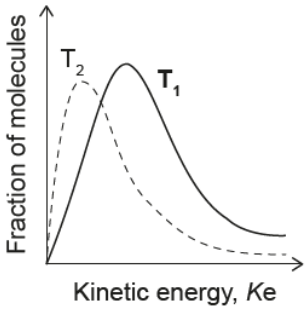
How fast [41 marks]

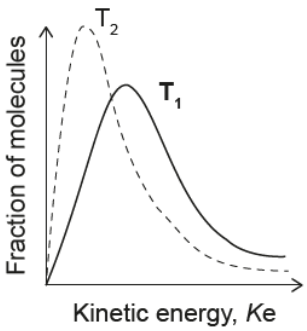
1. [Maximum mark: 1]

Which of the diagrams represents the Maxwell–Boltzmann distribution of kinetic energy of molecules of the same sample of a gas at two temperatures, T1 and T2, when T1>T2?

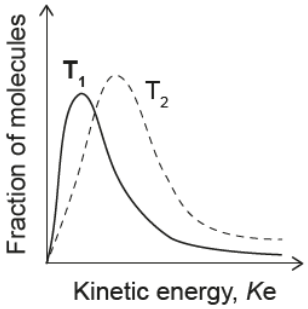
A.



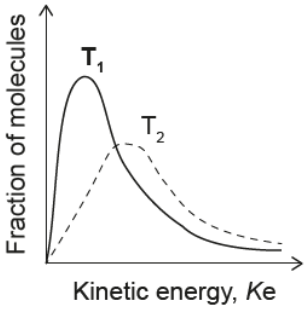
B.



C.



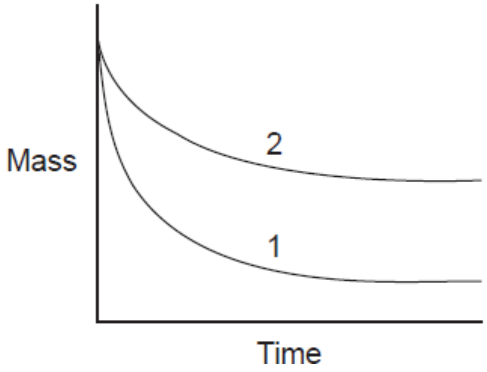
D.



[1]

2. [Maximum mark: 1]

Excess magnesium powder was added to a beaker of hydrochloric acid, HCl (aq). The mass of the beaker and its contents was recorded and plotted against time to give line 1.



Which change could give line 2?

A. Using the same volume of more dilute HCl (aq) [1]

B. Using the same mass of Mg ribbon

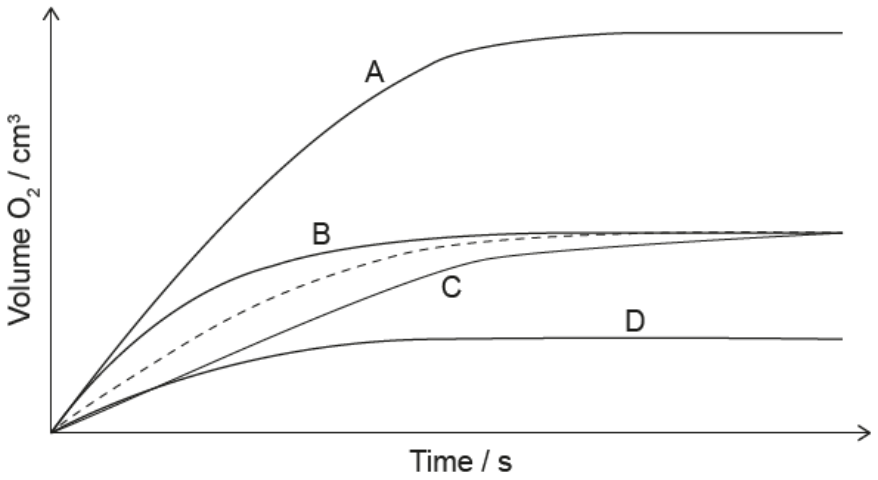
C. Increasing the temperature

D. Doubling the mass of powdered Mg

3. [Maximum mark: 1]

The non-catalysed decomposition of H_2O_2 was monitored giving the dotted line in the following graph.

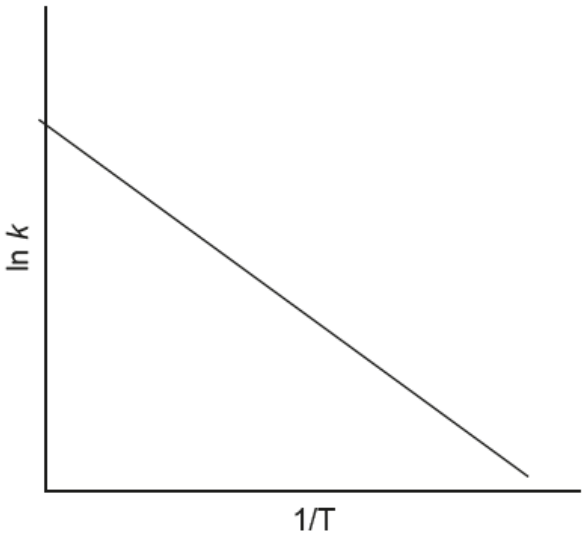
Which curve represents the catalysed reaction if performed at the same temperature and using the
same concentration of reactants?



[1]

4. [Maximum mark: 1]

The rate constants of a reaction at different temperatures were plotted giving the following graph.



What does the slope of the line represent?

$$\ln k = \frac{-E_a}{RT} + \ln A$$

A. $-E_a/R$

B. $-E_a$

C. $\ln A$

D. $-E_a/RT$

[1]

5. [Maximum mark: 22]

Sulfur trioxide is an important compound in industry.

(a) Sulfur trioxide has more than one possible Lewis (electron dot) structure.

(a.i) Sketch **two** Lewis (electron dot) structures for SO_3, one of which obeys the octet rule and one of which does not.

Obeys octet rule:

Does not obey octet rule:

[2]

(a.ii) State how chemists decide which Lewis (electron dot) structure is more stable. [1]

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(a.iii) Predict the length of each S to O bond in pm. Use section 10 of the data booklet.

[1]

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(b) Suggest why atmospheric $SO_3(g)$ is an environmental concern. [1]

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(c) State the name of a post-combustion method used to lower the quantity of $SO_3(g)$ released to the atmosphere. [1]

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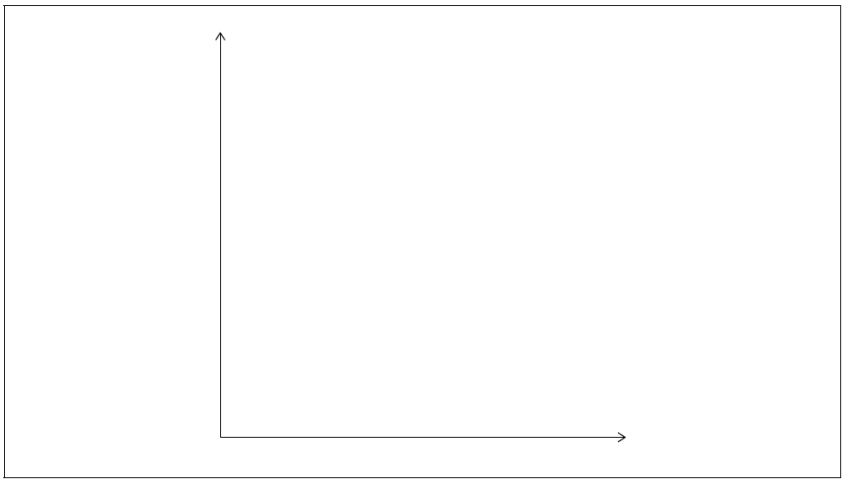
(d) $SO_3(g)$ is made using the contact process.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H^{\ominus} < 0$

(d.i) Sketch a potential energy profile for this reaction on the axes provided. Label E_a and include labels on the axes.



[3]

(d.ii) Explain why increasing the temperature increases the rate of reaction. [2]

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(d.iii) Vanadium pentoxide, V_2O_5, is used as a catalyst. Explain how a catalyst increases the rate of a reaction. [2]

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(d.iv) During the reaction, V_2O_5 changes to V_2O_4. Identify the oxidation states of vanadium in each compound.

V_2O_5: .....
V_2O_4: ..... [1]

(d.v) State the equilibrium constant expression, K_c, for the production of 1 mol of SO_3.

$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$ [1]

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(d.vi) Calculate the entropy change, $\Delta S^{\ominus}$, in J K^{-1} mol^{-1}, for the production of 1 mol of $SO_3(g)$. Use the absolute entropy values given in the table.

	$S^{\ominus}$ /J K^{-1} mol^{-1}
$SO_2(g)$	248.2
$O_2(g)$	205.2
$SO_3(g)$	256.8

[1]

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(d.vii) Outline, with reference to the equation, why the sign for the entropy change obtained in part (vi) is expected. [1]

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(d.viii) Calculate the value of Gibbs free energy, $\Delta G^{\ominus}$, of the reaction, in kJ mol^{-1}, at 773 K. Use section 1 of the data booklet and $\Delta H^{\ominus} = -98.5$ kJ mol^{-1}. If you did not obtain an answer for (d)(vi), use -100 J K^{-1} mol^{-1}, although this is not the correct answer. [1]

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(d.ix) Calculate the value of the equilibrium constant for the formation of $SO_3(g)$ at 773 K. Use sections 1 and 2 of the data booklet. If you did not obtain an answer to (d)(viii), use -25.0 kJ mol^{-1}, although this is not the correct answer. [2]

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(d.x) A flask contains 0.120 mol dm^{-3} SO_2 (g), 0.050 mol dm^{-3} O_2 (g) and 0.150 mol dm^{-3} SO_3 (g) at 773 K. Deduce whether the system is at equilibrium and in which direction the reaction will proceed spontaneously if not at equilibrium. [2]

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6. [Maximum mark: 1]
Which change would decrease the rate of reaction between magnesium ribbon and hydrochloric acid?

A. increasing the length of the magnesium ribbon

B. increasing the temperature of the acid

C. cutting the magnesium ribbon into smaller pieces

D. adding water to the hydrochloric acid

[1]

7. [Maximum mark: 1]

Which best explains the low rate of a reaction between two gases occurring at high temperature and high pressure?

A. The frequency of collisions is low.

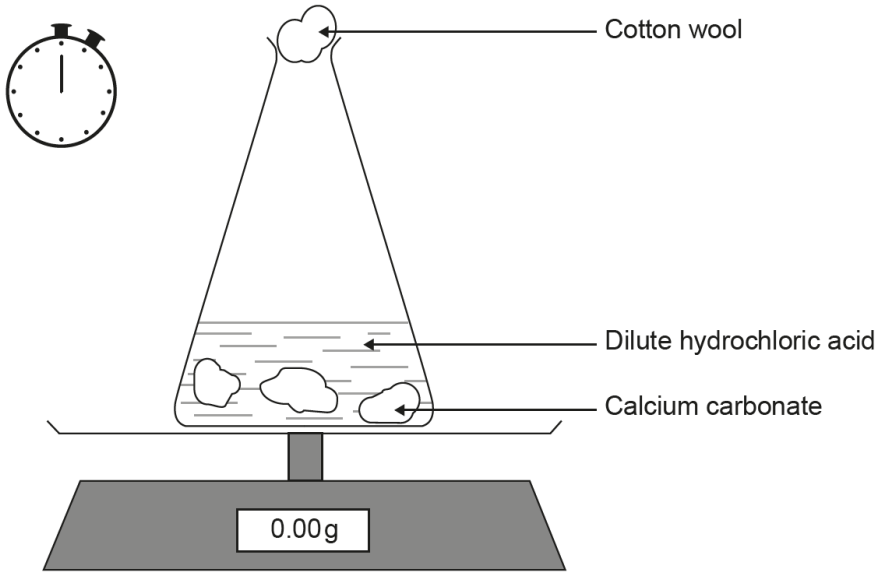
B. The bonds in the reactants are strong.

C. A high fraction of reactant molecules collides with the correct orientation.

D. The activation energy of the reaction is low. [1]

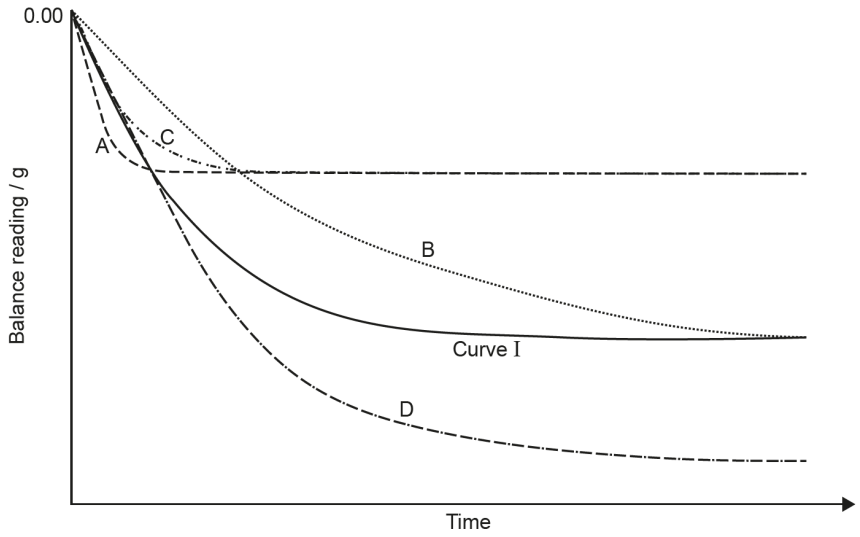
8. [Maximum mark: 1]

The mass of a flask containing excess calcium carbonate, $CaCO_3$ (s), reacting with 100 cm^3 of 0.50 mol dm^{-3} hydrochloric acid, HCl (aq), was monitored with time at 25 °C.



Curve I was obtained under these conditions.

Which curve corresponds to the experiment when it was repeated at the same temperature using the same mass of same sized pieces of calcium carbonate and 50 cm^3 of 0.50 mol dm^{-3} hydrochloric acid?



[1]

9. [Maximum mark: 1]

The reaction between NO_2 and CO gives the following rate data at a certain temperature.

$[NO_2]$ / mol dm^{-3}	[CO] / mol dm^{-3}	Rate / mol dm^{-3} sec^{-1}
0.25	0.80	1.4×10^{-5}
0.25	0.40	1.4×10^{-5}
0.50	0.40	5.6×10^{-5}

What is the overall order of reaction?

A. 0

B. 1

C. 2

D. 3 [1]

10. [Maximum mark: 1]

Which statement is correct for the components of the Arrhenius equation?

$$k = Ae^{\frac{-Ea}{RT}}$$

A. E_a decreases as temperature increases.

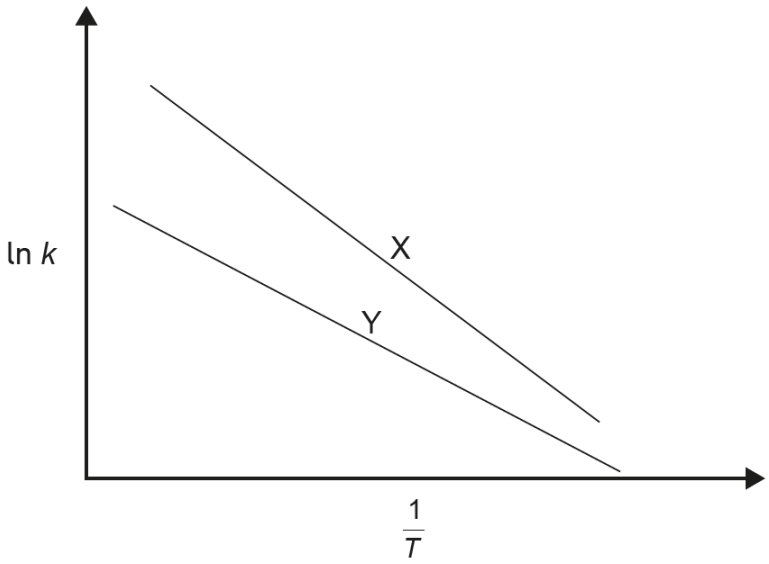
B. A relates to collisions with correct orientation.

C. k increases as E_a increases.

D. k is independent of the temperature of the reaction. [1]

11. [Maximum mark: 1]

The graphs below show a plot of ln k against $\frac{1}{T}$ for reactions X and Y.



Considering the Arrhenius equation

$$\ln k = \ln A - \frac{E_a}{RT}$$

which combination is correct for reactions X and Y?

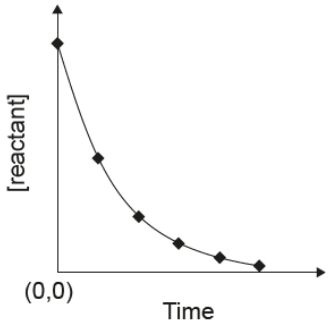
	Value of E_a	Value of A
A.	X > Y	X > Y
B.	X > Y	Y > X
C.	Y > X	X > Y
D.	Y > X	Y > X

[1]

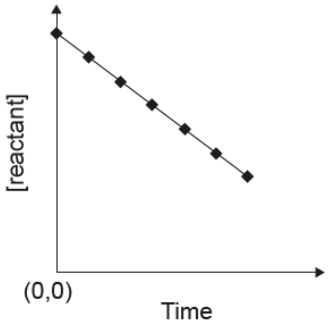
12. [Maximum mark: 1]

Which graph is correct for a first order reaction?

A.

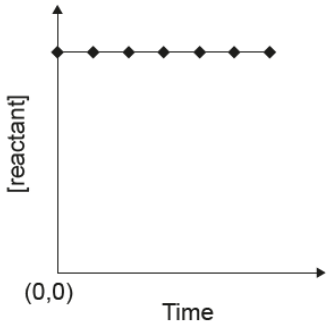


B.

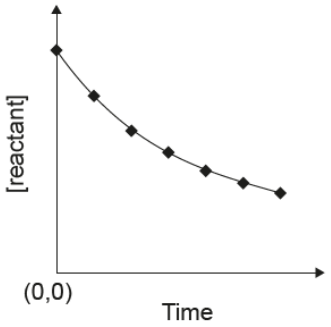


[1]

C.



D.



13. [Maximum mark: 8]

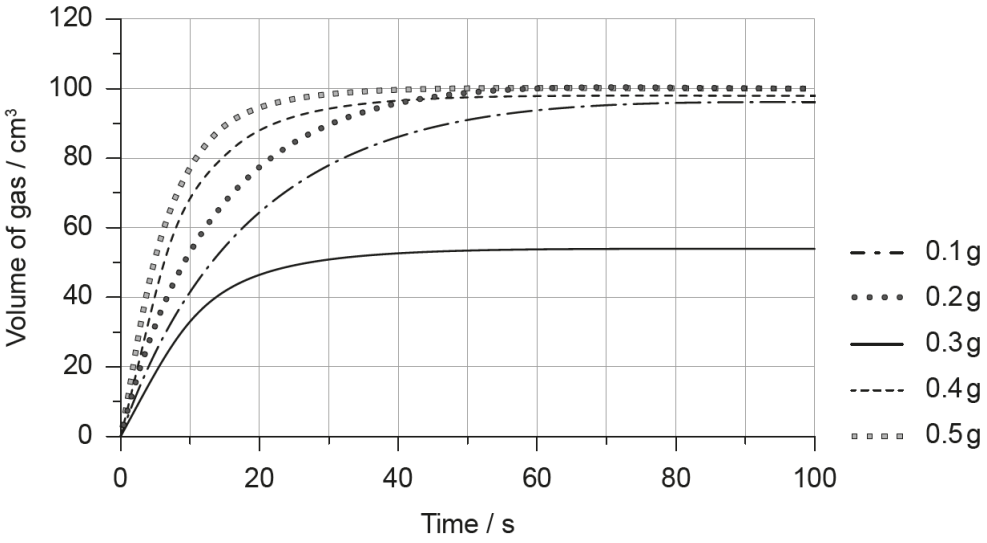
Hydrogen peroxide decomposes to form water and oxygen.

$2H_2O2\,(aq) \rightarrow 2H_2O\,(l) + O_2\,(g)$

The reaction is catalysed by solid manganese (IV) oxide, $MnO_2\,(s)$.

A student carried out a series of experiments to determine how the rate of decomposition depends on the mass of catalyst. Each time a different mass of MnO_2 was added to 25.0 cm^3 of hydrogen peroxide solution. The oxygen was collected in a graduated gas syringe and the volume recorded at regular intervals.

Figure 1



(a) The 0.3 g data seems to be anomalous. Suggest a possible cause for this. [1]

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(b) The student hypothesized, based on underlying theory, that doubling the mass of MnO_2 would double the rate of the catalysed reaction.

(b.i) Suggest why it is important to have hypotheses on the outcome of experiments. [1]

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(b.ii) Explain how the student's hypothesis might be supported by collision theory. [2]

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(b.iii) Identify the critical controlled variable that is not specified in the description of the method. [1]

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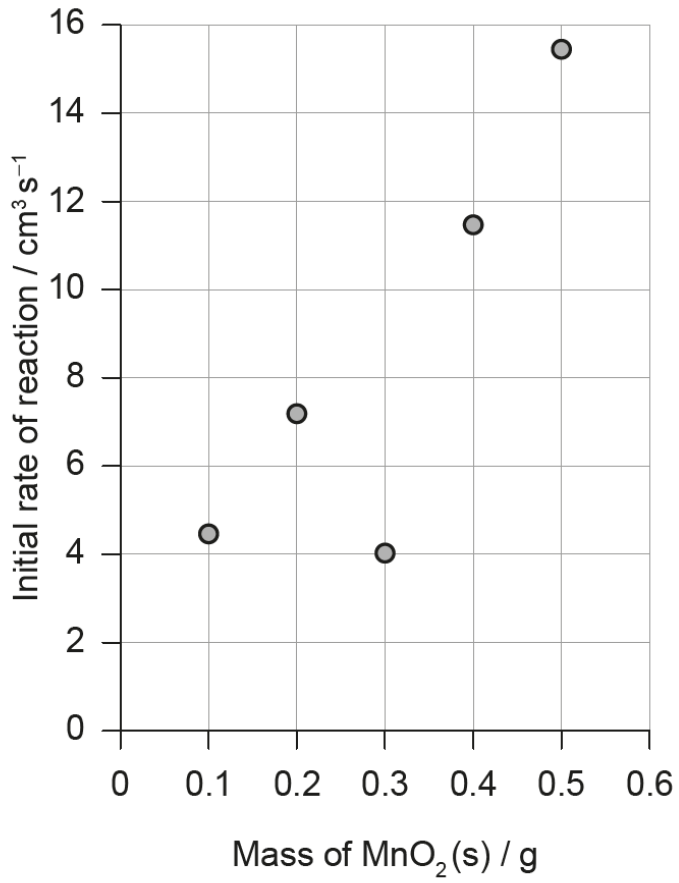
(c) The results from **Figure 1** were processed to produce a graph showing how the initial rate varied with the mass of catalyst.

Figure 2



(c.i) Outline how the y-axis values on **Figure 2** were obtained from the results in **Figure 1**. [2]

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(c.ii) Suggest, giving a reason, whether a best-fit line for **Figure 2** should pass through the origin. [1]