Knowledge Booklet: **Rates of Reaction**

Big Questions and Vocabulary

- Why do some reactions happen faster than others?
- Why are most reactions irreversible?
- How can we increase the rate of reaction?
- Why does the rate of reaction change over time?
- How can we maximise the yield of product in a reversible reaction.

Collisions Particles need to come together in order for a reaction to occur. For these collisions to be successful, they must have an energy greater than the activation energy	**Activation energy** The minimum amount of energy needed for a collision to be successful to form the product.	**Temperature** A measure of the average kinetic energy of the molecules. Increasing the temperature increases the average kinetic energy
Reactant A substance that is used up in a reaction. It is on the left hand side of the equation	**Product** A substance that is formed in a reaction. It is on the right hand side of the equation	**Rate of reaction** The speed at which a reactant is converted into a product.
Pressure Pressure is calculated by Force / area. In gases it is linked to the number of collisions per second with the container	**Catalyst** A chemical that lowers the activation energy by providing an alternative route for the reaction to take place by. It is not used up in the reaction	**Surface Area** The surface area is a measure of how many exposed particles are available to react.
Concentration The number of particles present in a certain volume . Typical units are g/dm^3 or mol/dm^3	**Limiting reactant** Whichever reactant is present in the smallest number of moles	**Gradient** The steepness of the curve calculated by the change in y / the change is x (rise over run)
Plateau The level (horizontal section) on a graph	**Dynamic equilibrium** When a reversible reaction reaches a point where the rate of the forward reaction equals rate of the reverse reaction in a closed system	**Reversible** When the reactants can react to form the products but the reverse reaction can also take place.
Kinetic energy The energy associated with movement. Particles with more kinetic energy are more likely to result in successful collisions	**Moles** A term used to describe the amount of a substance.	**Closed system** Where the reactants and products cannot escape, e.g in a sealed container.

Sample Extended Questions / Practical based questions

Explain how you could carry out an experiment to show how the rate of reaction changes over time

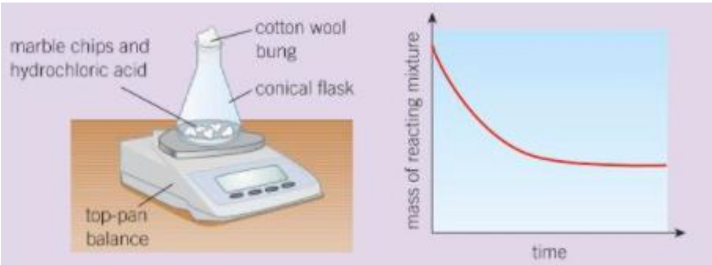
Compare how changing the temperature and changing the concentration would affect the rate of reaction between Magnesium and Hydrochloric acid

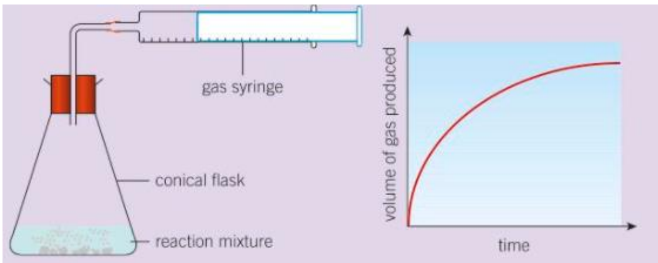
Explain how a catalyst increases the rate of reaction

Describe how the position of equilibrium can be shifted in a reaction

Explain how you can calculate the rate of reaction at a specific point in a reaction

The rate of reaction can be calculated by measuring the loss of reactant / time or by measuring the formation of product / time.





In this case, the mass decreases as a gas (CO_2) is formed an escapes the conical flask. The cotton wall is to stop and solution escaping.

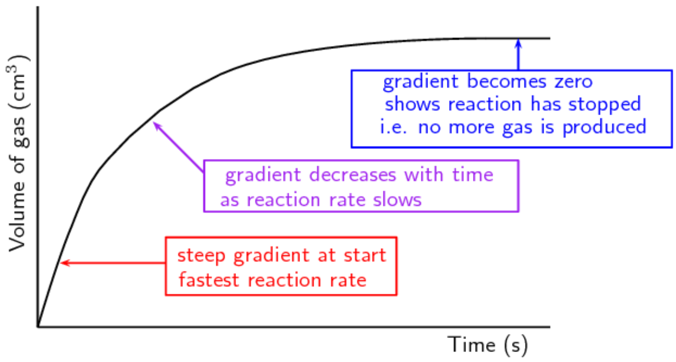
The graph plateaus as either the hydrochloric acid or the marble chips have been used up.

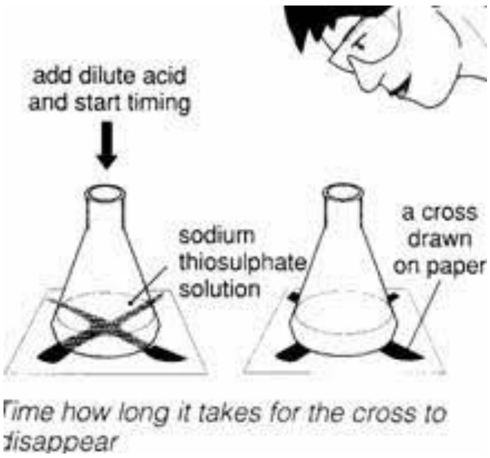
In this case, the volume of gas formed is collected in the syringe.

The graph plateaus as one of the reactants has been used up.

In both cases, the gradient decreases as time goes on. The rate is FASTEST at the beginning of the reaction as the concentration of the reactant particles is at its greatest, this results in more collision per second.

As the reaction progresses, the reactant particles concentration decreases as they form the products, this results in fewer collisions per second and a slower rate of reaction





Not all reactions produce a gas, so the rate cannot be calculated by measuring the change in mass over time or the rate of formation of a gas.

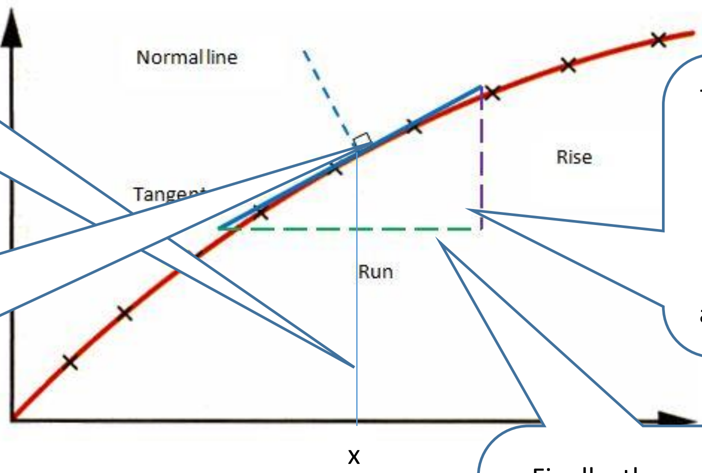
If a reaction involved involves a colour change, the rate can be calculated based on the time taken for the colour to appear, or based on the time taken for the solution to become opaque.

As the rate does not remain constant, we can use the graph to calculate the rate of a reaction at a specific point.

It's a common mistake to calculate the rise / run values just based on the point on curve at the time we are trying to find. This would only tell you the AVERAGE rate of reaction up until that point.

First, draw a line straight up from the time to find the point on the curve

Second draw a tangent to this point with a ruler. A tangent is a straight line that touches the curve at one point but does not cross it



Third, pick any two point that are ON your tangent, that ideally cross a square exactly

Draw a line down, and across to make a triangle

Finally, the gradient and therefore rate of reaction can be calculated by Rise / Run

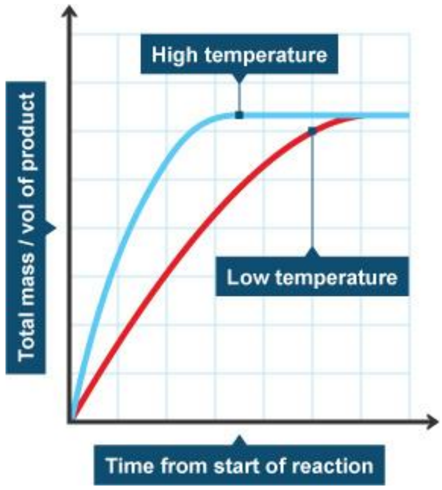
(change in y / change in x)

There are 4 factors that affect the rate of reaction, these are temperature, surface area, catalysts and concentration (pressure if a gas)

Temperature → Increasing the temperature increases the average kinetic energy of the particles. This means that there are more collisions per second, and that they collide with more energy.

It increases the proportion of particles with an energy greater than the activation energy.

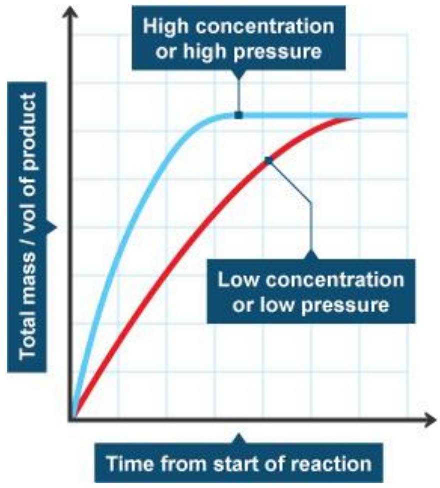
The amount of product formed does not change so the graph levels off at same point



Concentration → Increasing the concentration increases the number of particles in the same volume. This means that there are more collisions per second, which results in more successful collisions per second.

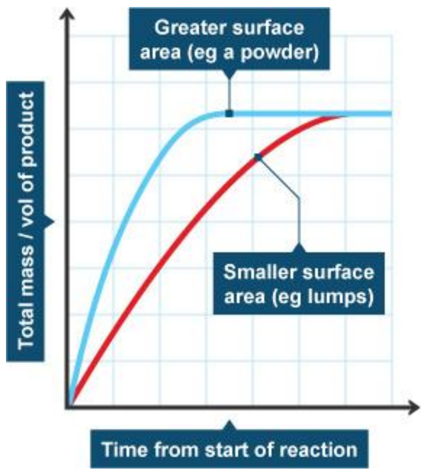
In gases, we talk in terms of pressure of the gas rather than concentration of the gas

The amount of product formed does not change so the graph levels off at same point



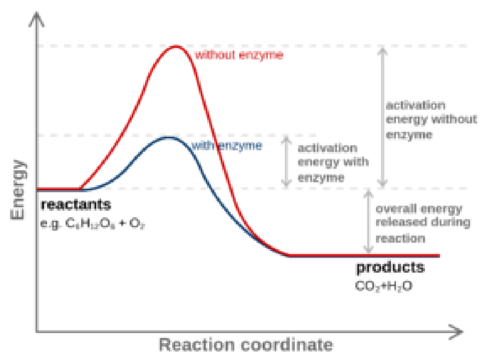
Surface area → Increasing the surface area increases the number of particles available to react from the start. This means that there are more collisions per second, which results in more successful collisions per second.

The amount of product formed does not change so the graph levels off at same point

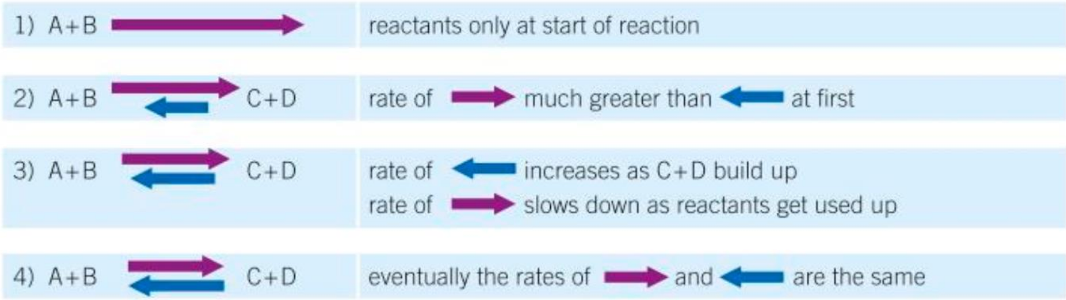


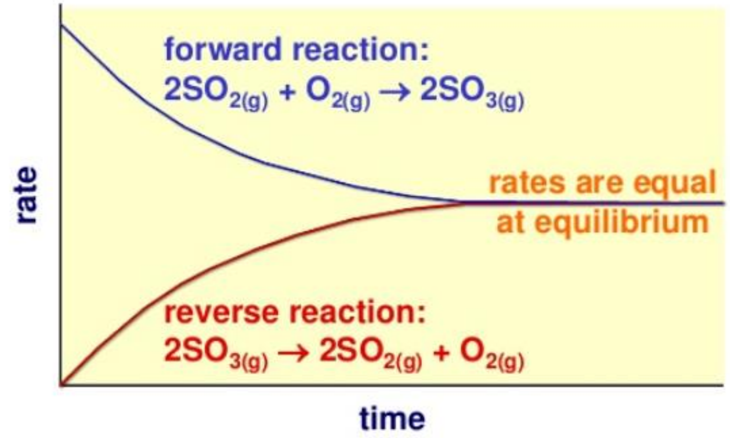
Catalyst → using a suitable catalyst lowers the minimum amount of energy required for a collision to be successful. This results in more successful collisions per second as a greater proportion of particles have an energy greater than the activation energy

The amount of product formed does not change so the graph levels off at same point



Dynamic equilibrium → When a reversible reaction reaches an equilibrium in a closed system. The rate of the forward and back ward reaction are the same, and stay the same until one of the conditions is changed.

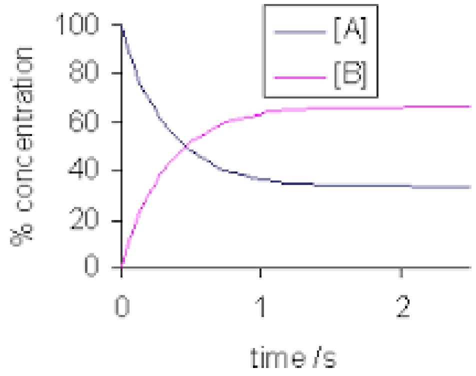




← The rates of reaction change as the reaction proceeds as the amount of the reactants and products change which affects their rate until the concentrations no longer change.

→ The graph show how the concentration of reactants and products changes with time until they remain constant when equilibrium is reached.

The reaction is still proceeding!



Le Chateliers principle explains what happens to systems in equilibrium when the conditions are changed.

Essentially, any changes that are made to this system will results in the equilibrium shift in order to reverse the change and restore a new equilibrium state

Changing the temperature will shift the equilibrium position
Increasing the temperature shifts the equilibrium in the **ENDOTHERMIC** direction
Decreasing the temperature shifts the equilibrium in the **EXOTHERMIC** direction

Changing the pressure will shift the equilibrium position
Increasing the pressure will shift the equilibrium to the side with LESS moles of gas
Decreasing the pressure will shift the equilibrium to the side with MORE moles of gas

Changing the concentration will shift the equilibrium position
Increasing the concentration will shift the equilibrium to reduce the concentration
Decreasing the concentration will shift the equilibrium to increase the concentration

A company manufactures ethanol (C_2H_5OH).

The reaction for the process is:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -45 \text{ kJ per mole}$$

The temperature and pressure can be changed to increase the yield of ethanol at equilibrium.

(a) Explain what is meant by equilibrium.

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Any time you have an equilibrium or dynamic equilibrium question, you must always include the same 3 points;

1) Reversible reaction
2) Closed system
3) Rate or forward reaction and reverse reaction are equal

(3)

(b) (i) How would increasing the temperature change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

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Any question linked to temperature and equilibrium needs you to first identify whether the reaction is endothermic or exothermic. Look at the Delta H value next to the equation

If it is negative, it is exothermic. According to Le Chateliers principle, increasing the temperature would cause the equilibrium to shift to counter the change… It would shift in the endothermic direction to reduce the temperature, and in this case the yield of ethanol

(ii) How would increasing the pressure change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

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Look at the equation and count the number of moles of gas both sides of the equation. Increasing the pressure shifts the equilibrium to the side with less moles of gas.

In this situation there are 2 moles on the left, 1 on the right, increasing pressure increases the yield of ethanol

(b) The conditions can affect the rate of the reaction.

(i) The pressure of the reacting gases was increased.

State the effect of increasing the pressure on the rate of reaction.

Explain your answer in terms of particles.

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In this question it is not talking about equilibrium, but about the rate of reaction.

Pressure is one of the factors that affect rate (similar to concentration) More particles in the same volume, more collisions per second mean more successful collisions per second and therefore a faster rate.

Useful Websites

- https://www.bbc.com/education/guides/zpkp7p3/revision/1
- https://www.bbc.com/education/guides/z32bpbk/revision/1
- https://www.youtube.com/watch?v=UkrBJ6-uGFA&list=PL9IouNCPbCxW8AN0t0py7LaKdKSwfL3fP (sequence of videos on right hand side
- https://www.youtube.com/watch?v=dUMmoPdwBy4

Wider Reading

Revision guide chapter C6