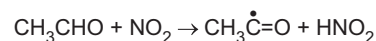


- 2 Ethanal,  $\text{CH}_3\text{CHO}$ , reacts with nitrogen dioxide,  $\text{NO}_2$ . The products of the first step of this reaction are a  $\text{CH}_3\dot{\text{C}}=\text{O}$  radical and a molecule of nitrous acid,  $\text{HNO}_2$ .



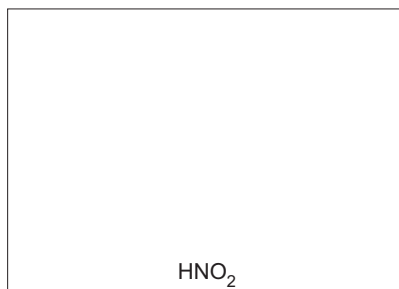
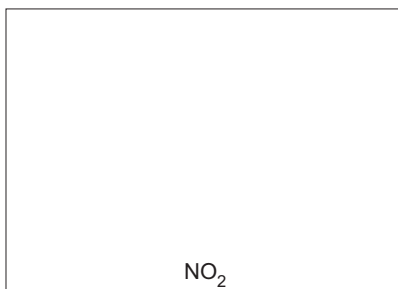
- (a) (i) Use **two** words to complete the sentence.

This reaction involves ..... of the single covalent bond between a hydrogen atom and a carbon atom in  $\text{CH}_3\text{CHO}$ .

[1]

- (ii) The hydrogen atom mentioned in (a)(i) forms a covalent bond with one of the oxygen atoms of an  $\text{NO}_2$  molecule. An  $\text{NO}_2$  molecule has a single, unpaired electron on the nitrogen atom. All electrons are paired in an  $\text{HNO}_2$  molecule.

Draw dot-and-cross diagrams of  $\text{NO}_2$  and  $\text{HNO}_2$  in the boxes. Show outer shell electrons only.



[1]

- (iii) Use VSEPR theory to predict the bond angle at the nitrogen atom in an  $\text{HNO}_2$  molecule.

bond angle = ..... [1]

- (b) The rate equation for the reaction between  $\text{CH}_3\text{CHO}$  and  $\text{NO}_2$  is shown.

$$\text{rate} = k[\text{CH}_3\text{CHO}][\text{NO}_2]$$

Under certain conditions, when the concentrations of both  $\text{CH}_3\text{CHO}$  and  $\text{NO}_2$  are  $0.200 \text{ mol dm}^{-3}$ , the rate of the reaction is  $1.53 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$ .

Calculate the value of the rate constant,  $k$ , under these conditions. Give the units of  $k$ .

$k = \dots\dots\dots$  units ..... [2]

- (c) The reaction mixture described in (b) is monitored over a period of time.

Predict whether the graph of  $[\text{NO}_2]$  against time shows a constant half-life.

Explain your answer.

prediction .....

explanation .....

[1]

- (d)  $\text{NO}_2$  also reacts with ozone,  $\text{O}_3$ .

The rate equation is shown.

$$\text{rate} = k_1[\text{NO}_2]$$

Under certain conditions, the value of  $k_1$  is  $0.0848 \text{ s}^{-1}$ .

The reaction has a constant half-life under these conditions.

Calculate the half-life in seconds.

half-life = ..... s [1]

- (e)  $\text{NO}_2$  is present in the exhaust gases of cars. It can react with carbon monoxide,  $\text{CO}$ , on the surface of a heterogeneous catalyst in the car's catalytic converter.

Describe the mode of action of this heterogeneous catalyst.

.....  
.....  
.....  
.....  
.....  
.....  
..... [2]

[Total: 9]