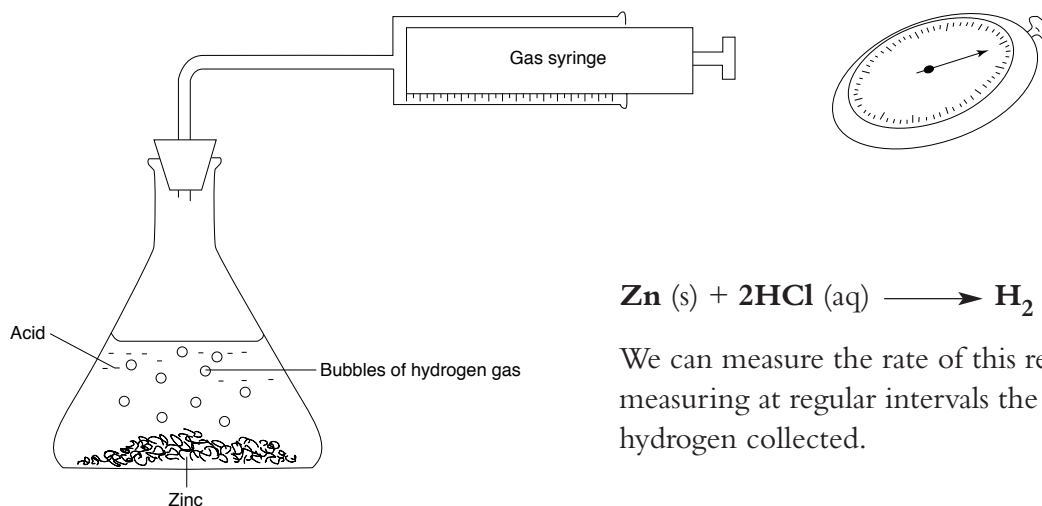# Rates of Reaction

Some reactions occur very quickly, like the burning of petrol in air in an engine. Other reactions can take a very long time, like the rusting of iron. The speed at which a reaction goes is called the **rate of reaction**.

Measuring the rate of a reaction

$$Zn \text{ (s)} + 2HCl \text{ (aq)} \longrightarrow H_2 \text{ (g)} + ZnCl_2 \text{ (aq)}$$

We can measure the rate of this reaction by measuring at regular intervals the volume of hydrogen collected.

Factors affecting the rate of a reaction

Plotting this data in a graph, as shown below, we find that after all the acid is used up, no more gas is evolved and the volume reading of the syringe stays constant (at volume M).

Repeating the experiment starting with the same amount of acid and zinc, but warming the acid solution, curve **B** will be produced. This shows a faster initial and overall rate of reaction because **B** reaches level M sooner than curve **A** did.
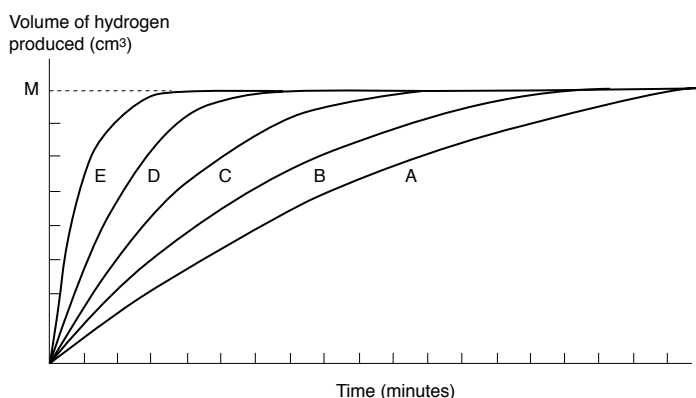
Graph showing the rate of evolution of hydrogen when an acid is added to metallic zinc

Starting with the same amount of acid but using powdered zinc instead of lumpy zinc, results in curve **C**.

Curve **D** shows the reaction rate when powdered zinc is reacted with warm acid. We can make the reaction go quicker still (**E**) by using concentrated **and** warm acid with powdered zinc. Note that each curve shows the same **final** volume (M) of hydrogen produced. Each curve differs from the others only in the **time** that it takes to reach the final volume M.

To summarise, the rate of reaction can be affected by: (1) **temperature**, (2) **particle size**, and (3) **concentration of the reactants**. Still another factor which can change a reaction's rate is a **catalyst**. This is a substance which changes the rate of a reaction but remains, itself, unchanged. Most catalysts are used to speed up reactions, although some others are used to slow down reactions; some glues, for example, are stronger when they set slowly, so 'slowing down' catalysts are used in this case.

Questions

Tick the box next to the correct answer.

1 The rate of reaction between hydrochloric acid and marble chips can be increased by:

    A   cooling   ☐

    B   stirring   ☐

    C   using larger chips   ☐

    D   using less hydrochloric acid   ☐

2 The rate at which ethanol can be produced from a fermenting mixture depends upon the:

i amount of yeast in the mixture
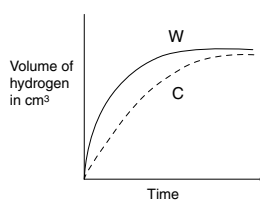ii amount of sugar in the mixture
iii temperature of the mixture

    A   i and ii   ☐

    B   i and iii   ☐

    C   ii and iii   ☐

    D   i, ii and iii   ☐

3 Zinc reacts with sulphuric acid according to the equation:

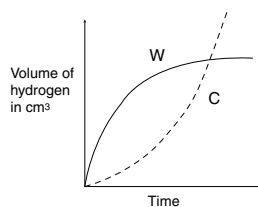$$Zn\ (s) + H_2SO_4\ (aq) \longrightarrow$$
$$ZnSO_4\ (aq) + H_2\ (g)$$
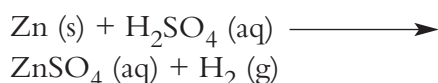
If we add a catalyst, it speeds up the reaction. Which of the following graphs correctly shows the results of the reactions, one without a catalyst **W** and one with a catalyst **C**?
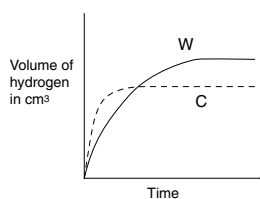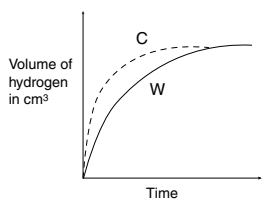
A ☐

B ☐

C ☐

D ☐

4 Increasing the concentration of reactants will increase the rate of a chemical reaction because:

    A   the reactant molecules are moving faster   ☐

    B   there are more collisions of reactant molecules   ☐

    C   the solution is more concentrated   ☐

    D   there is more space for reactants to react   ☐

5 Decreasing the temperature of a chemical reaction will decrease its rate of reaction because:

    A   the reactant molecules are moving more slowly   ☐

    B   there are fewer solvent molecules present   ☐

    C   there is less space for the reactants to collide   ☐

    D   the reactants are less soluble   ☐

6 A cube of marble 1 cm x 1 cm x 1 cm has a total surface areas of 6 cm^2. If the cube is cut into 8 equal sized cubes, the total surface area of the 8 smaller cubes is:

    A $\frac{6}{8}$ cm^2 ☐

    B   6 cm^2 ☐

    C   12 cm^2 ☐

    D   48 cm^2 ☐

7 The graph shows the rate of reaction in which CO_2 is produced at 60°C, without a catalyst. Sketch onto this graph two curves:

a One for this same reaction carried out at 30°C, with no catalyst; label it **L**.

b Sketch another for the reaction carried out at 60°C, with a catalyst; label it **C**.
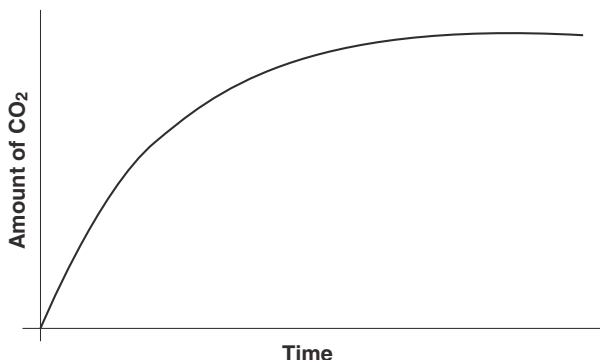
8 Magnesium was reacted with an excess of dilute hydrochloric acid as shown by this equation:

$$Mg\ (s) + 2\ HCl\ (aq) \longrightarrow H_2\ (g) + MgCl_2\ (aq)$$

The volume of hydrogen produced was measured at timed intervals and gave the following results:

Volume of H_2 produced (cm^3)	0	7	14	19	23	26	31	38	40	40	40
Time (min)	0	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0

a Plot a graph on a separate sheet of graph paper and label the axes as shown on page 9.

How much hydrogen was produced during:

b the first minute? _____

c the third minute? _____

d the sixth minute? _____

e When did the reaction finish? _____

f What was the total volume of hydrogen produced? _____

g What was the average rate of the reaction between the time it started and when it finished? (cm^3/min).

_____

Answers

1 **B** All other options would decrease the rate of the reaction. (1)

2 **D** (1)

3 **D** Although the option C also shows an increased reaction rate with curve C, it is incorrect in that the final total volume of gas produced is less than that of the uncatalysed reaction. This is an important point to make – that only the speed of the reaction is affected by the presence of a catalyst and not the final quantity of the products. (1)

4 **B** Increasing the temperature of the reaction would make option A correct. C is a repeat of the condition stated in the stem of the question, and D would apply if the solution were made less, rather than more concentrated. (1)

5 **A** More slowly moving molecules of the reactants means that there will be fewer contacts per unit time and hence fewer opportunities for reactions to occur. (1)

6 **C** This is a question more of geometry and mathematics than of chemistry. There is, however, a significant point to be made here. The doubling of the surface area from 6 cm^2 to 12 cm^2 will double (approximately) the reaction rate. Less than careful thinking might have led students to imagine that dividing the cube of reacting material into two equal pieces would double its surface area and hence double the rate of reaction; then, making eight equal cubes from one would increase the surface area, and the rate of reaction, by factors of eight. It would be a good exercise at this point to have students calculate what the actual increase in surface area, and hence the rate of reaction, would be by splitting the reactant cube in half. Halving the cube would produce two rhombus, each with a surface area of 4 cm^2; so the total area, and that of the reaction rate, would have increased to 8/6ths of the original, or an increase of only 33%. (1)

7 a The first curve L – that at 30°C – should be shown drawn totally beneath the given curve; it should not reach quite the plateau of the original curve, but approach near to it at the end of the time axis. (1)

   b The curve C showing the reaction rate with the catalyst at 60°C should be totally above the original, rising more steeply at first and reaching the plateau of maximum gas evolved before the plateau of the original, and meeting it about three-quarters of the way along the time axis. (1)

8 a The curve should be quite similar to that given in Question 7. (1 mark for correct plotting; 1 mark for two correctly labelled axes)

   b 14 cm^3. (1)

   c Volume from 23 cm^3 at the end of the second minute to 31 cm^3 at the end of the third minute, giving a volume of 8 cm^3 produced during the third minute. (1)

   d The reaction had finished by the end of the fifth minute, so the volume of hydrogen produced during the sixth minute was 0 cm^3. (1)

   e By the end of the fifth minute. (1)

   f 40 cm^3. (1)

   g 40 cm^3/5 min = 8 cm^3/min. (1)

   (Total for question = 8 marks)

Total for unit = 16 marks