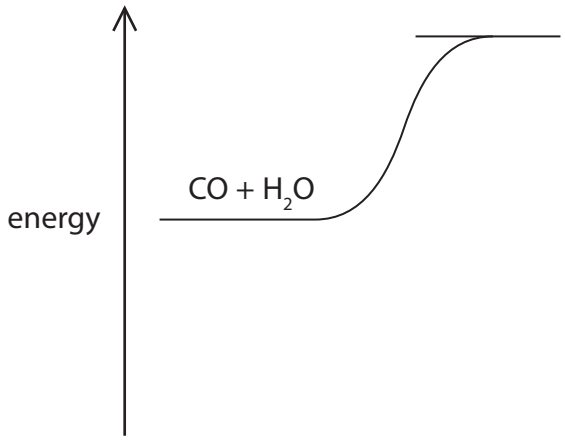
(c) Reaction 2 can be represented on an energy profile.



(i) Complete the profile by showing the products of the reaction and the enthalpy change for the reaction.

(2)

(ii) Reaction 2 is carried out using an iron oxide catalyst.

State the effect, if any, of using a catalyst on the enthalpy change for the reaction.

(1)

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.....

(iii) Explain how a catalyst increases the rate of a reaction.

(2)

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(d) The equations for some other reactions used in the manufacture of ammonium nitrate are

reaction 3 $N_2 + 3H_2 \rightleftharpoons 2NH_3$

reaction 4 $4NH_3 + 5O_2 \rightleftharpoons 4NO + 6H_2O$

reaction 5 $2NO_2 \rightleftharpoons N_2O_4$

reaction 6 $NH_3 + HNO_3 \rightarrow NH_4NO_3$

Explain which two of these are redox reactions.

(2)

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(e) The manufacturer produces a batch of 34 kg of ammonia.

Calculate the maximum mass of ammonium nitrate that can be made from this mass of ammonia, using reaction 6 in part (d).

Give a unit for your answer.

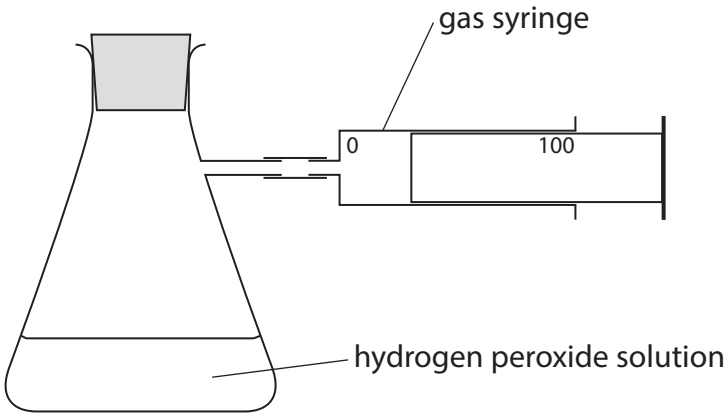
(3)

maximum mass of ammonium nitrate = ... unit .....

(Total for Question 2 = 15 marks)

3 A student investigates the rate of decomposition of hydrogen peroxide solution.

The diagram shows the apparatus he uses in his experiments.



The equation for the decomposition is

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

(a) The student keeps the amount, in moles, of H_2O_2 in the solution constant at the start of each experiment.

State two properties of the solution that he should keep the same to ensure that the amount of H_2O_2 is the same in each experiment.

(2)

1 .....

2 .....

(b) The student carries out the experiment five times.

He uses a different solid in each experiment to see how effective each solid is as a catalyst in the decomposition.

He removes the bung, adds a small amount of one of the solids and quickly replaces the bung.

He records the time taken to collect 100 cm^3 of oxygen in the syringe.

Solid	Time to collect 100 cm^3 of oxygen, in seconds
A	76
B	no oxygen collected
C	35
D	11
E	54

(i) Which solid does not seem to act as a catalyst?

(1)

.....

(ii) Which solid is the most effective catalyst?

(1)

.....

(c) In the first experiment the student added 1 g of solid A.

Describe what he could do with the contents of the conical flask at the end of the experiment to show that A was a catalyst, and not a reactant.

(2)

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.....

(d) The student repeats the experiment using the same apparatus, but this time he records the volume of oxygen collected at intervals of 20 seconds.

The table shows his results for two new solids F and G.

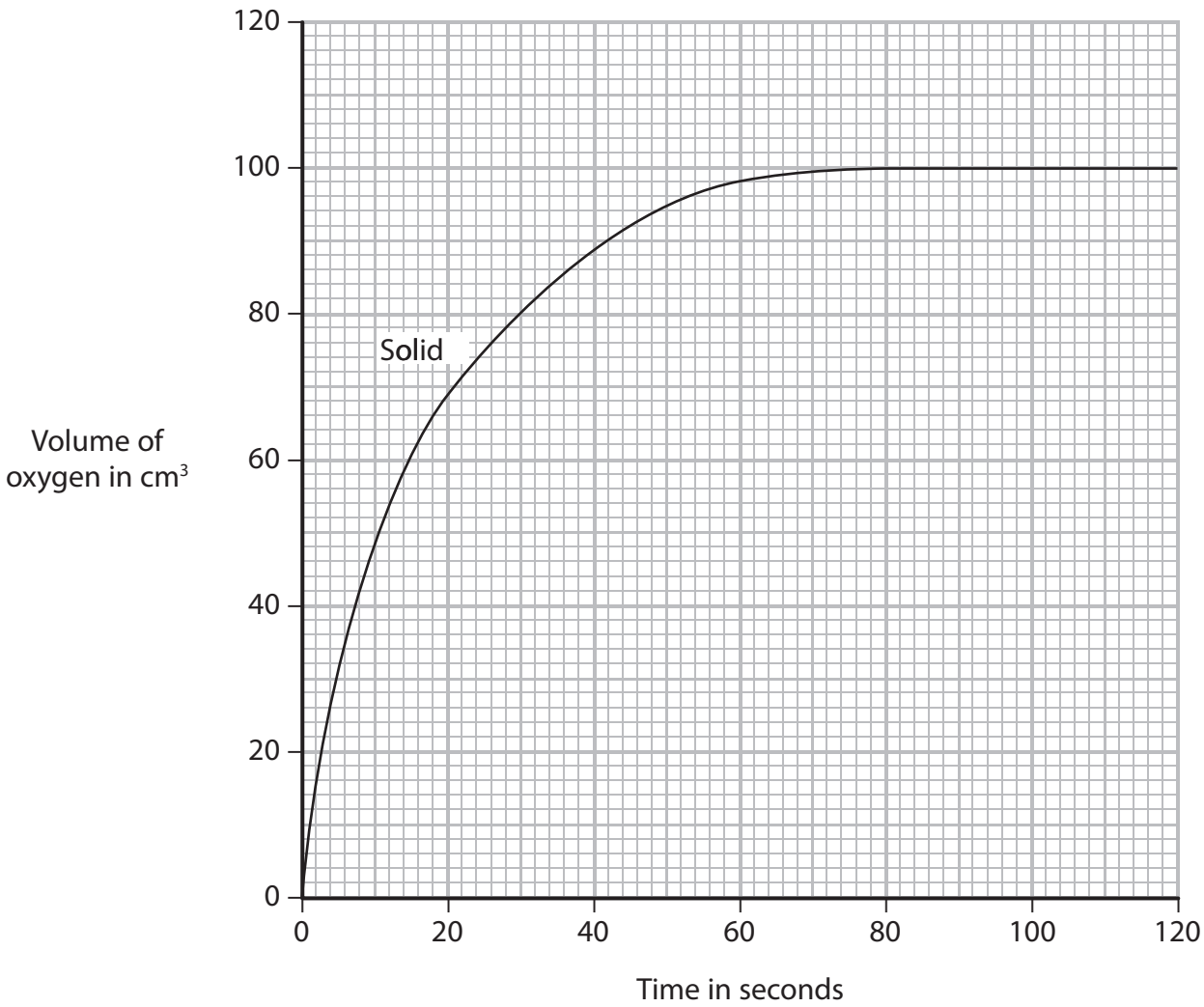
Time in seconds	Volume of oxygen collected in cm^3	
	solid F	solid G
0	0	0
20	69	36
40	89	58
60	98	74
80	100	86
100	100	96
120	100	100

(i) The grid shows the results plotted for solid F.

On the grid, plot the results for solid G.

Draw a curve of best fit.

(3)



(ii) Use your graph to estimate the volume of oxygen collected after 70 seconds for solid G.

Show on your graph how you obtained your answer.

(2)

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(iii) How do the curves on the graph show that the reaction is faster with solid F than with solid G?

(1)

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.....

(Total for Question 3 = 12 marks)

4 Hydrogen peroxide solution decomposes very slowly at room temperature.

The equation for this reaction is

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Very few bubbles can be seen in the solution because of the slow decomposition.

The rate of this reaction is greatly increased by adding a catalyst.

(a) A student added a solid to some hydrogen peroxide solution to see if the solid acted as a catalyst.

He noticed that a lot of bubbles formed, and that the solid was still present at the end of the reaction.

Outline a method to show that the solid acted as a catalyst and not as a reactant.

(2)

(b) The student investigated the effect that changing the concentration of the hydrogen peroxide solution has on the rate of the reaction.

He used solid manganese(IV) oxide as the catalyst in each experiment.

This is the method he used.

- pour some hydrogen peroxide solution into a conical flask on a top-pan balance
- add the catalyst and place some cotton wool loosely in the neck of the flask
- record the balance reading and start a timer
- record the balance reading every minute until the mass no longer changes
- repeat the experiment several times using different concentrations of hydrogen peroxide solution

(i) State one property of each substance that the student should keep the same in each experiment.

(2)

hydrogen peroxide solution .....

.....

manganese(IV) oxide .....

.....

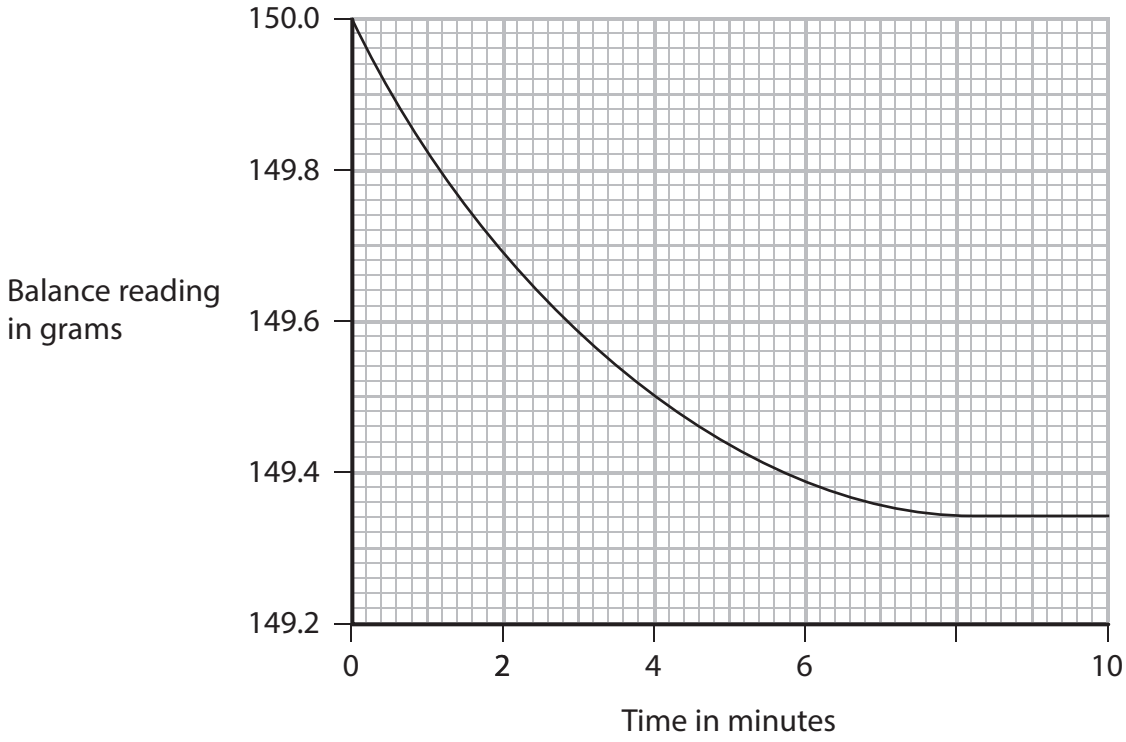
(ii) What is the purpose of the cotton wool?

(1)

.....

.....

(c) The graph shows the results of one of the student's experiments.



(i) Why does the balance reading decrease during the experiment?

(1)

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(ii) What does the slope of the curve indicate about the reaction?

(1)

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(iii) How long does the reaction take to complete?

(1)

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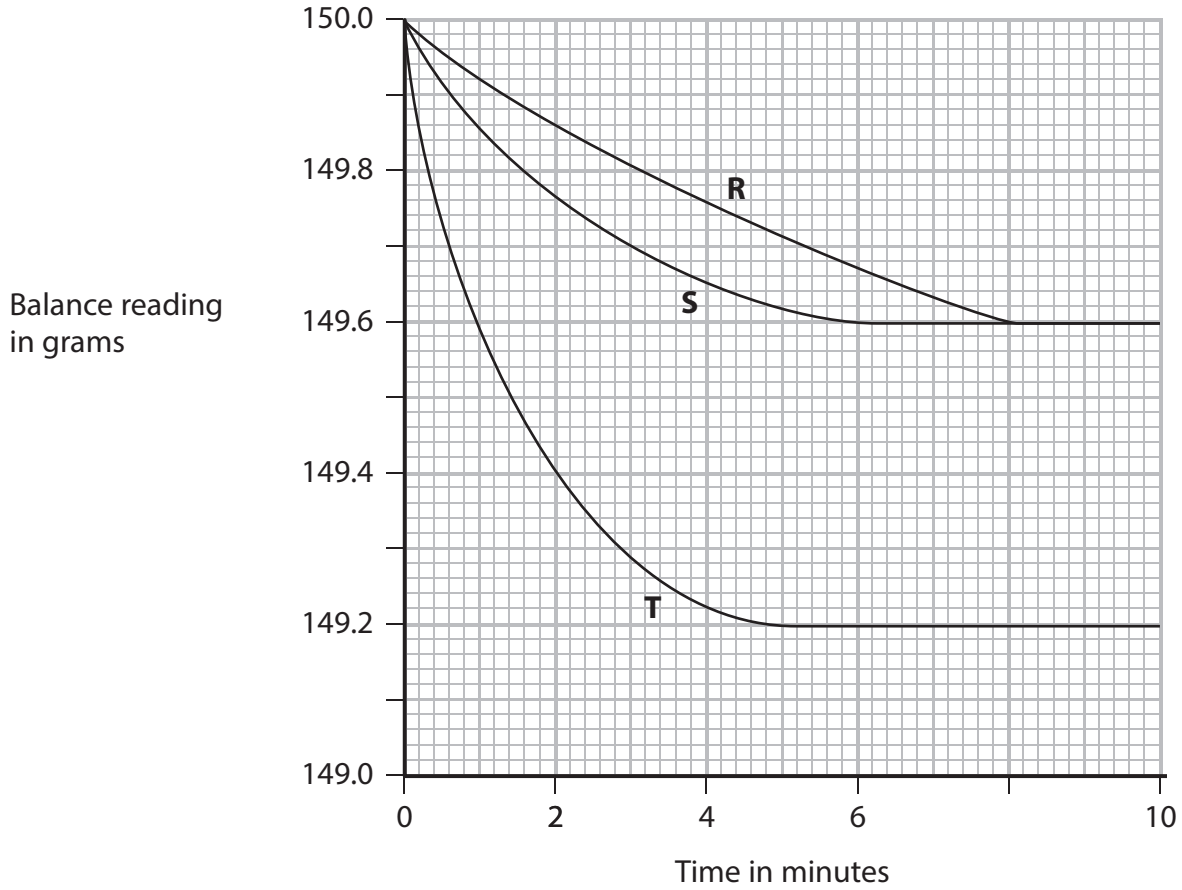
(d) The results of some of the student's other experiments are shown on this graph.



(i) Which one of the experiments, R, S or T, was the fastest?

(1)

.....

(ii) The concentration of the hydrogen peroxide solution in experiment S was 0.40 mol/dm^3.

Use the graph to deduce the concentration of the hydrogen peroxide solution in experiment T.

State how you deduced your answer.

(2)

concentration = ... mol/dm^3

.....

.....

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.....

(e) Another student repeated the investigation.

She recorded the time for the total mass of the beaker and contents to decrease by 0.50 g in each experiment. She then converted the times to relative rates of reaction.

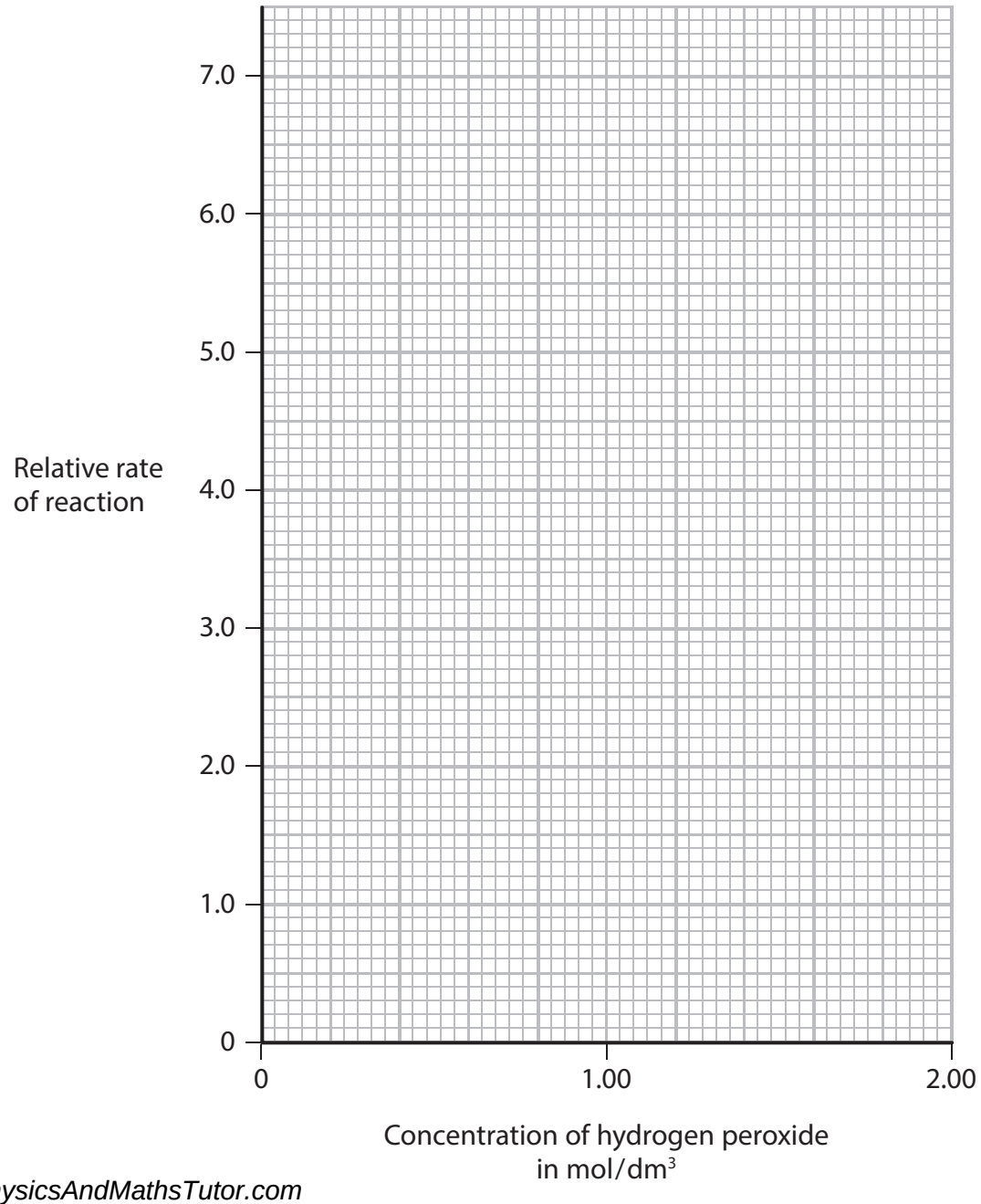
The table shows the concentrations she used and the relative rates of reaction she calculated.

Relative rate of reaction	1.5	2.2	3.0	4.4	5.1	6.0	7.4
Concentration in mol/dm^3	0.40	0.60	0.80	1.20	1.40	1.60	2.00

Plot a graph of these results on the grid.

Draw a straight line of best fit through the points.

(3)



(f) Explain, in terms of particles, why the rate of a reaction increases as the concentration of a reactant increases.

(2)

(Total for Question 4 = 16 marks)