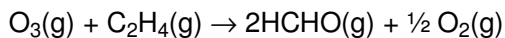


F325 Module 1: HW3

1. One cause of low-level smog is the reaction of ozone, O₃, with ethene, C₂H₄. The smog contains methanal, HCHO(g).

The equation for methanal production is shown below.



The rate of the reaction was investigated, using a series of different concentrations of either C₂H₄(g) or O₃(g), by measuring the initial rate of formation of HCHO(g).

The results are shown below.

experiment	[O ₃ (g)] / 10 ⁻⁷ mol dm ⁻³	[C ₂ H ₄ (g)] / 10 ⁻⁸ mol dm ⁻³	initial rate / 10 ⁻¹² mol dm ⁻³ s ⁻¹
1	0.5	1.0	1.0
2	2.0	1.0	4.0
3	4.0	2.0	16.0

- (i) Analyse and interpret the results to deduce the order of reaction of each reactant and the rate equation.

Explain your reasoning.

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[5]

F325 Module 1: HW3

- (ii) Calculate the value of the rate constant and state the units.

rate constant =..... units.....

[3]

- (iii) Using the equation above, deduce the initial rate of **formation** of $O_2(g)$ in experiment 1.

Explain your reasoning.

answer = $\text{mol dm}^{-3} \text{s}^{-1}$

[1]

- (iv) The experiment was repeated at a higher temperature.

How would the new conditions affect the rate of the reaction and the value of the rate constant?

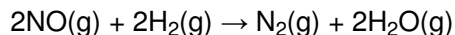
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[1]

[Total 10 marks]

F325 Module 1: HW3

2. Nitrogen monoxide reacts with hydrogen at 500 °C as in the equation below.



A series of experiments was carried out to investigate the kinetics of this reaction. The results are shown in the table below.

experiment	[NO] / mol dm ⁻³	[H ₂] / mol dm ⁻³	initial rate / mol dm ⁻³ s ⁻¹
1	0.10	0.20	2.6
2	0.10	0.50	6.5
3	0.30	0.50	58.5

In this question, one mark is available for the quality of spelling, punctuation and grammar.

(i) For each reactant, deduce the order of reaction. Show your reasoning.

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[4]

Quality of Written Communication [1]

(ii) Deduce the rate equation for this reaction.

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[1]

F325 Module 1: HW3

- (iii) Calculate the rate constant, k , for this reaction. State the units for k .

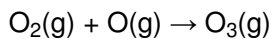
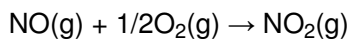
$k = \dots\dots\dots$ units $\dots\dots\dots$

[3]

[Total 9 marks]

3. Nitrogen monoxide, NO, is involved in formation of ozone at low levels and the breakdown of ozone at high levels.

- (i) In the lower atmosphere, NO is produced by combustion in car engines. Ozone is then formed following the series of reactions shown below.



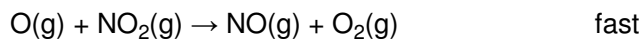
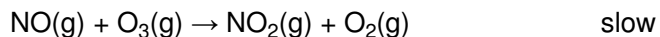
Write the overall equation for this reaction sequence.

Identify the catalyst and justify your answer.

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[3]

(ii) In the upper atmosphere, NO removes O₃ by the following reaction mechanism.



Suggest the rate equation for this process. Explain your reasoning.

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[2]

[Total 5 marks]

4. In this question, one mark is available for the quality of use and organisation of scientific terms.

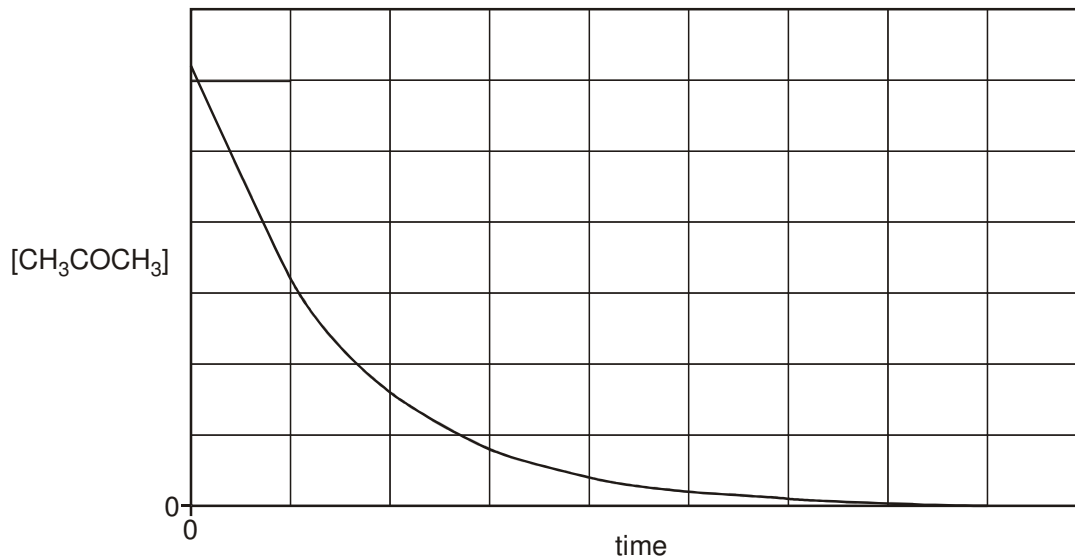
Propanone reacts with iodine in the presence of dilute hydrochloric acid.

A student carried out an investigation into the kinetics of this reaction.

He measured how the concentration of propanone changes with time. He also investigated how different concentrations of iodine and hydrochloric acid affect the initial rate of the reaction.

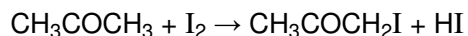
F325 Module 1: HW3

The graph and results are shown below.



$[\text{CH}_3\text{COCH}_3]$ / mol dm^{-3}	$[\text{I}_2]$ / mol dm^{-3}	$[\text{H}^+]$ / mol dm^{-3}	initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$
1.5×10^{-3}	0.0300	0.0200	2.1×10^{-9}
1.5×10^{-3}	0.0300	0.0400	4.2×10^{-9}
1.5×10^{-3}	0.0600	0.0400	4.2×10^{-9}

The overall equation for the reaction is given below.



This is a multi-step reaction.

- What conclusions can be drawn about the kinetics of this reaction from the student's investigation? Justify your reasoning.
- Calculate the rate constant for this reaction, including units.
- Suggest the equations for a possible two-step mechanism for this reaction. Label the rate-determining step and explain your reasoning.

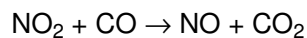
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Quality of Written Communication [1]

[Total 14 marks]

F325 Module 1: HW3

5. Nitrogen dioxide reacts with carbon monoxide emitted from car exhausts in the following reaction.



The rate equation for this reaction is $rate = k[\text{NO}_2]^2$.

This is a multi-step reaction. The first step is the rate-determining step.

- (i) What is meant by the *rate-determining step*?

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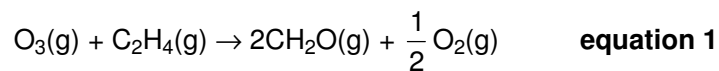
[1]

- (ii) Suggest a two-step reaction mechanism for this reaction that is consistent with the kinetic data and the overall reaction.

[2]

[Total 3 marks]

6. One cause of low-level smog is the reaction of ozone, O_3 , with ethene. The smog contains methanal, $\text{CH}_2\text{O}(\text{g})$, and the equation for its production is shown below.



F325 Module 1: HW3

(a) The rate of the reaction doubles when the initial concentration of either $O_3(g)$ or $C_2H_4(g)$ is doubled.

(i) What is the order of reaction with respect to

O_3

C_2H_4 ?

[1]

(ii) What is the overall order of the reaction?

.....

[1]

(iii) Write the rate equation for this reaction.

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[1]

(b) For an initial concentration of ozone of $0.50 \times 10^{-7} \text{ mol dm}^{-3}$ and one of ethene of $1.0 \times 10^{-8} \text{ mol dm}^{-3}$, the initial rate of methanal formation was $1.0 \times 10^{-12} \text{ mol dm}^{-3} \text{ s}^{-1}$.

(i) How could the **initial** rate of methanal formation be measured from a concentration/time graph?

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[2]

- (ii) Calculate the value of the rate constant and state the units.

rate constant = units.....

[3]

- (iii) The initial rate of methanal formation is different from that of oxygen formation in **equation 1**.

Explain why.

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[1]

- (iv) The experiment was repeated but at a higher temperature. What would be the effect of this change on the rate and the rate constant of the reaction?

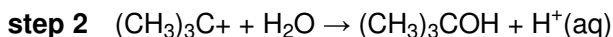
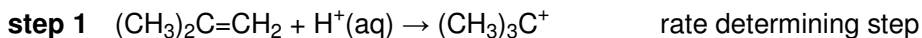
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[2]

[Total 11 marks]

7. A student investigated the hydration of 2-methylpropene, $(\text{CH}_3)_2\text{C}=\text{CH}_2$, with dilute aqueous acid to form 2-methylpropan-2-ol, $(\text{CH}_3)_3\text{COH}$.

The following mechanism has been proposed for this hydration.



F325 Module 1: HW3

- (i) Step 1 is the rate-determining step for this hydration.

What is meant by the term *rate-determining step*?

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[1]

- (ii) Write a balanced equation for the overall hydration reaction.

.....

[1]

- (iii) Suggest the role of $H^+(aq)$ in this mechanism. Explain your reason.

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[2]

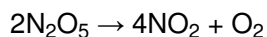
- (iv) Use the mechanism above to suggest the rate equation for this hydration.

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[1]

[Total 5 marks]

8. The decomposition of dinitrogen pentoxide, N_2O_5 , at 45 °C was investigated. The reaction that takes place is shown below.



In an experiment, N_2O_5 with a concentration of 0.60 mol dm^{-3} was decomposed at 45 °C.

At this temperature, the reaction has a constant half-life of 1200 s.

F325 Module 1: HW3

(i) How can you tell that this reaction is first order with respect to N_2O_5 ?

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[1]

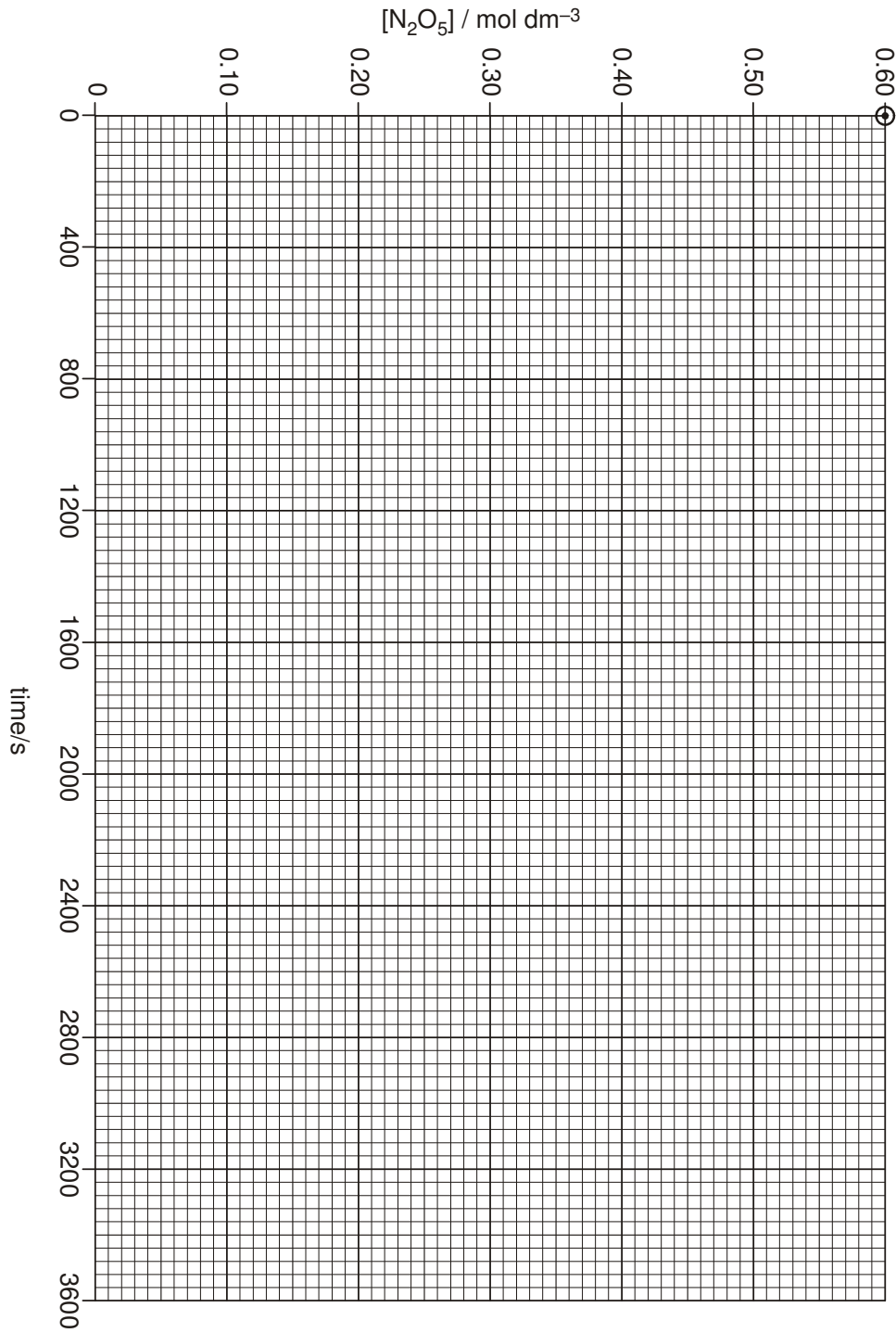
(ii) Write down an expression for the rate equation of this decomposition.

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[1]

F325 Module 1: HW3

- (iii) Complete the graph below to show how the $[N_2O_5]$ changes over the first 3600 s of the reaction.



[2]

F325 Module 1: HW3

(iv) The rate of this reaction can be determined from this graph.

Show on the graph how the rate can be measured after 1200 s.

[1]

(v) The rate can also be calculated from the rate equation. The rate constant for this reaction is $6.2 \times 10^{-4} \text{ s}^{-1}$.

Calculate the initial rate of this reaction. State the units.

rate =..... units.....

[2]

[Total 7 marks]