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**Chemistry**  
**Standard level**  
**Paper 2**

Friday 14 May 2021 (morning)

Candidate session number

1 hour 15 minutes

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**Instructions to candidates**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.



Answer **all** questions. Answers must be written within the answer boxes provided.

1. Iron may be extracted from iron(II) sulfide, FeS.

(a) Outline why metals, like iron, can conduct electricity. [1]

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(b) Justify why sulfur is classified as a non-metal by giving **two** of its chemical properties. [2]

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(c) Iron(II) sulfide, FeS, is ionically bonded.

(i) Describe the bonding in this type of solid. [2]

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(ii) State the full electron configuration of the sulfide ion. [1]

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(This question continues on the following page)



**(Question 1 continued)**

- (iii) Outline, in terms of their electronic structures, why the ionic radius of the sulfide ion is greater than that of the oxide ion. [1]

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- (iv) Suggest why chemists find it convenient to classify bonding into ionic, covalent and metallic. [1]

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- (d) The first step in the extraction of iron from iron (II) sulfide is to roast it in air to form iron (III) oxide and sulfur dioxide.

- (i) Write the equation for this reaction. [1]

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- (ii) Deduce the change in the oxidation state of sulfur. [1]

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- (iii) Suggest why this process might raise environmental concerns. [1]

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**(This question continues on the following page)**



**(Question 1 continued)**

(e) Explain why the addition of small amounts of carbon to iron makes the metal harder. [2]

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2. Iron(II) sulfide reacts with hydrochloric acid to form hydrogen sulfide, H<sub>2</sub>S.

(a) (i) Draw the Lewis (electron dot) structure of hydrogen sulfide. [1]

(ii) Predict the shape of the hydrogen sulfide molecule. [1]

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(b) In aqueous solution, hydrogen sulfide acts as an acid.

(i) State the formula of its conjugate base. [1]

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(ii) Saturated aqueous hydrogen sulfide has a concentration of 0.10 mol dm<sup>-3</sup> and a pH of 4.0. Demonstrate whether it is a strong or weak acid. [1]

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(iii) Calculate the hydroxide ion concentration in saturated aqueous hydrogen sulfide. [1]

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**(Question 2 continued)**

- (c) A gaseous sample of nitrogen, contaminated only with hydrogen sulfide, was reacted with excess sodium hydroxide solution at constant temperature. The volume of the gas changed from  $550 \text{ cm}^3$  to  $525 \text{ cm}^3$ .

Determine the mole percentage of hydrogen sulfide in the sample, stating one assumption you made.

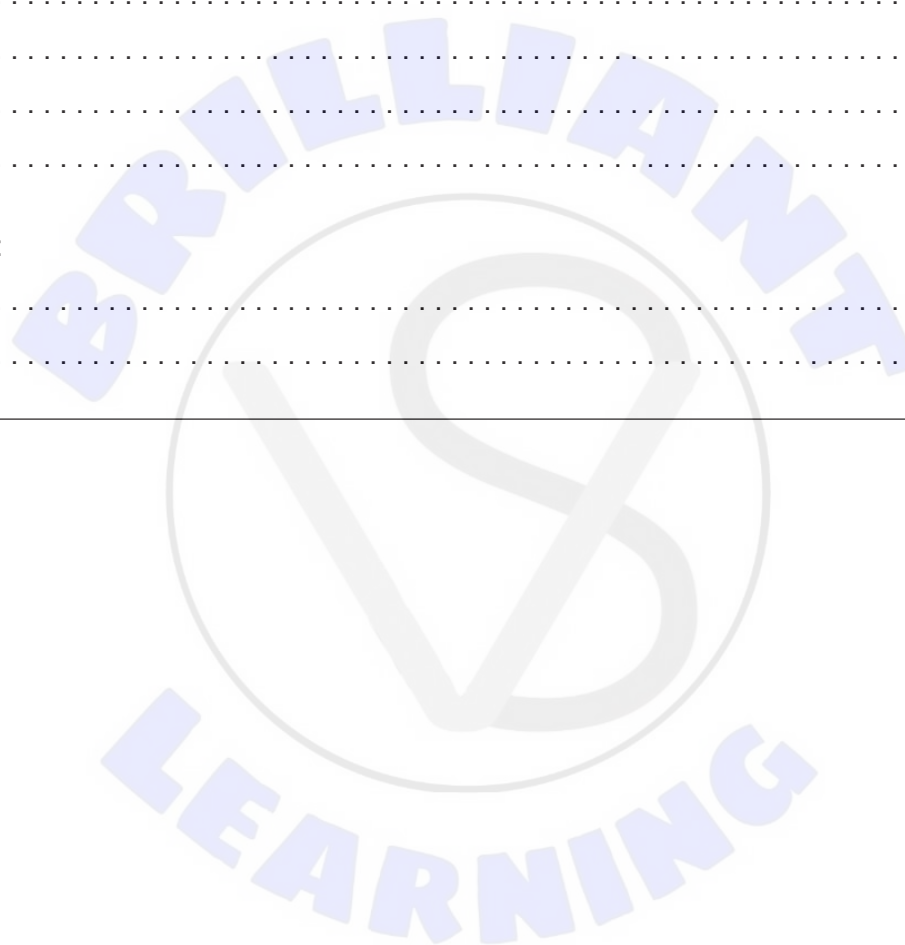
[3]

Mole percentage  $\text{H}_2\text{S}$ :

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Assumption:

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3. Magnetite, Fe<sub>3</sub>O<sub>4</sub>, is another ore of iron that contains both Fe<sup>2+</sup> and Fe<sup>3+</sup>.

(a) Deduce the ratio of Fe<sup>2+</sup>:Fe<sup>3+</sup> in Fe<sub>3</sub>O<sub>4</sub>. [1]

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(b) Iron exists as several isotopes.

(i) State the type of spectroscopy that could be used to determine their relative abundances. [1]

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(ii) State the number of protons, neutrons and electrons in each species. [2]

	Protons	Neutrons	Electrons
<sup>54</sup> <sub>26</sub> Fe	.....	.....	.....
<sup>56</sup> <sub>26</sub> Fe <sup>3+</sup>	.....	.....	.....

(c) Iron has a relatively small specific heat capacity; the temperature of a 50 g sample rises by 44.4°C when it absorbs 1 kJ of heat energy.

Determine the specific heat capacity of iron, in J g<sup>-1</sup>K<sup>-1</sup>. Use section 1 of the data booklet. [1]

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**(Question 3 continued)**

(d) In acidic solution, hydrogen peroxide,  $\text{H}_2\text{O}_2$ , will oxidize  $\text{Fe}^{2+}$ .



(i) Write the half-equation for the reduction of hydrogen peroxide to water in acidic solution.

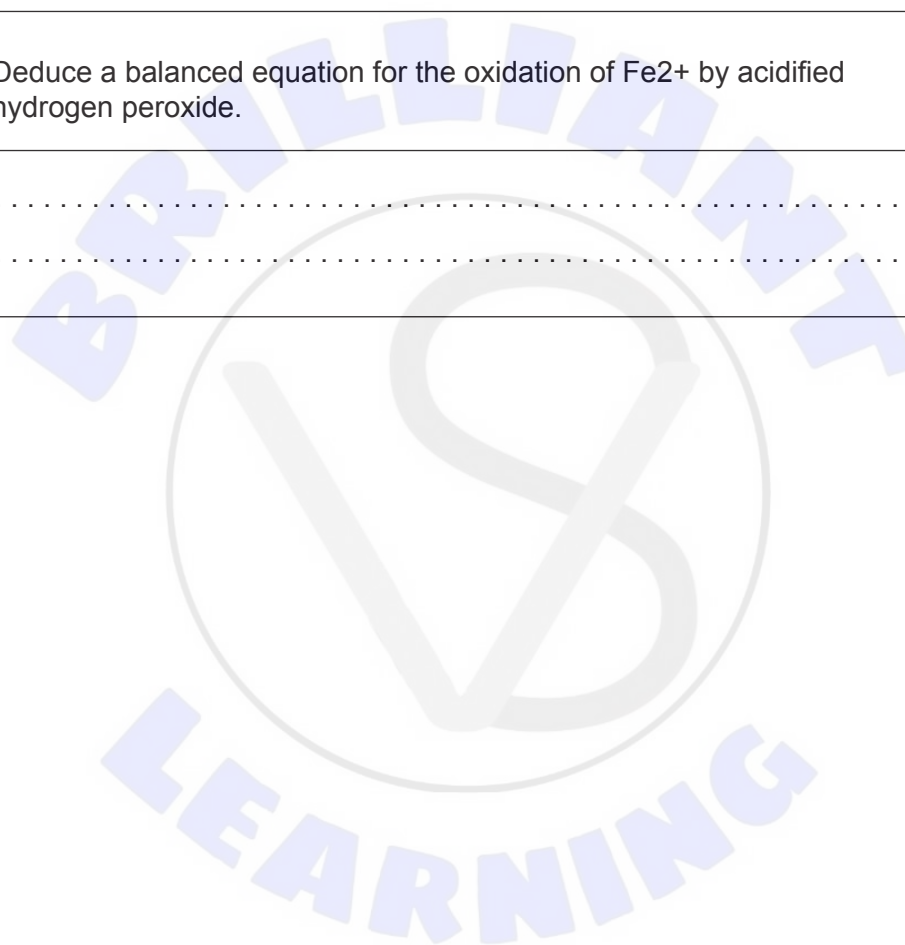
[1]

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(ii) Deduce a balanced equation for the oxidation of  $\text{Fe}^{2+}$  by acidified hydrogen peroxide.

[1]

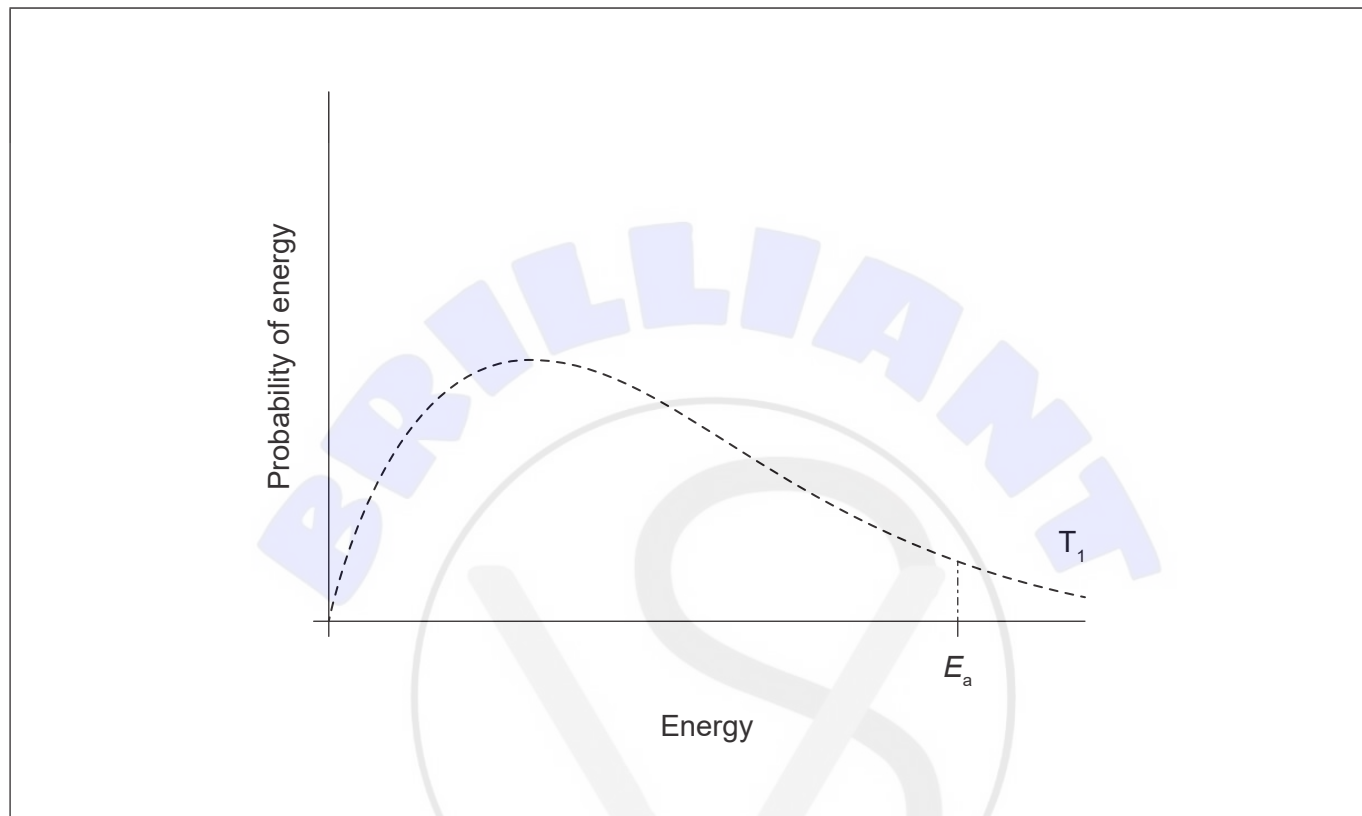
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4. Hydrogen peroxide can react with methane and oxygen to form methanol. This reaction can occur below 50°C if a gold nanoparticle catalyst is used.

(a) The diagram shows the Maxwell-Boltzmann curve for the uncatalyzed reaction.

Draw a distribution curve at a lower temperature ( $T_2$ ) **and** show on the diagram how the addition of a catalyst enables the reaction to take place more rapidly than at  $T_1$ . [2]



(b) The hydrogen peroxide could cause further oxidation of the methanol. Suggest a possible oxidation product. [1]

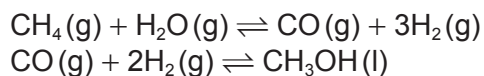
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**(Question 4 continued)**

(c) Methanol is usually manufactured from methane in a two-stage process.



(i) Determine the overall equation for the production of methanol. [1]

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(ii) 8.00 g of methane is completely converted to methanol. Calculate, to three significant figures, the final volume of hydrogen at STP, in dm<sup>3</sup>. Use sections 2 and 6 of the data booklet. [3]

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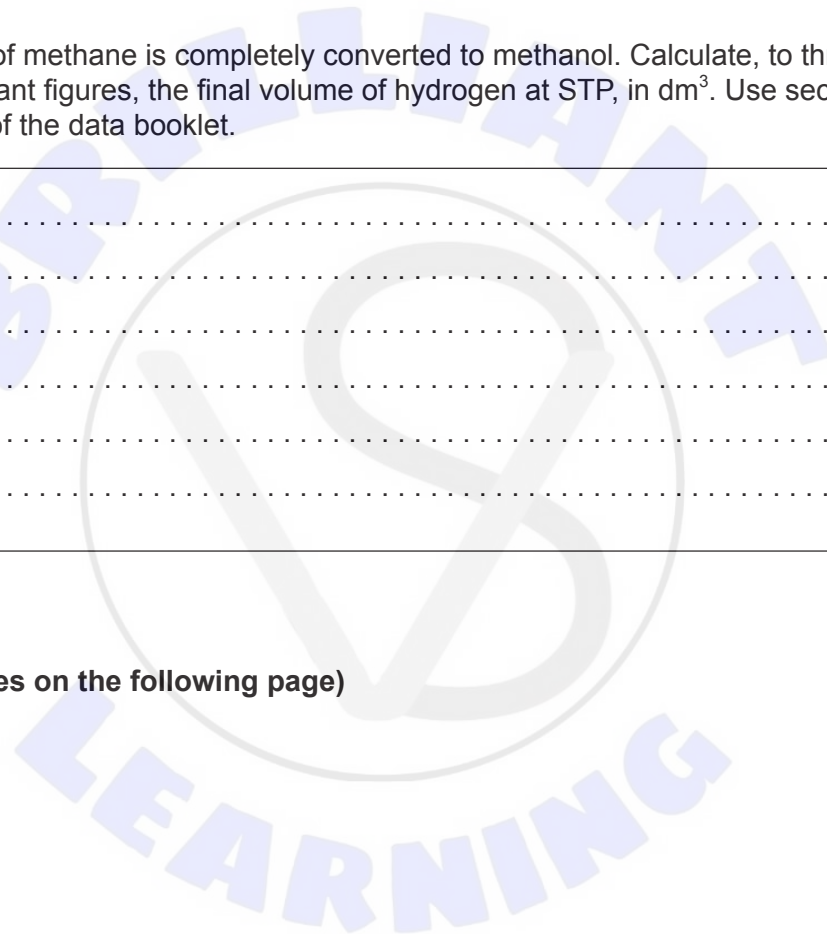
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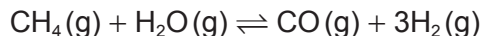
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**(Question 4 continued)**

(d) Consider the first stage of the reaction.



(i) Determine the enthalpy change,  $\Delta H$ , in kJ. Use section 11 of the data booklet.

Bond enthalpy of CO = 1077 kJ mol<sup>-1</sup>. [3]

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(ii) State the expression for  $K_c$  for this stage of the reaction. [1]

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(iii) State and explain the effect of increasing temperature on the value of  $K_c$ . [1]

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will not be marked.



5. Ethanol is obtained by the hydration of ethene,  $C_2H_4$ .

(a) (i) State the class of compound to which ethene belongs. [1]

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(ii) State the molecular formula of the next member of the homologous series to which ethene belongs. [1]

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(b) Justify why ethene has only a single signal in its  $^1H$  NMR spectrum. [1]

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(c) Suggest **two** possible products of the incomplete combustion of ethene that would not be formed by complete combustion. [1]

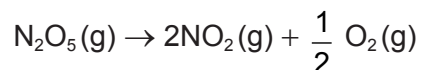
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(d) A white solid was formed when ethene was subjected to high pressure.  
Deduce the type of reaction that occurred. [1]

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6. When dinitrogen pentoxide,  $N_2O_5$ , is heated the colourless gas undergoes thermal decomposition to produce brown nitrogen dioxide:



- (a) Suggest how the extent of decomposition could be measured.

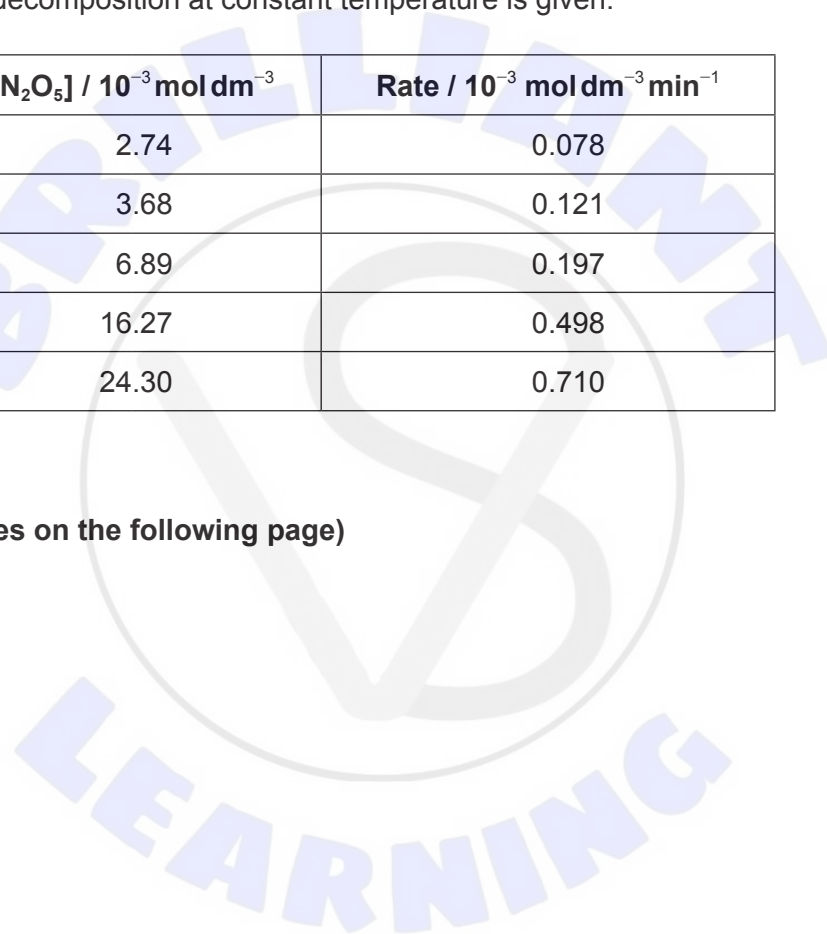
[1]

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- (b) Data for the decomposition at constant temperature is given.

$[N_2O_5] / 10^{-3} \text{ mol dm}^{-3}$	Rate / $10^{-3} \text{ mol dm}^{-3} \text{ min}^{-1}$
2.74	0.078
3.68	0.121
6.89	0.197
16.27	0.498
24.30	0.710

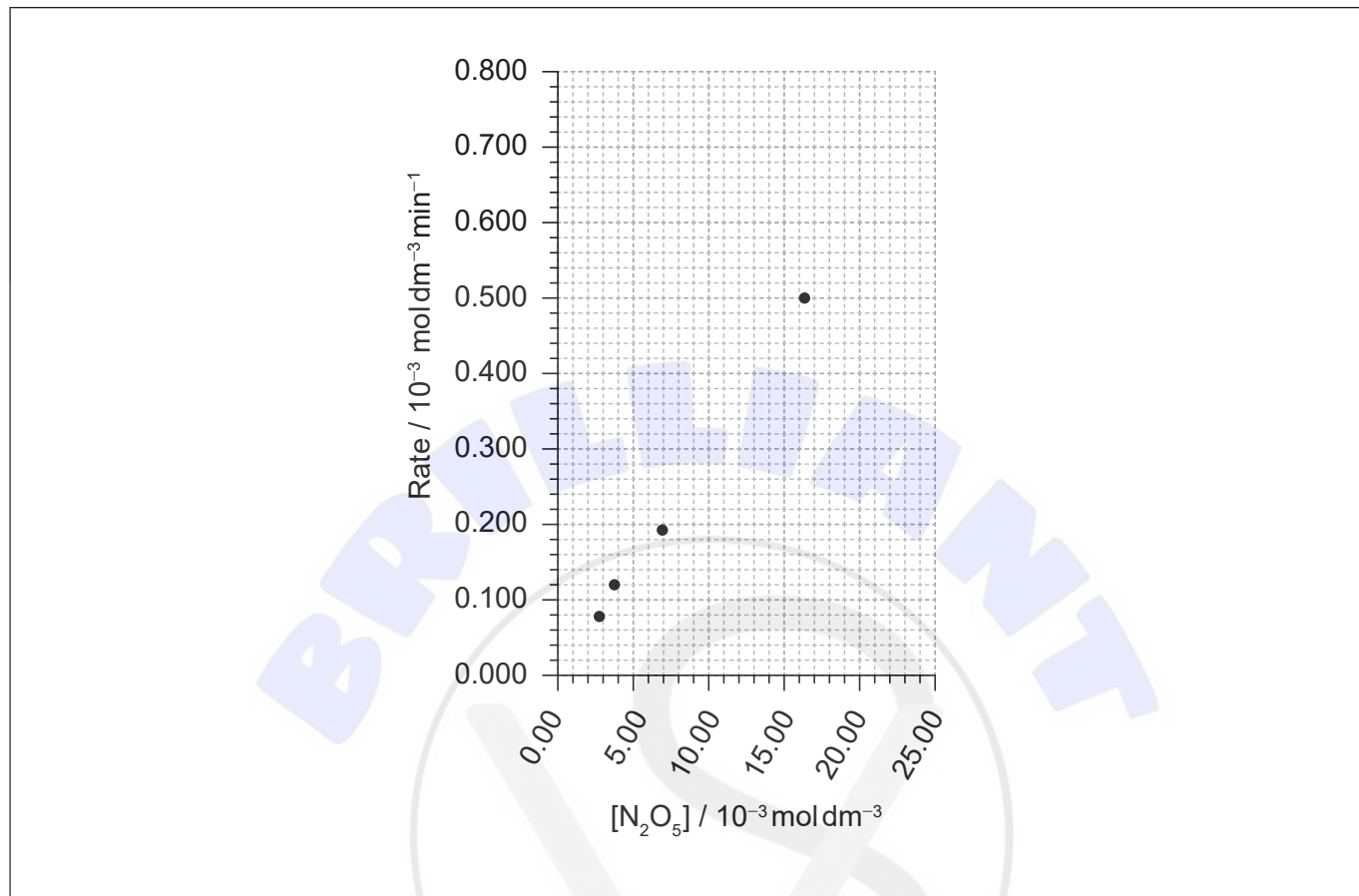
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(Question 6 continued)

(i) Plot the missing point on the graph and draw the best-fit line.

[2]



(ii) Deduce the relationship between the concentration of N<sub>2</sub>O<sub>5</sub> and the rate of reaction.

[1]

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(iii) Outline why increasing the concentration of N<sub>2</sub>O<sub>5</sub> increases the rate of reaction.

[1]

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References:

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