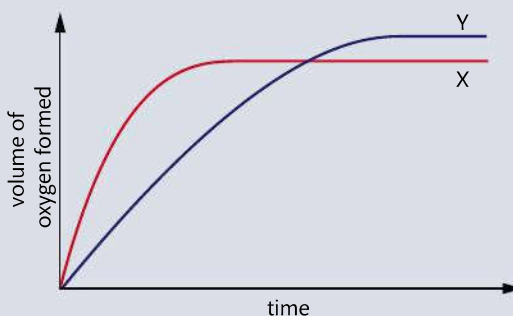
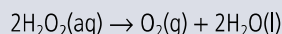


- 12** Catalytic converters are now used in most cars to convert some components of exhaust gases into less environmentally damaging molecules. One of these reactions converts carbon monoxide and nitrogen monoxide into carbon dioxide and nitrogen. The catalyst usually consists of metals such as platinum or rhodium.
- Write an equation for this reaction.
 - Explain why it is important to reduce the concentrations of carbon monoxide and nitrogen monoxide released into the atmosphere.
 - Why do you think the converter sometimes consists of small ceramic beads coated with the catalyst?
 - Suggest why the converter usually does not work effectively until the car engine has warmed up.
 - Discuss whether the use of catalytic converters in cars solves the problem of car pollution.

Practice questions

- 1** Curve X on the graph below shows the volume of oxygen formed during the catalytic decomposition of a 1.0 mol dm^{-3} solution of hydrogen peroxide:



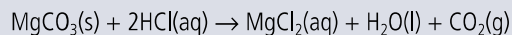
Which change would produce the curve Y?

- adding water
 - adding some 0.1 mol dm^{-3} hydrogen peroxide solution
 - using a different catalyst
 - lowering the temperature
- 2** Which changes increase the rate of the reaction below?
- $$\text{C}_4\text{H}_{10}(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow \text{C}_4\text{H}_9\text{Cl}(\text{l}) + \text{HCl}(\text{g})$$
- increase of pressure
 - increase of temperature
 - removal of $\text{HCl}(\text{g})$
- A** I and II only **B** I and III only **C** II and III only **D** I, II, and III
- 3** Which experimental procedure could be used to determine the rate of reaction for the reaction between a solution of cobalt chloride, $\text{CoCl}_2(\text{aq})$, and concentrated hydrochloric acid, $\text{HCl}(\text{aq})$?
- $$\text{Co}(\text{H}_2\text{O})_6^{2+}(\text{aq}) + 4\text{Cl}^-(\text{aq}) \rightleftharpoons \text{CoCl}_4^{2-}(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$$
- measure the change in pH in a given time
 - measure the change in mass in a given time
 - use a colorimeter to measure the change in colour in a given time
 - measure the change in volume of the solution in a given time
- 4** Powdered manganese(IV) oxide, $\text{MnO}_2(\text{s})$, increases the rate of the decomposition reaction of hydrogen peroxide, $\text{H}_2\text{O}_2(\text{aq})$. Which statements about MnO_2 are correct?
- The rate is independent of the particle size of MnO_2 .

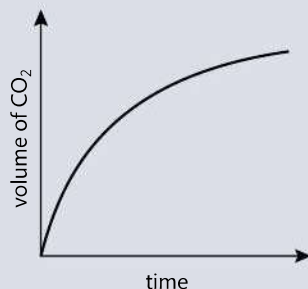
- II MnO_2 provides an alternative reaction pathway for the decomposition with a lower activation energy.
III All the MnO_2 is present after the decomposition of the hydrogen peroxide is complete.
- A** I and II only **B** I and III only **C** II and III only **D** I, II, and III

- 5 Which of the following statements is **incorrect**?
- A** The rate of a chemical reaction depends on the temperature.
B Rate and time are directly proportional.
C The rate of most chemical reactions decreases with time.
D A catalyst for a reaction increases the rate of both its forward and backward reactions.
- 6 A student measures the rate of a reaction by timing the appearance of a precipitate that forms in aqueous solution. Which of the following factors would increase the time required for the precipitate to form?
- A** raising the temperature
B adding a catalyst
C diluting the solution
D stirring the reaction mixture

Questions 7–9 refer to the reaction between magnesium carbonate and hydrochloric acid, which is as follows:



- 7 Which of the conditions described below will produce the fastest rate of reaction?
- A** 2.0 mol dm^{-3} HCl and MgCO_3 lumps
B 1.0 mol dm^{-3} HCl and MgCO_3 powder
C 2.0 mol dm^{-3} HCl and MgCO_3 powder
D 1.0 mol dm^{-3} HCl and MgCO_3 lumps
- 8 Which of the following measurements would **not** be a suitable means to follow the rate of this reaction?
- A** increase in mass
B increase in volume at constant pressure
C decrease in pH
D increase in pressure at constant volume
- 9 The sketch graph below represents the result of an experiment to measure the rate of this reaction.

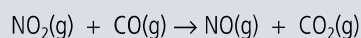


Which of the following is the best explanation for the shape of the graph?

- A** The rate of the reaction increases with time because the acid becomes more dilute.
B The rate of the reaction increases with time because the calcium carbonate pieces become smaller.

- C The rate of the reaction decreases with time because the acid becomes more dilute.
 D The rate of the reaction decreases with time because the calcium carbonate pieces become smaller.
- 10 Collision theory states that collisions between reactant molecules do not always lead to the formation of product. Which of the following is the best explanation for this statement?
- A The reactant molecules are at too low a concentration.
 B The reaction is at equilibrium.
 C The reaction needs a catalyst in order to occur.
 D The reactant molecules do not have sufficient energy.

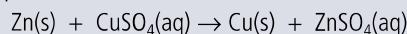
11 It is found that in the reaction:



an increase in temperature increases the rate of the reaction. Which of the statements below is the **main** reason for this?

- A The molecules collide more frequently.
 B The proportion of molecules with energy greater than the activation energy increases.
 C The pressure exerted by the molecules increases.
 D The proportion of the molecules with the correct collision geometry increases.

12 Zinc metal reacts with copper(II) sulfate solution as follows:

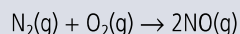


Which of the following factors will increase the rate of this reaction?

- I increasing the concentration of $\text{CuSO}_4(\text{aq})$
 II decreasing the size of the zinc pieces
 III carrying out the reaction at a higher temperature

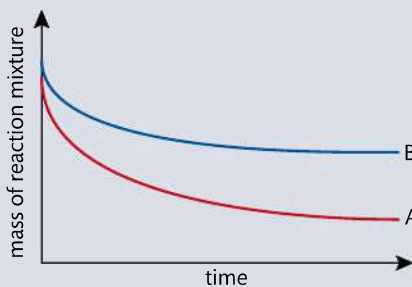
- A I and II B I and III C II only D I, II, and III
- 13 Which of the following units could **not** be used to express the rate of a reaction?
- A $\text{mol dm}^{-3} \text{ s}$ B $\text{g cm}^{-3} \text{ s}^{-1}$ C $\text{mol dm}^{-3} \text{ s}^{-1}$ D $\text{g dm}^{-3} \text{ s}^{-1}$

14 The atmosphere consists mostly of nitrogen, N_2 gas and oxygen, O_2 gas. Under normal conditions these two gases react together to form nitrogen oxide, NO , extremely slowly.

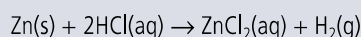


Which statement below is the best explanation for the low rate of this reaction?

- A The atmosphere does not contain a catalyst for this reaction.
 B The reaction between nitrogen and oxygen has a very high activation energy.
 C Oxygen molecules are more likely to collide with themselves than with nitrogen molecules.
 D The simultaneous collision of three molecules is unlikely.
- 15 The graph below was obtained when zinc carbonate reacted with dilute hydrochloric acid under two different conditions, denoted as experiments A and B.



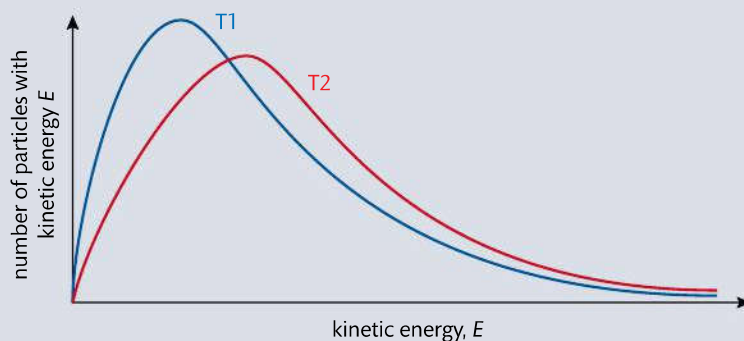
- (a) Write an equation including state symbols for the reaction occurring. (2)
- (b) Explain why the mass of the reaction mixture decreases in both cases. (1)
- (c) Make reference to collision theory to explain the shape of curve A. (3)
- (d) Describe the measurements that could be made from the graph to compare the initial rates of the reactions in A and B. Comment on the results expected. (3)
- (e) The concentration of hydrochloric acid used in experiments A and B was the same. Suggest three possible differences in the conditions of experiments A and B. (3)
- (f) For each of the conditions given in (d), explain why it would affect the rate of the reaction. (6)
- (g) The experiment was repeated using zinc metal in place of zinc carbonate. (2)



Describe the differences you would expect in the results, and evaluate whether this is likely to be a satisfactory method for following the rate of the reaction. (2)

(Total 20 marks)

- 16 The figure below shows a Maxwell–Boltzmann distribution curve for a sample of a gas at two different temperatures, T1 and T2.



- (a) Deduce the relative values of T1 and T2. (1)
- (b) Make reference to your answer to (a) to explain the differences in the shape of the two graphs. (2)
- (c) 'A catalyst provides a reaction route with a lower activation energy, and so increases the rate of reaction.'
Justify this statement by means of a suitably labelled Maxwell–Boltzmann distribution curve, showing the proportion of reacting particles with and without a catalyst. (4)
- (d) Explain why catalysts increase the rate of a reaction but have no effect on:
(i) the enthalpy change
(ii) the stoichiometric yield of product (4)

(Total 11 marks)



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