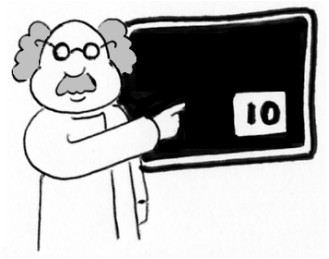


STARTER FOR 10...

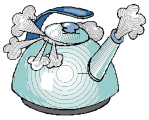
1.1. Rate determining step

1. For each of the everyday processes described below, identify the step that slows the process down.

(a) Making a cup of tea.

Step 1: Get a mug out of the cupboard 

Step 2: Add a tea bag 

Step 3: Boil the water 

Step 4: Leave the tea bag to stew 

(b) Playing with a model helicopter received as a Christmas present.

Step 1: Spot the present under the tree 

Step 2: Unwrap the present 

Step 3: Charge the batteries for 24 h 

Step 4: Play with the helicopter 

(c) Getting out of the house in the morning on time.

Step 1: Alarm goes off 

Step 2: Get out of bed 

Step 3: Have a shower 

Step 4: Eat breakfast 

(3 marks)

The overall rate of these processes is controlled by the *rate of the slowest step*. For a chemical reaction we call this step the **rate determining** or **rate limiting step**.

For each of the multi-step reactions below, write the overall equation for the reaction and identify the rate limiting step.

2. **Step 1:** $CH_3Br \xrightarrow{\text{slow}} CH_3^+ + Br^-$

Step 2: $CH_3^+ + OH^- \xrightarrow{\text{fast}} CH_3OH$

Overall equation .....

Rate limiting step .....

3. **Step 1:** $NO + NO \xrightarrow{\text{slow}} N_2O_2$

Step 2: $N_2O_2 + O_2 \xrightarrow{\text{fast}} 2\,NO_2$

Overall equation .....

Rate limiting step .....

4. **Step 1:** $NO + NO \xrightarrow{\text{fast}} N_2O_2$

Step 2: $N_2O_2 + H_2 \xrightarrow{\text{slow}} N_2O + H_2O$

Step 3: $N_2O + H_2 \xrightarrow{\text{fast}} N_2 + H_2O$

Overall equation .....

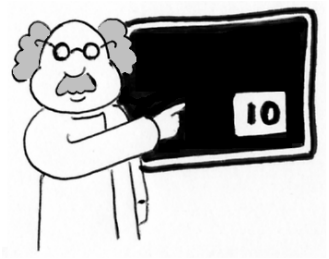
Rate limiting step .....

(6 marks)

BONUS MARK

In a chemical reaction, any step that occurs after the rate determining step will not affect the rate. Therefore any species that are involved in the mechanism after the rate determining step do not appear in the rate expression. Use this information to predict which of the options below is the correct rate expression for the reaction shown in question **2**.

(a) Rate = $k\,[CH_3Br]$ or (b) Rate = $k\,[CH_3Br][OH^-]$ (1 mark)



STARTER FOR 10...

1. Kinetics answers

1.1. Rate determining step

1. (a) Step 3 Boil the water

(b) Step 3 Charge the batteries for 24 h

(c) Step 2 Get out of bed (although this may depend on the individual!) *(3 marks)*

2. *Overall equation:* $CH_3Br + OH^- \rightarrow CH_3OH + Br^-$

Rate limiting step: $CH_3Br \rightarrow CH_3^+ + Br^-$ (Step 1) *(2 marks)*

3. *Overall equation:* $2\ NO + O_2 \rightarrow 2\ NO_2$

Rate limiting step: $NO + NO \rightarrow N_2O_2$ (Step 1) *(2 marks)*

4. *Overall equation:* $2\ NO + 2\ H_2 \rightarrow N_2 + 2\ H_2O$

Rate limiting step: $N_2O_2 + H_2 \rightarrow N_2O + H_2O$ (Step 2) *(2 marks)*

BONUS MARK Answer = (a) Rate = $k\ [CH_3Br]$ *(1 mark)*

1.2. Calculating reaction rate

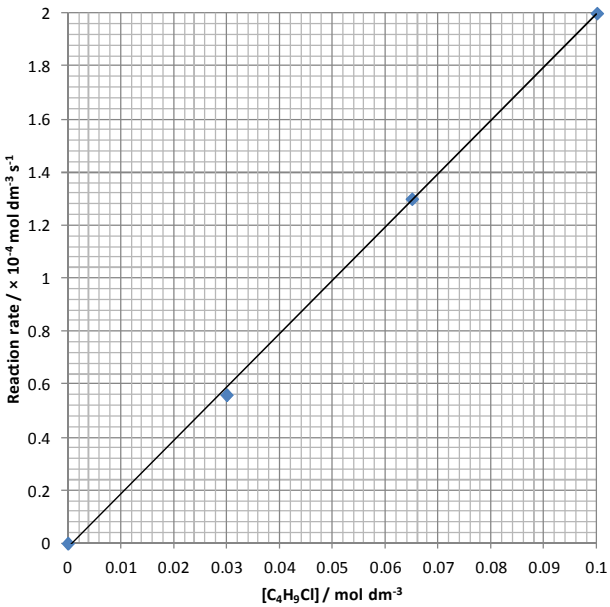
1. The rate of a reaction is the <u>change in concentration of reactants or products</u> per <u>unit time</u> *(2 marks)*

2. (a) i. 2.0×10^{-4} mol dm^{-3} s^{-1}

ii. 1.3×10^{-4} mol dm^{-3} s^{-1}

iii. 5.5×10^{-5} mol dm^{-3} s^{-1} *(1 mark for each correct value, 1 mark for the correct units for rate)*

(b)



(3 marks)

(c) The reaction is first order with respect to C_4H_9Cl. *(1 mark)*