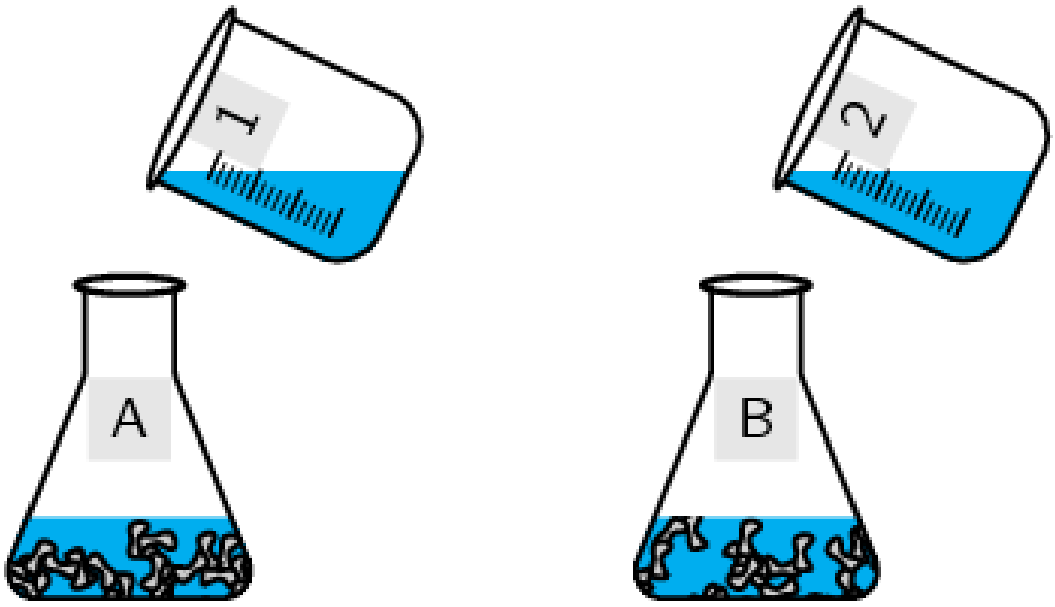
Year 10 Chemistry Workbook



The Polesworth School

Rates of Reaction

Use bitesize for extra help if needed: https://www.bbc.co.uk/bitesize/guides/z3nbqhv/revision/1

The rate of a reaction is how quickly a reaction proceeds. As a reaction proceeds, the amount of reactant will decrease and the amount of product will be increased. The amount of time this takes determines the rate of the reaction.

Part 1: Measuring the rate

The rate can therefore be measured as:

$Rate\ of\ reaction = \frac{mass\ of\ reactant\ lost\ (g)}{time\ (s)}$ and the unit would for the rate would be g/s

The same can be achieved by measuring the mass of the products:

$Rate\ of\ reaction = \frac{mass\ of\ product\ gained\ (g)}{time\ (s)}$ and the unit would for the rate would be g/s

Worked example 1:

A reaction is set up between magnesium and hydrochloric acid. After 30 seconds, the magnesium had decreased in mass by 45g. What was the rate of this reaction?

$$Rate\ of\ reaction = \frac{mass\ of\ reactant\ lost\ (g)}{time\ (s)} = \frac{45}{30} = 1.5g/s$$

When the reaction involves a gas, the equation is the same but we measure the amount of gas in cm^3 and not g. The rate is therefore given in cm^3/s

Worked example 2:

A reaction is set up between magnesium and hydrochloric acid. After 30 seconds, $81cm^3$ of gas had been produced. What was the rate of this reaction?

$$Rate\ of\ reaction = \frac{volume\ of\ product\ gained\ (cm^3)}{time\ (s)} = \frac{81}{30} = 2.7cm^3/s$$

Mastery questions:

1. In a reaction the mass of a reactant decreases by 58g in 233 seconds. What is the rate?
2. In a reaction the mass of a reactant decreases by 0.43g in 80 seconds. What is the rate?
3. In a reaction the mass of a product increases by 3kg in 210 seconds. What is the rate?
4. In a reaction the mass of a reactant decreases by 41g in 2 seconds. What is the rate?
5. In a reaction the $48cm^3$ of gas is produced in 97 seconds. Remember to check worked example 2 and calculate the rate of reaction.
6. In a reaction the mass of a reactant changes from 43g at the start to 22g at the end. This takes 79 seconds. What is the rate? (*hint - you can use the two masses to work out the mass of reactant lost)*
7. In a reaction 480g of reactant is completely used up in 1300 seconds. What is the rate?
8. In a reaction the mass of a product changes by 3.1kg in 95 seconds. What is the rate?
9. In a reaction the mass of a reactant changes by 0.845kg in 450 seconds. What is the rate?
10. In a reaction the mass of a product changes by 21kg in 10 minutes. What is the rate? (*hint - see the maths for science box to turn minutes into seconds)*
11. In a reaction the mass of a reactant changes by 19kg in 0.902 minutes. What is the rate?
12. In a reaction, $641cm^3$ of gas is produced in 55 minutes. What is the rate?
13. In a reaction the mass of a reactant changes by 3.1kg in 2 hours. What is the rate?
14. In a reaction, the mass of reactant changes from 4.5kg to 381g in 5 hours. What is the rate?
15. A student performs a reaction between magnesium and oxygen to make magnesium oxide
    a. Why does the mass in the reaction increase?
    b. Calculate the Mr of every substance in the reaction
    c. *Challenge: 30g of magnesium is fully reacted with oxygen. The reaction lasts for 7.5 seconds. Calculate the mass of magnesium oxide produced and work out the rate of the reaction.*

Maths for science:
to change g into kg you need to divide by 1000
to change kg into g you need to multiply by 1000
to change minutes into seconds you need to multiply by 60
to change hours into seconds you need to multiply by 3600

Challenge: a reaction has a rate of 0.026g/s. This was established from measuring the mass lost from a sample of calcium carbonate across three and a half days. If the sample of calcium carbonate had a mass of 581kg at the beginning of the reaction, what was its mass at the end?

Part 2: Using graphs to measure the rate of a reaction

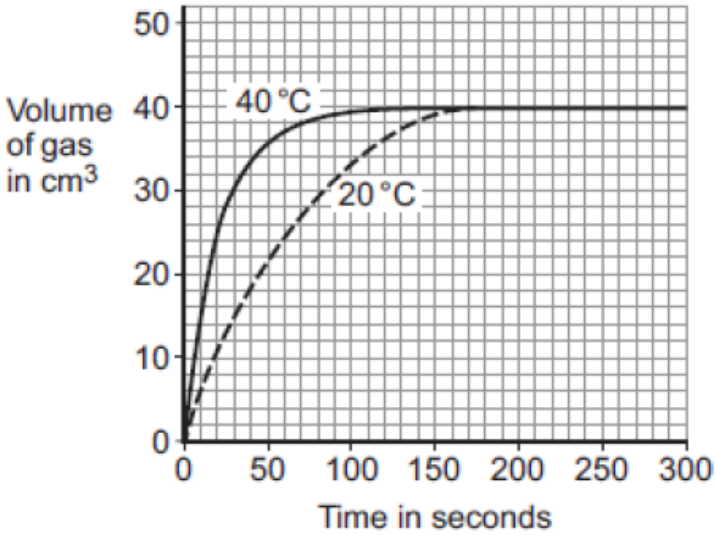
Often, you will not be given the mass values but will have to work them out from a graph. The graph will either be provided for you or you will have to draw it yourself.

Worked example:

The graph on the right shows how the volume of gas produced in a reaction changes with time. The reaction was conducted at two different temperatures.

Question: For the reaction conducted at 40°C, what is the rate of reaction across the first 150 seconds?

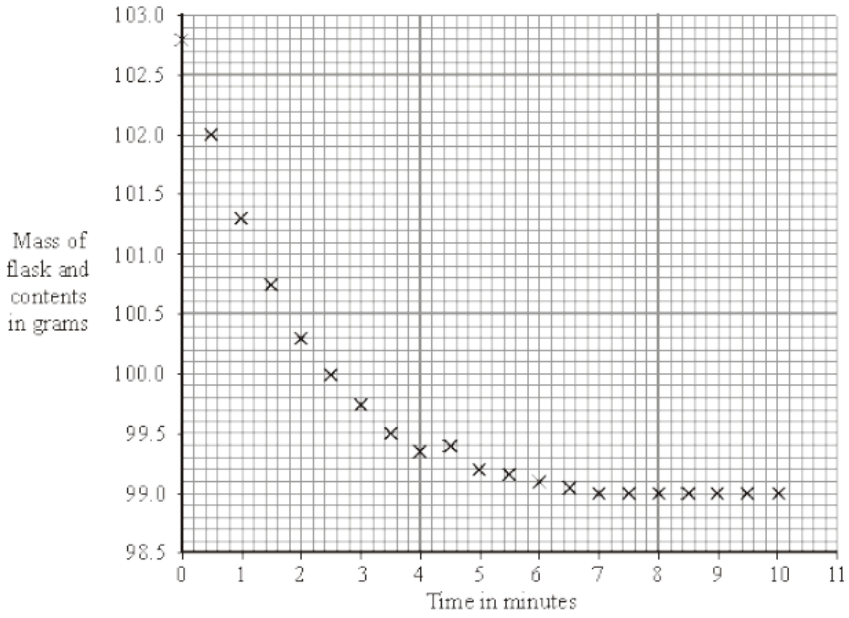
After 150 seconds on the graph, 40cm^3 of gas had been produced:



$$Rate\ of\ reaction = \frac{volume\ of\ product\ gained\ (cm^3)}{time\ (s)} = \frac{40}{150} = 0.27 cm^3/s$$

Mastery questions:

16. For the reaction above conducted at 40°C, what is the rate of reaction across the first 50 seconds?
17. For the reaction above conducted at 40°C, what is the rate of reaction across the first 10 seconds?
18. For the reaction above conducted at 40°C, what is the rate of reaction across the first 300 seconds?
19. For the reaction above conducted at 20°C (which is the dotted line), what is the rate of reaction across the first 50 seconds?
20. For the reaction above conducted at 20°C, what is the rate of reaction across the first 80 seconds?
21. For the reaction above conducted at 20°C, what is the rate of reaction across the first 20 seconds?
22. For the two reactions above, what is the difference in rates across the first minute?
23. For the two reactions above, what is the difference in rates across 200 seconds?

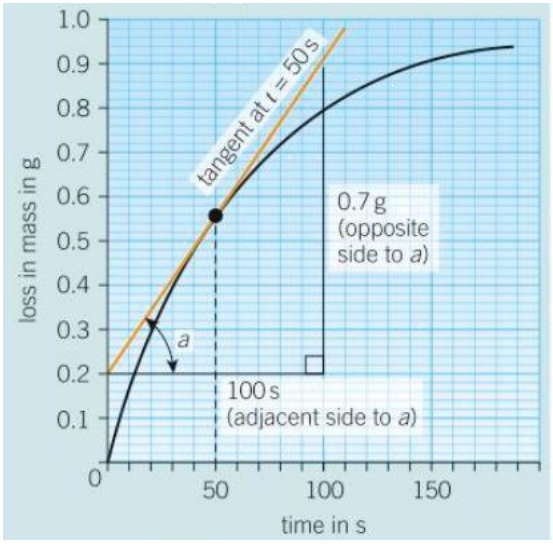


24. An experiment was conducted to see how the mass of magnesium changes with time after it has been placed in acid. The graph to the left was plotted. Draw a line of best fit to complete the graph.
25. One result is **anomalous**. This means it does not fit the pattern shown by the other results. Which result is the anomalous one?
26. What is the rate of reaction across the first five minutes? (*hint - this is similar to question 15-20. Look at the mass at 0 minutes and the mass at 5 minutes to calculate the change in mass)*
27. What is the rate of reaction across ten minutes?
28. What is the rate of reaction:
    a. Across the last five minutes?
    b. Across the last three minutes?
    c. Across the first 450 seconds?
    d. Between the second and eighth minute?
    e. Between the second and third minute?
    f. What is the difference in the rate of reaction between the first and last minute of the reaction?
29. A student reacts a metal carbonate with acid to produce a salt, carbon dioxide and water.
    a. What is a salt?
    b. The acid used was a weak acid. What is a weak acid?
    c. The student found that the temperature of the reaction increased. What does this say about the reaction?
    d. What will happen to the mass of the reaction as time goes on? Explain your answer.
    e. *Challenge: the reaction is conducted again with a strong acid. Will the reaction have the same or different rate?*

Part 3: Using graphs to measure the rate of a reaction at a specific time by drawing a tangent

The **gradient** of a line is how steep it is. The graphs above show curved lines, which means that the gradient (steepness) is different at different times. In both graphs, the gradient is steepest at the start of the reaction.

Drawing a **tangent** to the curve at a specific point allows us to work out the gradient of the curve at a specific time. We can use that line to work out the rate at that specific time.



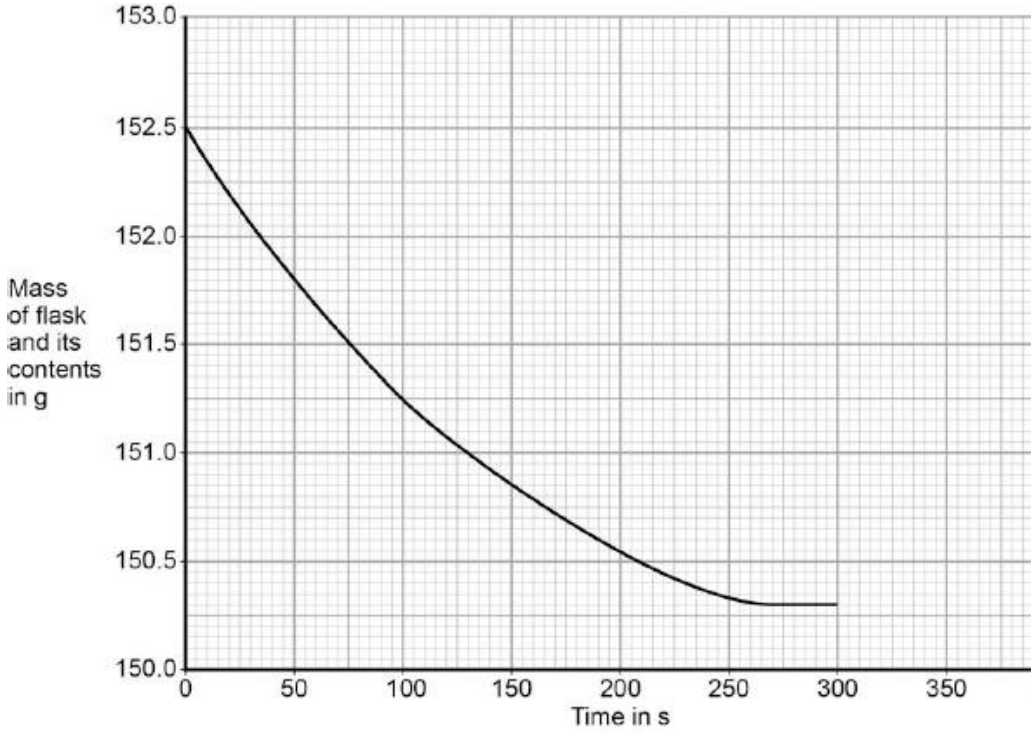
First you need to draw the tangent. Then you draw a right angled triangle using the tangent as the longest side (the hypotenuse). Calculate the gradient of that line by dividing the height of the triangle by the length of its base.

Worked example:

The graph on the right shows the change in mass of a reactant with time. Use the graph to work out the rate of reaction at 50 seconds.

First, draw a tangent to the curve at 50 seconds.
Next, construct a right angle triangle around it.
Height of the triangle: 0.7g
Base of triangle: 100s

Rate at 50 seconds = 0.7/100
Answer: 0.007g/s



30. A student plots the graph shown on the right. Use the graph to calculate the rate of reaction at 150 seconds. Your answer should fall between *0.0065 – 0.0075.*
31. Calculate the mean rate of reaction from the start until 150 seconds.
32. Calculate the rate of reaction at 50 seconds.
33. Calculate the mean rate of reaction from the start until 50 seconds.
34. How does the mean until 50 seconds differ from the rate at 50 seconds?
35. Calculate the mean rate of reaction from the 100th second until the end of the reaction.

A student performs a reaction involving a piece of magnesium placed in acid. The mass of gas produced was measured as below:

Time (s)	0	30	60	90	120	150	180
Mass (g)	0	1.6	2.6	3.25	3.7	4.0	4.0

36. On graph paper, draw a graph to show these results. Time should be on the x axis and mass on the y axis. Make sure your graph fills as much of the page as possible.
37. Draw a line of best fit for these results.
38. What is the rate of reaction at 30 seconds? To do this:
    a. Draw a tangent to the curve at 30 seconds
    b. Draw a right angle triangle around your tangent
    c. Measure the height of the triangle
    d. Measure the size of the base of the triangle
    e. Divide the height by the base
39. What is the rate of reaction at 90 seconds?
40. What is the average rate of reaction across the first minute? (*hint – look back at question 16 to remind yourself how to do this)*
41. What is the average rate of reaction across the first two minutes?

42. What is the average rate of reaction between the first and second minutes? (*hint – look back at question 28d and e)*
43. What is the rate of reaction at 10 seconds?
44. What is the rate of reaction at 150 seconds?

Challenge: At which point on the curve is the rate of reaction half the rate at 20 seconds?

Part 4: How the rate is measured in the lab

There are three main ways to measure the rate of a reaction:

1) Conduct the experiment on a balance. This enables you to watch the mass changing as the reaction proceeds. **Only suitable for reactions where a gas is produced** – the gas escapes the vessel and the mass decreases.
2) Collect gas in a syringe or cylinder. You can use a stopwatch to see how much gas is produced with time. **Only suitable for reactions where a gas is produced.**
3) The "Disappearing Cross" method is where you start with clear reactants which become cloudy as the reaction goes on. This occurs because the reaction produces a solid (precipitate). You can time how long it takes for a cross underneath the reaction vessel (the flask) to become completely blocked by the precipitate. **Only suitable for reactions which start with solutions and produce a solid.**

Mastery questions:

For each of the reactions below, state which methods would be most suitable. For some of them you will have to work out what the products are from previous topics. **You will also need to balance the equations**.

37. $Mg(s) + HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
38. $Na_2S_2O_3(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + SO_2(g) + S(s)$
39. Calcium carbonate + sulphuric acid
40. $PbNO_3(aq) + KI(aq) \rightarrow KNO_3(aq) + PbI(s)$
    a. Calculate the Mr of every substance in the reaction
    b. KNO_3 conducts electricity in solution, but not when solid. Explain why.
    c. Pb conducts electricity when solid. Explain why
    d. KI is made from reacting K with I_2. Construct a balanced symbol equation for this reaction.
    e. I_2 has a very low melting point and does not conduct electricity. What type of substance is it?
    f. Explain why it has a low melting point.
    g. KI cannot be reacted back to form K by reduction with carbon. Explain why.
    h. KI can be separated into its elements by electrolysis of KI(l). State which element forms at which electrode.
    i. *Challenge: give half equations for the reactions at each electrode*
    j. When KI(aq) is electrolysed, different products are formed. What are they?
    k. *Super challenge: construct an ionic equation for the reaction at the start of the question*

Part 5: Collision Theory

In order for a chemical reaction to take place, the atoms or molecules involved need to collide with each other. However, they also need to collide with enough energy before a reaction will take place. If they don't have enough energy they will just bump off each other. We call this amount of energy the **activation energy**.

In order to increase the rate of reaction, you must therefore either

1) Increase the frequency of collisions
2) Increase the energy that reactants have when they collide

These are the variables which can be changed to increase the rate of reaction:

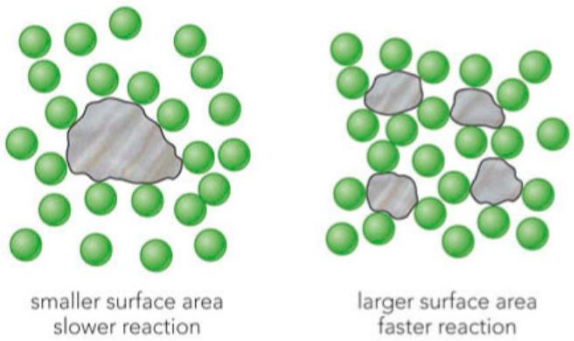
1) Surface area
2) Concentration (for solutions)
3) Pressure (for gases)
4) Temperature
5) Catalyst

Part 5.1: The effect of surface area on the rate of reaction

By increasing the surface area of a substance, you are increasing the number of particles available to react

In this diagram, a lump of metal is being reacted with a solution. In the first image, only the particles at the very edge of the metal can collide with particles from solution. Particles from inside the metal cannot collide.

In the second image, particles from the inside are now on the edges of the material and are free to collide with the solution. This results in **more frequent collisions** and a greater rate of reaction. In order to increase the surface area of a solid, it can be crushed up into smaller pieces.



Worked examples (past GCSE questions)

Example 1:

A student investigated the rate of reaction between calcium carbonate (marble chips) and hydrochloric acid.

Explain, in terms of particles and collisions, the effect that increasing the surface area of the marble chips has on the rate of reaction (3).

The rate of reaction is increased. This is because more particles are available to collide , resulting in more frequent collisions.

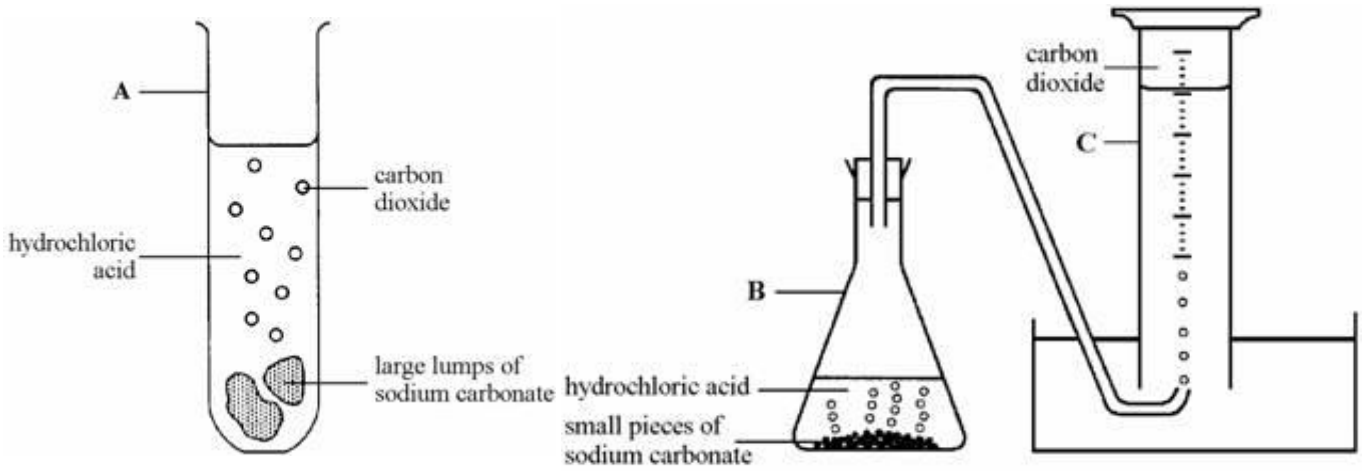
Teacher's notes: this answer correctly references the most important ideas of particles colliding more **frequently**. Students often write "more collisions" but the important part is that they are more **frequent**, meaning that there are more collisions in the same amount of time. Students also often forget to actually state the effect (the rate increases) so this answer avoids that problem.

Example 2:

Dilute hydrochloric acid reacts with sodium carbonate. The word equation for this reaction is:

sodium carbonate + hydrochloric acid → sodium chloride + water + carbon dioxide

(a) The diagram on the left shows apparatus used by student X to investigate this reaction. The diagram on the right shows the apparatus used by student Y.



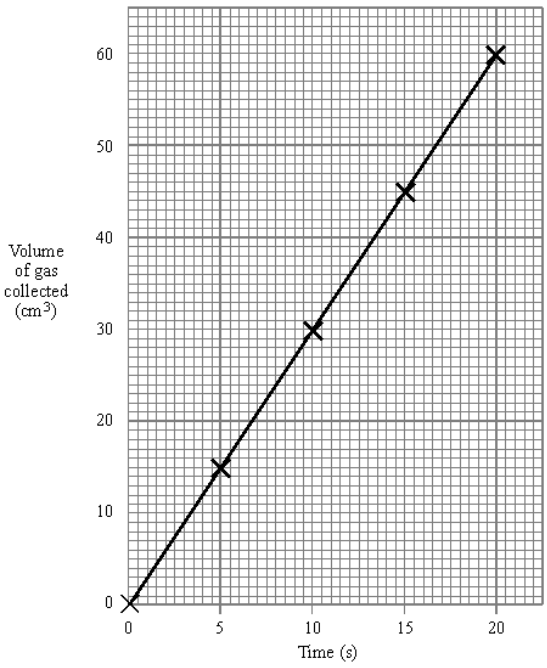
(ii) Both students X and Y used the same volume of acid, concentration of acid, temperature, mass of sodium carbonate. Use information from the diagrams to explain why the reaction that student Y carried out was faster. (3)

Student Y's reaction was faster because the pieces of sodium carbonate were smaller. This meant there were more collisions and a greater rate of reaction.

Teacher's notes: the student has correctly identified that there was a greater rate of reaction in Y than X. However, they just wrote that there were more collisions, not more **frequent** collisions. They also did not specifically mention that the smaller pieces of sodium carbonate meant a **greater surface area**

Mastery questions:

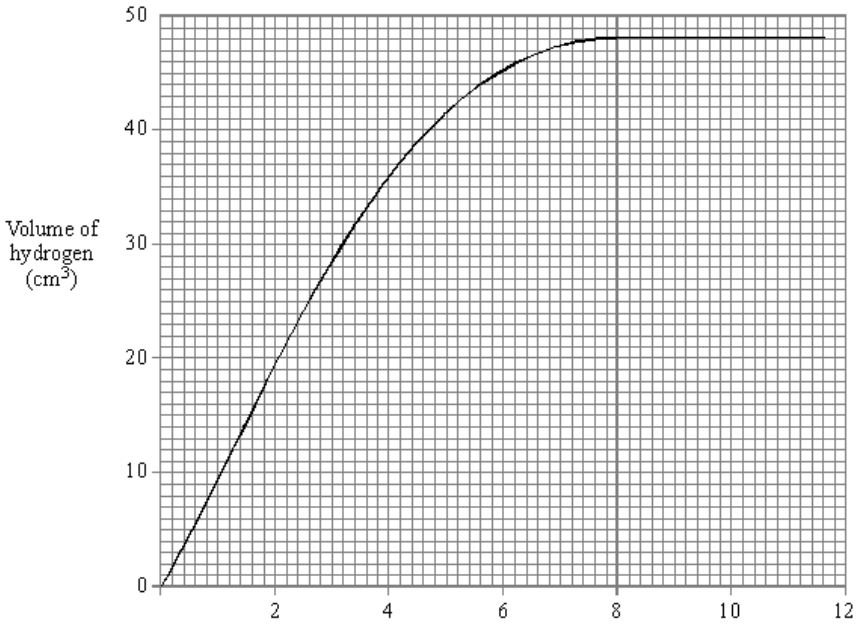
41. A number of questions related to surface area have been provided, as well as suggested answers. Assess each one to see if it contains all the most important information.
    a. Explain why the acid in your stomach is more effective at digesting food if the food has been chewed.
    Chewing food into smaller pieces gives it a larger surface area. This results in a greater rate of reaction
    b. A student leaves an iron nail and some iron wool out in the air. Which will rust quicker?
    The iron nail is made of smaller bits so will have a greater rate of reaction.
    c. A student wishes to investigate the rate of reaction of marble chips with acid and different temperatures. Explain why the student must use the same sized chips for both experiments.
    Different sized chips will have different rates of reactions due to more collisions.



42. The graph to the left shows the amount of gas produced when medium sized chips of calcium carbonate are added to acid. Draw a line to predict how much gas would be produced for:
    a. Small chips of calcium carbonate
    b. Large chips of calcium carbonate
    c. Explain your answers.
43. Calculate the mean rate of reaction between 10 and 20 seconds.
44. Calculate the mean rate of reaction between 0 and 10 seconds.

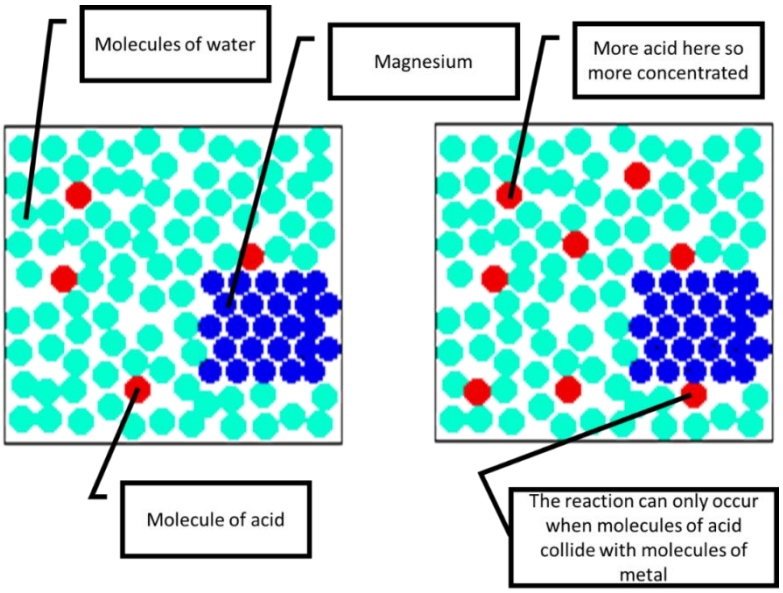
The graph below shows the amount of gas produced when large lumps of iron are added to acid with minutes being on the x axis.

a. Calculate the mean rate of reaction across the first 8 minutes.
b. Calculate the rate of reaction at 6 minutes.
c. Draw a line to predict how much gas is produced from a reaction involving the same mass of iron but used as a powder. Explain your answer.



Part 5.2: The effect of concentration on the rate of reaction

When a reaction involves a solution (like an acid), the greater the concentration, the greater the number of particles. So a concentrated acid has more acid particles in it than not. More particles mean more frequent collisions, so a greater concentration increases the rate of reaction. The diagram below on the left shows a less concentrated acid, and the one on the right shows a more concentrated acid.

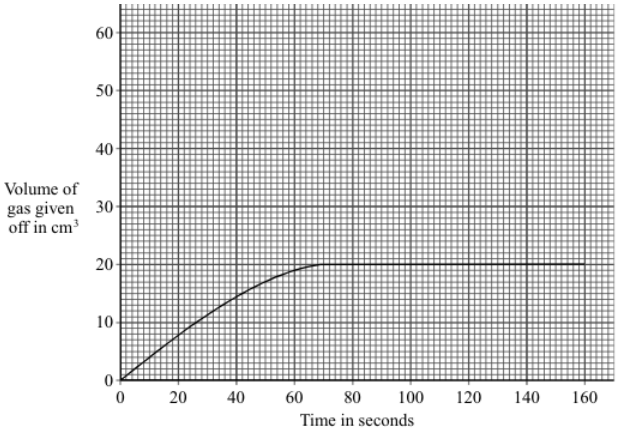


Remember also that if you are increasing the concentration, you are also increasing the amount of reactant which will also increase the amount of product.

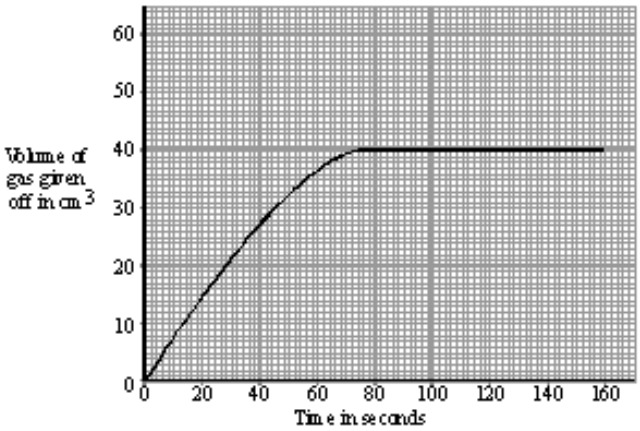
Worked Example (past GCSE question)

The graph shows the volume of gas given off during an experiment using hydrogen peroxide solution and manganese oxide.

Draw on the graph to show the result you would expect if the volume of hydrogen peroxide solution had been the same, but it was **twice** as concentrated. **(Total 3 marks)**

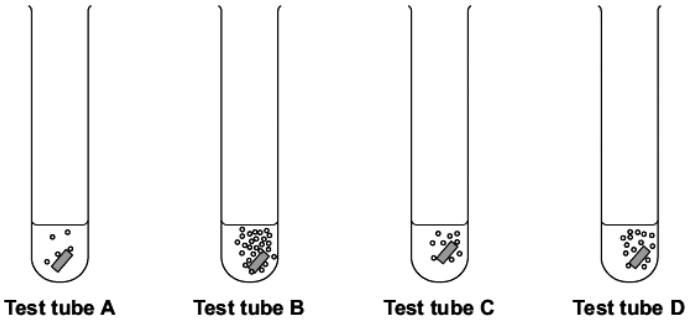


The line would have to be steeper as the rate of reaction would be increased. But it would also have to go higher. If you generated 20cm^3 of gas in the first experiment, you would expect double that if you double the concentration. The second line would therefore go up to 40cm^3:



Mastery Questions:

46. A student investigates the reaction between magnesium and hydrochloric acid.
    a. Write a word and symbol equation for this reaction.
    b. Which ions does hydrochloric acid split up into?
    c. Hydrochloric acid is a strong acid. What is the difference between a strong acid and a weak acid?
    d. The student investigated how changing the concentration of the hydrochloric acid affects this reaction. Each test tube below contained a different concentration of hydrochloric acid. The diagrams show the results of this experiment.

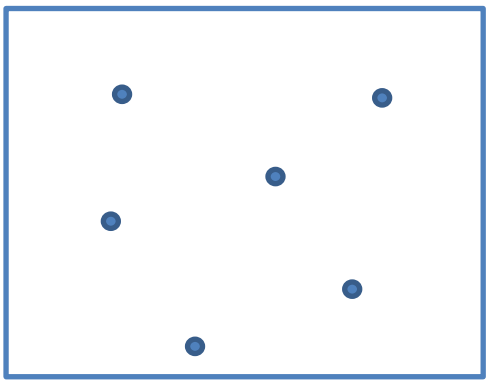


        i. Which test tube had the most concentrated acid?
        ii. How can you tell from the diagram?
        iii. Which test tube had the least concentrated acid?
        iv. Once the reaction in each test tube had finished, which one will have produced the most gas?
        v. Suggest one control variable for this experiment.
        vi. State the effect of increasing the concentration on the rate of reaction.
        vii. Explain your answer to vi.

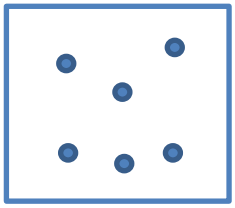
Part 5.3: The effect of pressure on the rate of reaction

When reactions involve a gas as a reactant, increasing the pressure means you have moved the gas particles closer to each other by reducing the space available to them.

When a reaction is conducted under high pressure, there are more frequent collisions as the particles are closer together. This results in a greater rate of reaction.



Low



High pressure

Worked Example:

Methane reacts with steam as below:

$CH_4(g) + H_2O(g) \rightarrow CO(g) + H_2(g)$

State and explain the effect of increasing the pressure on the rate of the reaction (3 marks)

Increasing the pressure will increase the rate of the reaction. This is because the molecules of gas will be closer together, resulting in more frequent collisions.

47. Methane (formula above) reacts with oxygen (O_2) to produce carbon dioxide (CO_2) and steam (H_2O). Write a balanced symbol equation for this reaction.
48. Calculate the enthalpy (energy) change for this reaction. You may need to look back in your notes. The bond energies have been provided for you.
    C-H 413kJ/mol
    H-O 464kJ/mol
    O=O 498kJ/mol
    C=O 532kJ/mol
49. Is this reaction endo or exothermic?
50. The pressure under which the reaction is conducted is decreased. State the effect this has on the rate of reaction.
51. Explain your answer to Q50.

Part 5.4: The effect of temperature on the rate of reaction

Increasing the temperature increases the rate of reaction. This is for **two separate reasons**. It is important that you do not confuse these reasons – this is a common student error.

1) Increasing the temperature makes the particles move faster
    a. This results in more frequent collisions
2) Increasing the temperature means that more particles have the activation energy
    a. This means that more collisions result in a reaction

Worked example

The graph below shows the amount of gas produced in a reaction which was conducted at two different temperatures.

Explain, in terms of particles and collisions, the effect of increasing the temperature on the rate of reaction. Use data from the graph to support your answer. (6 marks)

The graph shows that as the temperature increases, the gas is produced quicker. This can be proved at 50 seconds, where the 20°C reaction had produced 22cm^3, but the 40°C reaction had produced 36cm^3.

This proves that as temperature is increased, the rate of reaction increases.

This is because as the temperature is increased, the particles move faster and collide more frequently.

Also, a higher temperature means that more particles have the activation energy so more collisions result in a reaction.

Figure 2

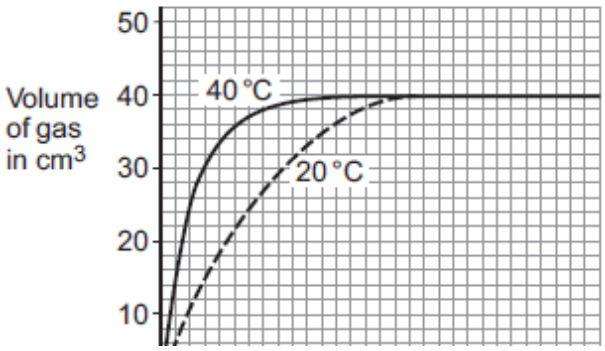
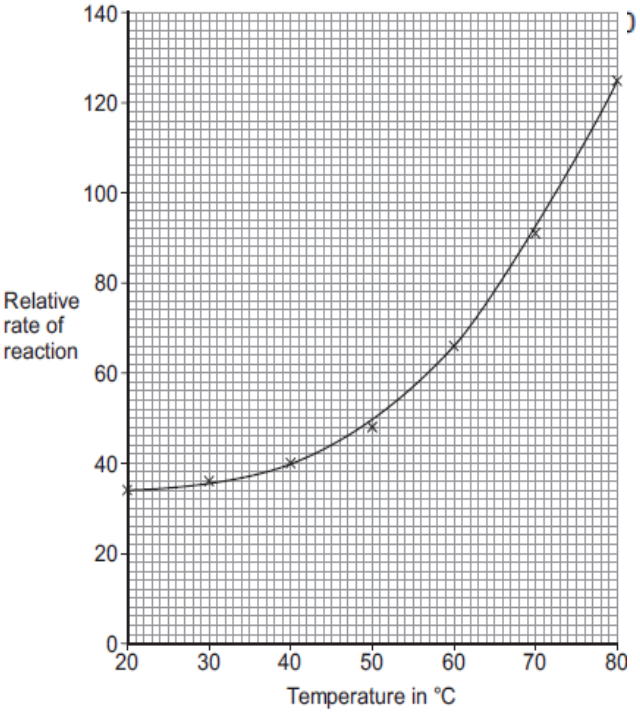


Figure 2

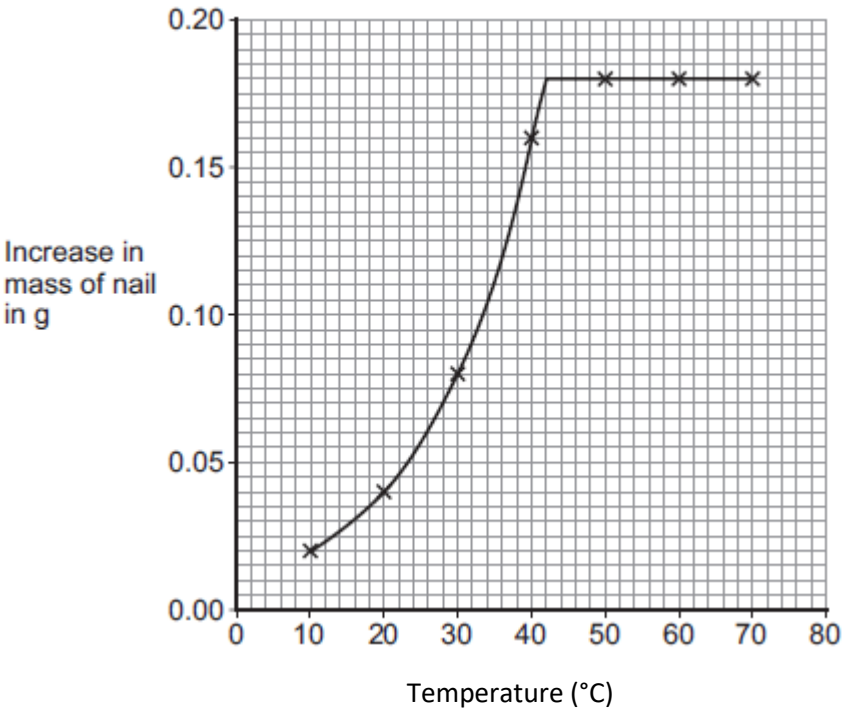


Mastery Questions

The graph above (top of the page) shows the rate of reaction at a number of different temperatures for a reaction between marble and acid.

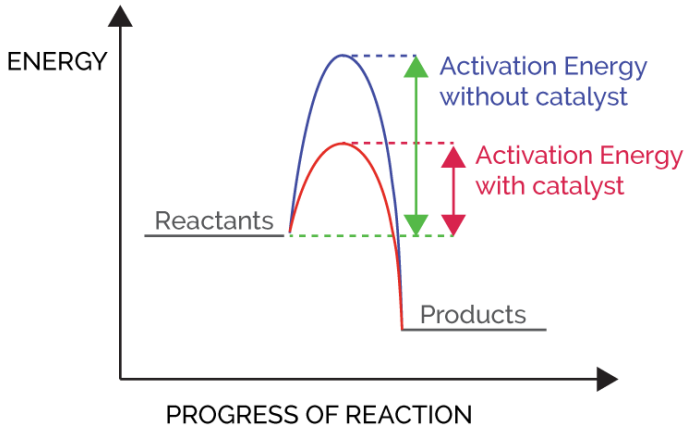
52. Describe how the rate of reaction changes as the temperature is increased.
53. Explain this effect.
54. State three variables that would need to be controlled for this reaction.
55. State and explain the effect of using the same mass of marble but larger pieces on the rate of reaction.
56. The experiment was repeated with acid that was twice as concentrated. State two differences you would expect in the results.

57. A student investigate the change in mass of a nail that was sealed in a box with air and water. The word equation for this reaction is:
    Iron + oxygen → Iron (III) oxide
    Write a balanced symbol equation for this reaction *(hint - formula for iron (III) oxide is Fe_2O_3)*.
58. The mass of the nail was found to increase over time. Explain this change (*hint - think about the number of atoms there are in the substances being weighed)*.
59. The experiment was conducted at a number of different temperatures. The results are shown in the graph to the right. Use the graph to describe the relationship between the temperature and the increase in mass of the nail.
60. The student increased the pressure inside the box. How would this affect the rate of reaction?
61. Explain your answer.
62. The nail was cut up into smaller pieces. How would this affect the rate of reaction?
63. Explain your answer.



Part 6: Catalysts

A catalyst is something which is added to a reaction to increase its rate. It is not used up as part of the reaction. It works by lowering the activation energy of the reaction, so when particles with less energy collide a reaction can still occur.



Worked Example

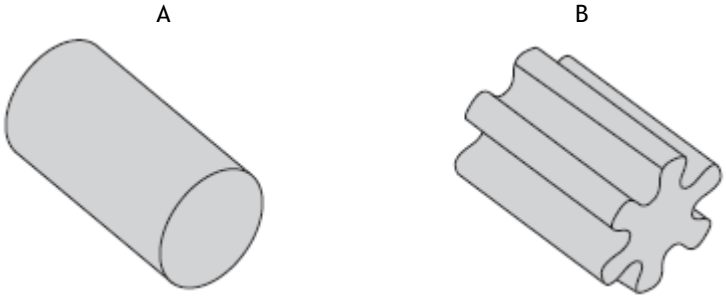
A reaction is conducted between magnesium and oxygen. At the end of the reaction, the mass of the magnesium had increased by 14g. This took 4 minutes. The reaction was repeated again, but a catalyst had been added to the reaction. It took 3 minutes for the magnesium to increase by 14g. Explain this observation.

Catalysts increase the rate of a reaction by lowering the activation energy required for the reaction to take place.

64. For the reaction above, calculate the rate of reaction in both cases.
65. The catalyst initially had a mass of 5.5g. At the end of the reaction it was re-weighed and had a mass of 5.5g. Explain this result.
66. Hydrogen peroxide decomposes into water and oxygen gas in the presence of a catalyst. The formula for hydrogen peroxide is H_2O_2(aq). Write a word and balanced symbol equation for this reaction.
67. Draw a covalent bonding diagram for water (*hint* - https://www.bbc.co.uk/bitesize/guides/zxxn82p/revision/2).
68. Draw a covalent bonding diagram for oxygen.
69. Explain the effect of a catalyst on the rate of reaction.

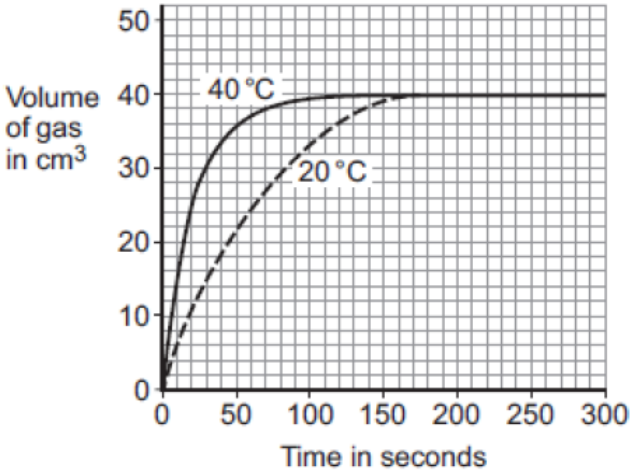
70. The diagram below shows the shapes of different catalysts

Suggest and explain why shape B is more effective as a catalyst than shape A.

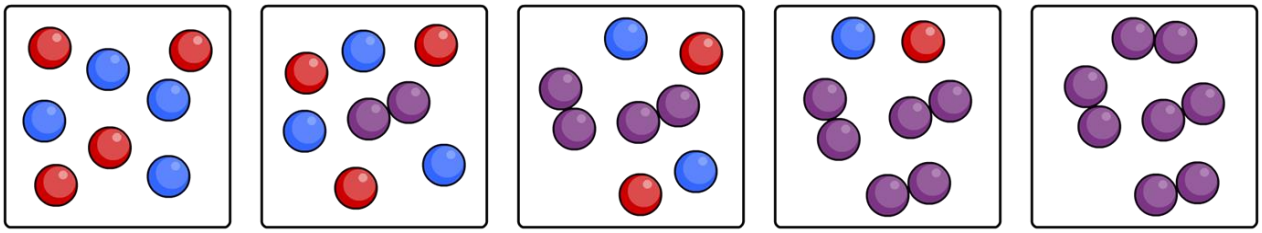


Part 7: How the rate changes with time

You may have noticed that in all the graphs we have seen so far, the curve always starts off very steep, then becomes less steep and then completely flat. This is because at the beginning of a reaction the rate is very high, but as the reaction goes on the rate decreases until it is zero; this is when the reaction has finished.



This is because as a reaction proceeds, the reactant particles collide with each other and turn into product. As time goes on, there is less and less reactant and more and more product. If there is less reactant it makes collisions between reactants less likely, reducing the rate of the reaction. By the end of the reaction there are no reactants left, only products. At this point the reaction has completed and the rate is zero.



A student is investigating the rate of reaction of an electrolysis experiment, where they are electrolysing NaCl(aq)

71. What does the (aq) stand for?
72. Explain why NaCl(s) cannot be electrolysed
73. The student uses graphite electrodes. Making full reference to its structure and bonding, explain why graphite conducts electricity.
74. The student dissolves 12g of NaCl in 200cm^3 of water. What is the concentration of this solution in g/dm^3? (Triple: work out the concentration in mol/dm^3 too)
75. Two gases are produced in this electrolysis. Which gases are they?
76. Explain why solid sodium is not produced.
77. Give a half equation for the reaction at the anode.
78. Give a half equation for the reaction at the cathode.
79. When the student first performs the reaction, 20cm^3 of gas is produced in 41s. What is the rate of this reaction?
80. The student increases the temperature of the solution. State and explain the effect this will have on the rate of reaction.
81. Sodium chloride has sodium and chlorine in it.
    a. Give a word and symbol equation for the reaction of sodium with water
    b. Explain why sodium is called an “alkali metal”
    c. Explain why chlorine has a low melting point
    d. Explain why chlorine is less reactive than fluorine
    e. What is the mass of 5 moles of sodium chloride?

Reversible Reactions

Reversible reactions are ones where the products can turn back into reactants. Use your notes to help you answer the questions below.

Part 1: Fundamentals

1. Copy the word and symbol equation for the reversible reaction where ammonium chloride breaks down into ammonia and hydrogen chloride from the image

2. How can you change this to show it is a reversible reaction?
3. A reaction between A and B makes C and D. The reaction is reversible.
    a) Write an equation for this reaction. A and C are liquids, B and D are gases.
    b) Explain what it means that this is a reversible reaction
    c) When A and B react together they release 71kJ of energy to the surroundings. What does this say about the reaction?
4. How does the enthalpy for a reversible reaction in one direction compare with the energy change in the other direction?
5. What can anhydrous copper (II) sulphate be used to test for? (Hint: https://www.bbc.co.uk/bitesize/guides/z88739q/revision/1)
6. The word equation shows the reaction between anhydrous cobalt chloride and water.

    Anhydrous cobalt chloride (blue) + water ⇌ hydrated cobalt chloride (pink)

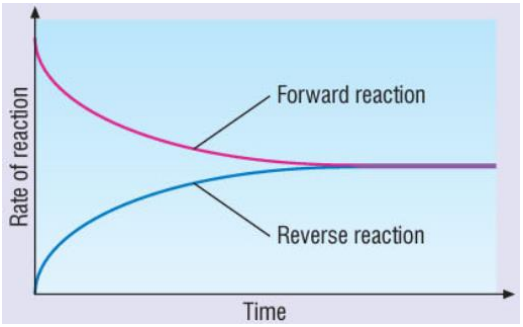
    a) Name the type of reaction shown by the sign ⇌
    b) When the student added water to anhydrous cobalt chloride what happened?
    c) A student measured the temperature rise when anhydrous cobalt chloride was added to water. The student's results are shown in the table below.

	Trial 1	Trial 2	Trial 3
Temperature at start (°C)	22	21	22.5
Temperature at end (°C)	44	43	47

    d) Calculate a temperature change for each trial
    e) Calculate the mean temperature change
    f) Is this reaction endothermic or exothermic? Explain your answer.
    g) Name the type of reaction when hydrated cobalt chloride reacts to form anhydrous cobalt chloride and water.
    h) What temperature change would you expect for this?
    i) Explain your answer to (g)

Higher and Triple only from here!

Part 2: Dynamic Equilibrium



The graph to the right shows how the rate of a reversible reaction changes with time. The forward reaction starts off with a high rate, and then slows down to a steady rate. The reverse reaction starts off at 0 and then increases to a steady rate. Dynamic equilibrium is reached when the rate of the forward reaction is the same as the rate of the reverse reaction in a closed system.

7. Describe the shape of the graph for the forward reaction
8. Why does the forward reaction's rate decrease? Refer to particles and collisions in your answer.
9. Why does the reverse reaction's rate increase? Refer to particles and collisions in your answer.
10. What point on the graph represents equilibrium
11. How does the rate of the reverse reaction compare with the rate of the forward reaction at equilibrium?
12. Explain why chemists refer to equilibrium as **dynamic** rather than **static**
13. At equilibrium, the rate of the forward reaction is 1.2cm^3/s. What is the rate of the reverse reaction?
14. A student investigates the dynamic equilibrium of a displacement reaction
    a) What is a displacement reaction?
    b) The student constructs an ionic equation for their reaction. What needs to be done to complete the equation below?
    $Na^+(aq) + Cl^-(aq) + K(s) \rightarrow K^+(aq) + Cl^-(aq) + Na(s)$
    c) Explain why Na(s) conducts electricity
    d) Explain why K is more reactive than Na
    e) The student increases the concentration of the solutions involved. State and explain how this affects the rate of reaction
    f) The student increases the temperature of the reaction. State and explain how this affects the rate of the reaction.
    g) The student chops up the K(s) into smaller pieces .State and explain how this affects the rate of the reaction
    h) The student used 0.8g of K. How many moles are in this amount of K?
    i) *Challenge: construct half equations and identify which substances have been oxidised and which have been reduced*

Part 3a - Changes to equilibrium: the effect of adding reactant or removing product

Le Chatelier's principle can be summarised as "When a system is at equilibrium, any change you make to the system will result in the system opposing your change"

$$\text{Reactant} \rightleftharpoons \text{Product}$$

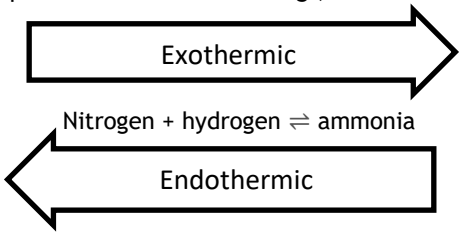
If I add some more reactant, I am changing the system. The system will oppose my change by trying to remove reactant. The only way for it to do that is by generating more product. Similarly, if I take away product, the system will also try to make more of it.

Note that if one of the products (or reactants) is a gas, the reaction will need to be conducted in a closed vessel otherwise the gas will escape and the system will not reach equilibrium.

15. The reaction below is set up in a closed vessel and allowed to reach dynamic equilibrium:
    $A(s) + B(aq) \rightleftharpoons C(aq) + D(g)$
    What is the meaning of the $\rightleftharpoons$ symbol?
16. If more A and B are added, what will the effect on C and D be?
17. Explain your answer.
18. If A and B are completely removed from the reaction, what will the effect on C and D be?
19. Explain your answer.
20. A valve is opened and some of D is allowed to escape. How will this affect A and B?
21. At equilibrium, the rate of reaction for A with B is 0.65g/s. What is the rate of reaction for C and D?
22. The reaction vessel weighs 4kg at the beginning of the reaction. Remembering that it is completely sealed, what will its mass be at the end of the reaction? Explain your answer.
23. The concentration of B is increased. What effect will this have on the rate of reaction? Explain your answer.
24. When A is added to B, the reaction is exothermic. How will this affect the temperature of the surroundings?
25. What type of reaction must be involved when C and D react?

Part 3b - Changes to equilibrium: the effect of changing the temperature

Remember that if a reversible reaction is exothermic in one direction, it will be endothermic in the other. This means that one direction will increase the temperature of the surroundings, but the other will decrease it.



So when nitrogen and hydrogen combine, they increase the temperature of the surroundings. When ammonia turns back into nitrogen and hydrogen, the temperature of the surroundings decrease.

If the temperature of a system is changed, the system will seek to oppose that change. So if the temperature is decreased, the system will oppose this by increasing the temperature. The way it does this is by favouring the exothermic side of the reaction (as this will increase the temperature).

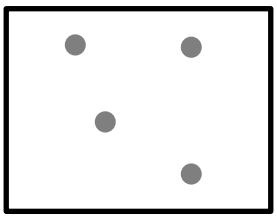
In the example above, if the temperature of the system is decreased, the system increases the temperature by combining more nitrogen and hydrogen together. This is exothermic and increases the temperature of the surroundings.

The reverse is also true. If the temperature of the system is increased, the system opposes this by having more ammonia turn into nitrogen and hydrogen. This is endothermic so decreases the temperature of the surroundings.

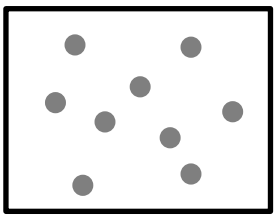
26. The reaction below is set up in a closed vessel and allowed to reach dynamic equilibrium:
    $A(s) + B(aq) \rightleftharpoons C(aq) + D(g)$
    The forward reaction (A+B) is exothermic, and the reverse one (C+D) is endothermic.
    The temperature of the vessel is decreased. What effect will this have on C and D?
27. What effect will this have on A and B?
28. Explain your answer to 25 and 26
29. The temperature is increased. What effect will this have on A, B, C and D?
30. The reaction below is endothermic in the forward direction:
    $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
    Why does the reaction need to be conducted in a closed vessel in order to reach equilibrium?
31. What will the effect of increasing the temperature be?
32. What will the effect of decreasing the temperature be?
33. What will the effect of adding more $CaCO_3$ be?
34. How does increasing the temperature affect the rate of the reaction? Explain your answer.

Challenge: a reaction between X(aq) and Y(aq) produces Z(aq). It also produces water. Write an equation for this reaction. When X and Y react, the temperature of the surroundings increases. Adding sulphuric acid is a way of removing water from the reaction mixture. However, it does this through an exothermic reaction. State and explain the effect on the amounts of X, Y and Z of adding sulphuric acid.

Part 3c - Changes to equilibrium: the effect of changing the pressure



A gas at low pressure



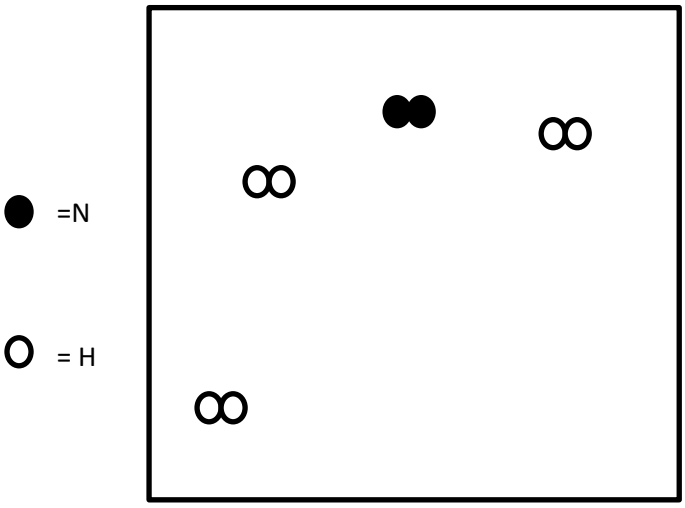
A gas at high pressure

High pressure is achieved when there are lots of gas particles (atoms or molecules) in an area. The more particles, the higher the pressure.

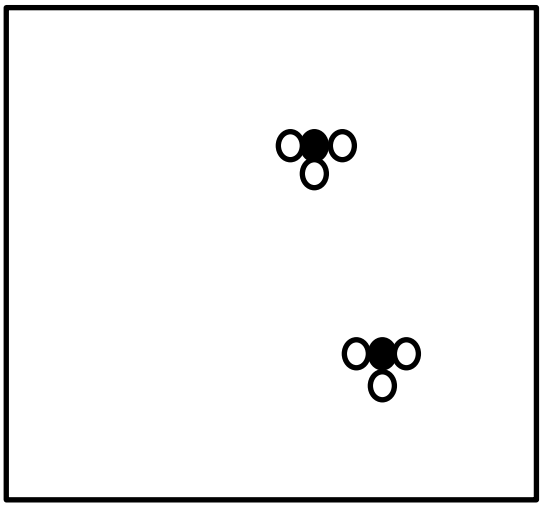
When H_2 and N_2 react they form NH_3 in a reversible reaction:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The balancing of this equation shows that one molecule of nitrogen reacts with three molecules of hydrogen to produce ammonia (as shown in the diagram). If you start four molecules and end up with two molecules, you have reduced the pressure.

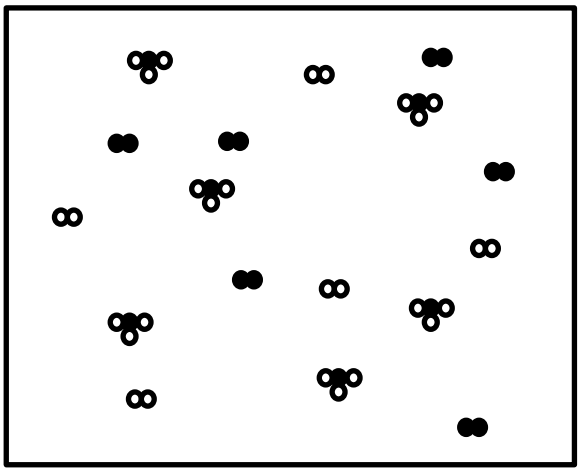


$N_2 + 3H_2$ = High pressure



$2NH_3$ = Low pressure

At equilibrium, there will be lots of molecules of product and reactant:



If the pressure is increased (by decreasing the volume of the vessel) then the reactants will start to turn into products. This reduces the total number of molecules present and will decrease the pressure. This is how the system opposes my change.

35. The pressure of the above reaction is reduced. Explain why this causes NH_3 to start forming N_2 and H_2
36. The reaction below is allowed to reach equilibrium:
    $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
    Which side of the equation has more gas molecules?
37. If the pressure is increased. The amount of SO_3 increases. Explain this result.
38. What is the effect on the reactants of increasing the pressure?
39. What is the effect on the product of decreasing the pressure?
40. A small amount of O_2 is allowed to escape. What effect will this have on the amount of SO_3?
41. The forward reaction is exothermic. What effect will decreasing the temperature have on the product?
42. What effect will it have on the reactant?
43. What conditions (temperature and pressure) would be best for the production of SO_3?
44. Explain the effect of increasing the pressure on the equilibrium mixture:
    $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
45. Look at the reaction below:
    $H_2O(g) + C(s) \rightleftharpoons CO(g) + H_2(g)$
    Explain why the reaction must take place in a sealed vessel.
46. What effect will increasing the pressure have on the amount of hydrogen produced?
47. What effect will decreasing the pressure have on the amount of hydrogen produced?
48. The reaction is carried out in a sealed vessel. Explain how the mass of the vessel will change throughout the reaction?
49. Look at the reaction below:
    $2NO_2(g) \rightleftharpoons N_2O_4(g)$
    The reactant is a brown gas and the product is a yellow gas. How will the colour change if the pressure of the reaction is increased?

50. How will the colour change if the pressure of the reaction is decreased?

Summary question:

When heated, ammonium sulfate reacts to form ammonia and hydrogen sulfate:

$(NH_4)_2SO_4(s) \rightleftharpoons 2NH_3(g) + H_2SO_4(g)$

51. Calculate the Mr of every substance in the equation
52. If 20g of ammonium sulfate is completely reacted, what mass of ammonia will be produced?
53. The reaction is conducted in an open beaker. Explain why the mass decreases over time.
54. The temperature of the reaction is increased. State the effect this will have on the rate of reaction.
55. Explain your answer.
56. Ammonia is a simple molecular substance. Explain why it does not conduct electricity.
57. H_2SO_4 can be dissolved in water to give sulphuric acid. Which ions will be present in the sulphuric acid?
58. How is the pH of the acid related to the ions in the solution?
59. *Challenge: A sample of sulphuric acid has a concentration of 10g/dm^3 and a pH of 2. What concentration would it need to have a pH of 1?*
60. What are the products from a reaction between sulphuric acid and calcium carbonate?
61. What charge does a calcium ion take?
62. In the reaction above, the ammonium sulfate needs to be heated before it forms ammonia and hydrogen sulfate. Does this mean that it is endothermic or exothermic?
63. A student wants the reaction to go to dynamic equilibrium. Why must they put a tight lid on the beaker?
64. The reaction above is allowed to reach dynamic equilibrium. What can be said about the rate of the forward and reverse reactions at dynamic equilibrium?
65. The student increases the pressure of the reaction. What effect does this have on the position of the equilibrium? Explain your answer.
66. The student adds a catalyst. What is the effect of adding a catalyst on the position of the equilibrium?