Name ..... Class: .....

Start Time ..... End Time ..... Time Taken .....

**Time allowed: minutes**

**INSTRUCTIONS TO CANDIDATES**

- This document is designed to be used as a practice test.
- Complete the test under exam conditions in one sitting.
- Optional: Before marking it, go through the paper with a set of notes and improve your answers.
- Mark the test using the mark scheme make corrections on the paper.
- Complete the table on the front page.
- Improve your notes so that they better reflect your weaknesses.
- Make a note of your strengths and weaknesses for future revision.

| **Success Criteria** | **Questions in Paper** | **Mark** | **Out of** | **%** | **Rank Order** |
|---|---|---|---|---|---|
| Interpreting the rate equation | 1a<br>1c | | 2<br>2 | | |
| Calculations using the rate equation | 1b<br>1d<br>2bi<br>3a | | 3<br>3<br>2<br>4 | | |
| Initial rates data | 2a<br>2bii | | 2<br>2 | | |
| Mechanisms | 3b | | 2 | | |
| Concentration time graphs | 4 | | 6 | | |
| Dilutions | 5a<br>5b | | 2<br>2 | | |
| Titration calculations | 5c | | 4 | | |
| Continuous monitoring | 5d<br>5e<br>5f | | 5<br>2<br>2 | | |
| **Total** | | | 45 | | |

**Q1.**

Iodine and propanone react in acid solution according to the equation

$$I_2 + CH_3COCH_3 \rightarrow CH_3COCH_2I + HI$$

The rate equation for the reaction is found to be

$$\text{rate} = k\,[CH_3COCH_3][H^+]$$

(a) Deduce the order of reaction with respect to iodine and the overall order of reaction.

*Order with respect to iodine* _____

*Overall order* _____

**(2)**

(b) At the start of the experiment, the rate of reaction was found to be $2.00 \times 10^{-5}$ mol $dm^{-3}$ $s^{-1}$ when the concentrations of the reactants were as shown below.

| Reactant | Concentration / mol $dm^{-3}$ |
|---|---|
| $CH_3COCH_3$ | 1.50 |
| $I_2$ | $2.00 \times 10^{-2}$ |
| $H^+$ | $3.00 \times 10^{-2}$ |

Use these data to calculate a value for the rate constant and deduce its units.

*Rate constant* _____

_____

_____

*Units* _____

**(3)**

(c) How can you tell that $H^+$ acts as a catalyst in this reaction?

_____

_____

_____

**(2)**

(d) Calculate the initial rate of reaction if the experiment were to be repeated at the same temperature and with the same concentrations of iodine and propanone as in part (b) but at a pH of 1.25

**(3)**

**(Total 10 marks)**

## Q2.

(a) The following data were obtained in a series of experiments on the rate of the reaction between compounds **A** and **B** at a constant temperature.

| Experiment | Initial concentration of **A**/mol $dm^{-3}$ | Initial concentration of **B**/mol $dm^{-3}$ | Initial rate/mol $dm^{-3}$ $s^{-1}$ |
|---|---|---|---|
| 1 | 0.15 | 0.24 | $0.45 \times 10^{-5}$ |
| 2 | 0.30 | 0.24 | $0.90 \times 10^{-5}$ |
| 3 | 0.60 | 0.48 | $7.20 \times 10^{-5}$ |

(i) Show how the data in the table can be used to deduce that the reaction is first-order with respect to **A**.

(ii) Deduce the order with respect to **B**.

**(2)**

(b) The following data were obtained in a second series of experiments on the rate of the reaction between compounds **C** and **D** at a constant temperature.

| Experiment | Initial concentration of **A**/mol $dm^{-3}$ | Initial concentration of **B**/mol $dm^{-3}$ | Initial rate/mol $dm^{-3}$ $s^{-1}$ |
|---|---|---|---|
| 4 | 0.75 | 1.50 | $9.30 \times 10^{-5}$ |
| 5 | 0.20 | 0.10 | To be calculated |

The rate equation for this reaction is

rate = $k$[**C**]$^2$[**D**]

(i) Use the data from Experiment 4 to calculate a value for the rate constant, $k$, at this temperature. State the units of $k$.

*Value for k* _____

_____

_____

*Units of k* _____

_____

(ii) Calculate the value of the initial rate in Experiment 5.

_____

_____

_____

**(4)**

**(Total 6 marks)**

**Q3.**

(a) In the presence of the catalyst rhodium, the reaction between NO and $H_2$ occurs according to the following equation.

$$2NO(g) + 2H_2(g) \longrightarrow N_2(g) + 2H_2O(g)$$

The kinetics of the reaction were investigated and the rate equation was found to be

$$\text{rate} = k[NO]^2[H_2]$$

The initial rate of reaction was $6.2 \times 10^{-6}$ mol dm$^{-3}$ s$^{-1}$ when the initial concentration of NO was $2.9 \times 10^{-2}$ mol dm$^{-3}$ and the initial concentration of $H_2$ was $2.3 \times 10^{-2}$ mol dm$^{-3}$.

(i) Calculate the value of the rate constant under these conditions and give its units.

Calculation _____

_____

_____

Units _____

_____

**(3)**

(ii) Calculate the initial rate of reaction if the experiment is repeated under the same conditions but with the concentrations of NO and of $H_2$ both doubled from their original values.

_____

_____

**(1)**

(b) Using the rate equation and the overall equation, the following three-step mechanism for the reaction was suggested. X and Y are intermediate species.

Step **1** $NO + NO \longrightarrow X$

Step **2** $X + H_2 \longrightarrow Y$

Step **3** $Y + H_2 \longrightarrow N_2 + 2H_2O$

Suggest which **one** of the three steps is the rate-determining step.

Explain your answer.

Rate-determining step _____

Explanation _____

_____

**(2)**

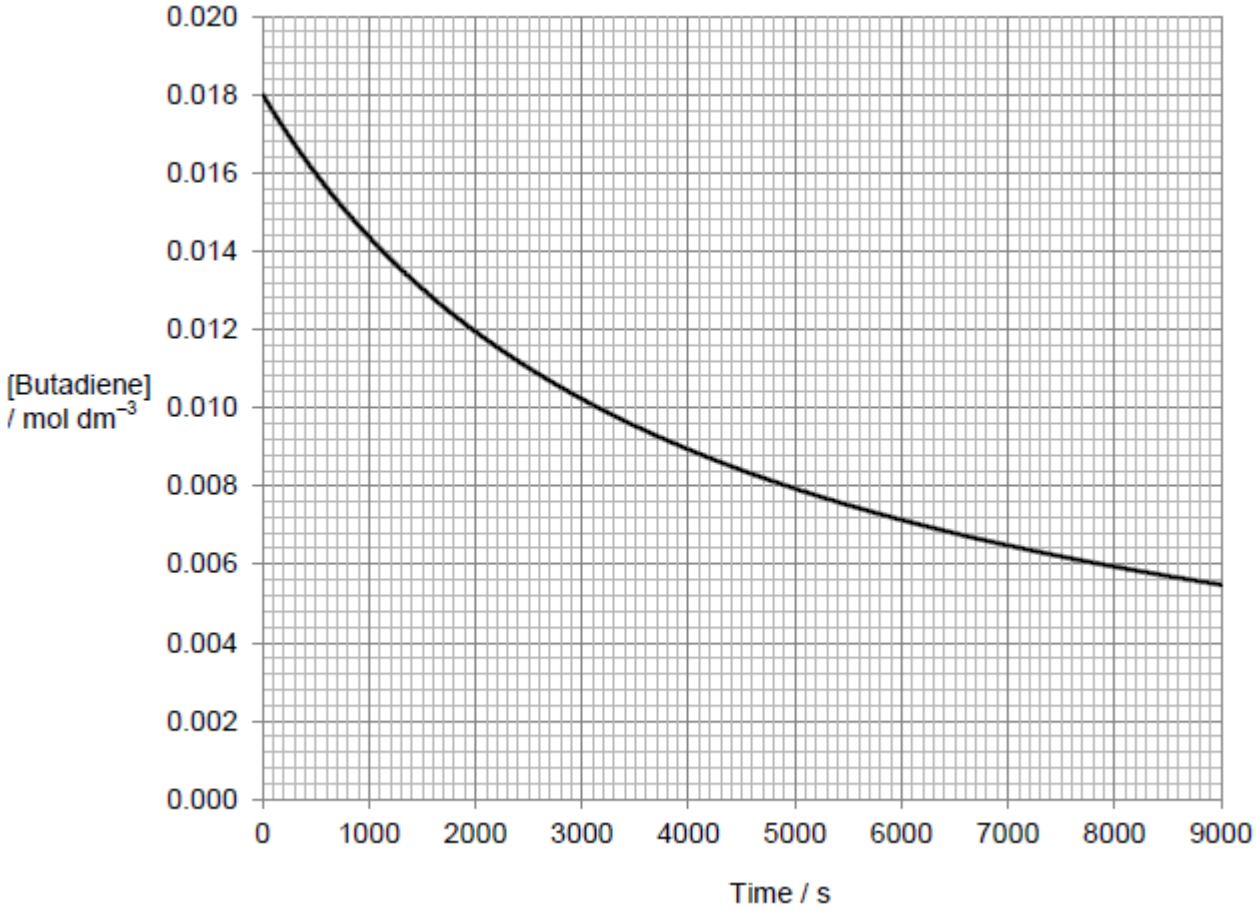
**(Total 6 marks)**

**Q4.**

Butadiene dimerises according to the equation

$$2C_4H_6 \longrightarrow C_8H_{12}$$

The kinetics of the dimerisation are studied and the graph of the concentration of a sample of butadiene is plotted against time. The graph is shown below.




(a) Draw a tangent to the curve when the concentration of butadiene is 0.0120 mol $dm^{-3}$.

**(1)**

(b) The initial rate of reaction in this experiment has the value $4.57 \times 10^{-6}$ mol $dm^{-3}$ $s^{-1}$.

Use this value, together with a rate obtained from your tangent, to justify that the order of the reaction is 2 with respect to butadiene.

_____

_____

_____

_____

_____

**(5)**

**(Total 6 marks)**

## Q5.

Iodine reacts slowly with propanone in the presence of an acid catalyst according to the equation

$$CH_3COCH_3 + I_2 \longrightarrow CH_3COCH_2I + HI$$

The rate of this reaction can be followed by preparing mixtures in which only the initial concentration of propanone is varied. At suitable time intervals, a small sample of the mixture is removed and titrated with sodium thiosulfate solution. This allows determination of the concentration of iodine remaining at that time.The rate of this reaction can be followed by preparing mixtures in which only the initial concentration of propanone is varied. At suitable time intervals, a small sample of the mixture is removed and titrated with sodium thiosulfate solution. This allows determination of the concentration of iodine remaining at that time.

Five mixtures, **A**, **B**, **C**, **D** and **E**, are prepared as shown in **Table 1**.

**Table 1**

| **Mixture** | **A** | **B** | **C** | **D** | **E** |
|---|---|---|---|---|---|
| Volume of 0.0200 mol $dm^{-3}$ $I_2(aq)/cm^3$ | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 |
| Volume of 0.100 mol $dm^{-3}$ $H_2SO_4(aq)/cm^3$ | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| Volume of 1.00 mol $dm^{-3}$ $CH_3COCH_3(aq)/cm^3$ | 25.0 | 20.0 | 15.0 | 10.0 | 6.5 |
| Volume of distilled water/$cm^3$ | 0.0 | 5.0 | 10.0 | 15.0 | 18.5 |

(a) Calculate the initial concentration, in mol $dm^{-3}$, of the propanone in mixture **A**.

Concentration = _____ mol $dm^{-3}$

**(2)**

(b) State and explain why different volumes of water are added to mixtures **B**, **C**, **D** and **E**.

_____

_____

_____

_____

**(2)**

(c) Calculate the volume of 0.0100 mol $dm^{-3}$ sodium thiosulfate solution required to react with all of the iodine in a 10.0 $cm^3$ sample of mixture **E**, before the iodine reacts with propanone.

The equation for the reaction in the titration is

$$2Na_2S_2O_3(aq) + I_2(aq) \longrightarrow Na_2S_4O_6(aq) + 2NaI(aq)$$

Volume = _____ $cm^3$

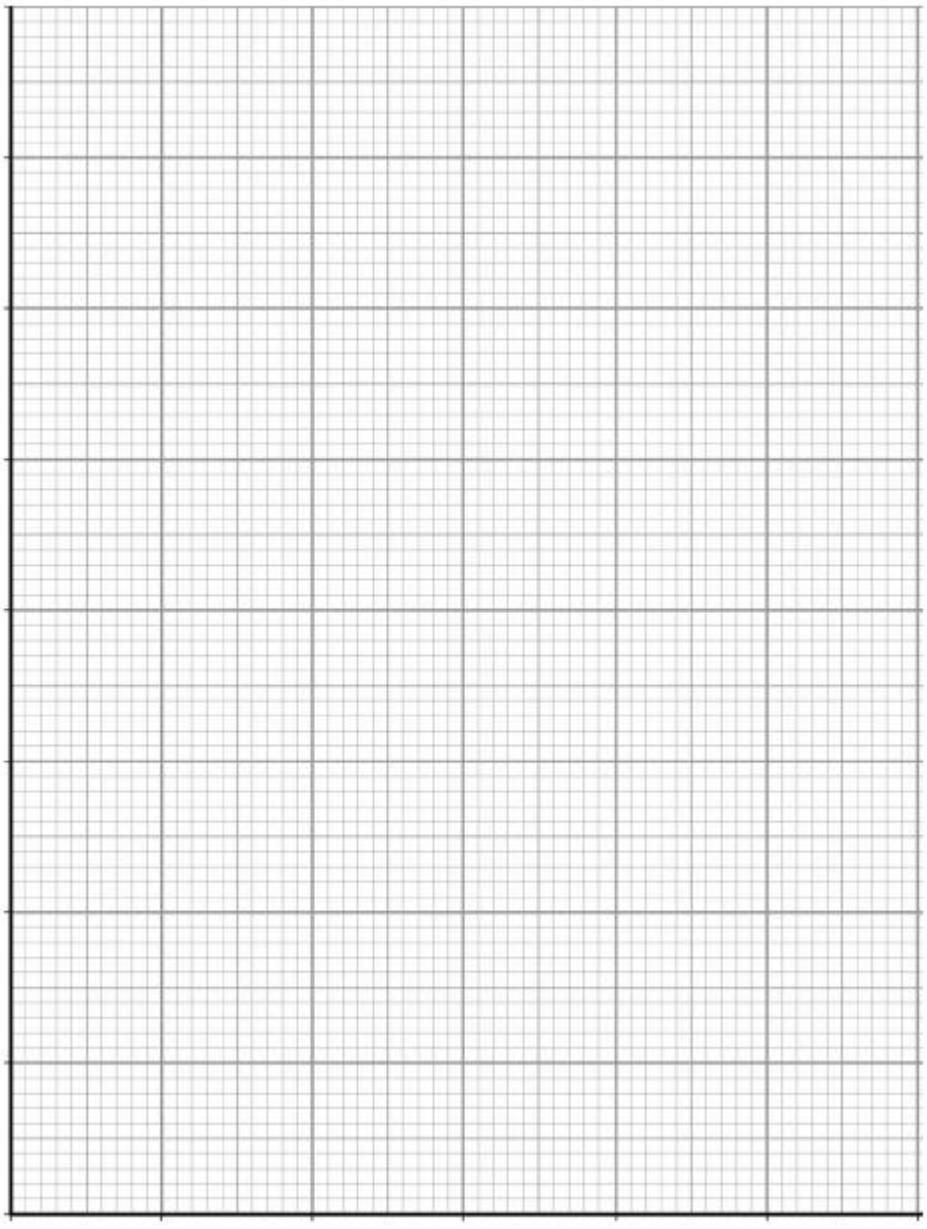
**(4)**

(d) The results for mixture **E** are shown in **Table 2**.
**V** is the volume of 0.0100 mol $dm^{-3}$ sodium thiosulfate solution needed, at different times, **t**, to react with the iodine in a 10.0 $cm^3$ sample of **E**.

**Table 2**

| **t/min** | 5 | 10 | 20 | 30 |
|---|---|---|---|---|
| **V/$cm^3$** | 17.5 | 17.2 | 16.6 | 16.0 |

Use these data and your answer to part **(c)** to plot a graph of **V** (*y*-axis) against **t** (*x*-axis) for mixture **E**.
Draw a best-fit straight line through your points and calculate the gradient of this line.



gradient = _____ $cm^3$ $min^{-1}$

**(5)**

(e) The gradients for similar graphs produced by mixtures **A**, **B**, **C** and **D** are shown in **Table 3**.
Each gradient is a measure of the rate of the reaction between iodine and propanone.

**Table 3**

| **Mixture** | **A** | **B** | **C** | **D** |
|---|---|---|---|---|
| **Gradient / $cm^3\ min^{-1}$** | −0.24 | −0.20 | −0.15 | −0.10 |

Use information from **Table 1** and **Table 3** to deduce the order with respect to propanone.
Explain your answer.

**(2)**

(f) Each sample taken from the reaction mixtures is immediately added to an excess of sodium hydrogencarbonate solution before being titrated with sodium thiosulfate solution.

Suggest the purpose of this addition.
Explain your answer.

**(2)**
**(Total 17 marks)**