Changing Reaction Rates
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Rates of reaction

- The effect of temperature
- The effect of concentration
- The effect of surface area
- Summary activities
Rates of reaction

Why are some reactions faster than others?
Collision theory says that reactions can only take place when particles collide with a certain amount of energy.

The minimum amount of energy needed for the particles to react is called the **activation energy**, and is different for each reaction.

The rate of a reaction depends on two things:

- **the frequency** of collisions between particles
- **the energy** with which particles collide.

If particles collide with less energy than the activation energy, they will not react. The particles will just bounce off each other.
What can a graph show about the rate of a reaction?

<table>
<thead>
<tr>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of product</td>
</tr>
</tbody>
</table>
Calculating rate of reaction from graphs

How can the rate of reaction be calculated from a graph?

The gradient of the graph is equal to the initial rate of reaction at that time.

rate of reaction = \frac{\text{hydrogen produced (cm}^3\text{)}}{\text{time (seconds)}}

rate of reaction = \frac{45\text{ cm}^3}{20\text{ s}} = 2.25\text{ cm}^3/\text{s}
Changing the rate of reactions

Anything that increases the number of successful collisions between reactant particles will speed up a reaction.

What factors affect the rate of reactions?

- increased **temperature**
- increased **concentration** of dissolved reactants, and increased **pressure** of gaseous reactants
- increased **surface area** of solid reactants
- use of a **catalyst**.
Reactions do not proceed at a steady rate. They start off at a certain speed, then get slower and slower until they stop. As the reaction progresses, the concentration of reactants decreases. This reduces the frequency of collisions between particles and so the reaction slows down.

Reactants | Product
---|---
0% | 25% | 50% | 75% | 100%

Percentage completion of reaction:
- 0% reactants
- 25% reactants, 75% product
- 50% reactants, 50% product
- 75% reactants, 25% product
- 100% product
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Temperature and collisions

How does temperature affect the rate of particle collisions?
Effect of temperature on rate

The higher the temperature, the faster the rate of a reaction. In many reactions, a rise in temperature of 10 °C causes the rate of reaction to approximately double.

Why does increased temperature increase the rate of reaction?

At a higher temperature, particles have more energy. This means they move faster and are more likely to collide with other particles.

When the particles collide, they do so with more energy, and so the number of successful collisions increases.
Temperature and particle collisions

How does temperature affect particle collisions?

- Low temperature: 0
- High temperature: 15

- Fewer collisions at low temperature
- More collisions at high temperature
How does temperature affect rate?

The reaction between sodium thiosulfate and hydrochloric acid produces sulfur.

\[
\text{Na}_2\text{S}_2\text{O}_3^{(aq)} + 2\text{HCl}^{(aq)} \rightarrow 2\text{NaCl}^{(aq)} + \text{SO}_2^{(g)} + \text{S}^{(s)} + \text{H}_2\text{O}^{(l)}
\]

Sulfur is solid and so it turns the solution cloudy.

How can this fact be used to measure the effect of temperature on rate of reaction?
How does temperature affect rate of reaction?

The reaction between sodium thiosulphate and hydrochloric acid can be used to investigate the effect of temperature on rate of reaction.

Press "start" to find out how.
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The higher the concentration of a dissolved reactant, the faster the rate of a reaction.

Why does increased concentration increase the rate of reaction?

At a higher concentration, there are more particles in the same amount of space. This means that the particles are more likely to collide and therefore more likely to react.
How does concentration affect particle collisions?

Low concentration: 0
High concentration: 15
The effect of concentration on rate
Why does increasing the pressure of gaseous reactants increase the rate of reaction?

As the pressure increases, the space in which the gas particles are moving becomes smaller.

The gas particles become closer together, increasing the frequency of collisions. This means that the particles are more likely to react.
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For a solid with a fixed volume, the surface area will depend on how small the pieces are. The ratio between the surface area and the volume will affect the rate of reaction.

For example, suppose we have a solid rectangular prism with dimensions 2 cm x 2 cm x 1 cm. The surface area to volume ratios for different sized pieces are shown in the table below.

<table>
<thead>
<tr>
<th>pieces</th>
<th>surface area (cm²)</th>
<th>volume (cm³)</th>
<th>surface area to volume ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>
Effect of surface area on rate of reaction

Any reaction involving a solid can only take place at the surface of the solid. If the solid is split into several pieces, the surface area to volume ratio increases.

What effect will this have on rate of reaction?

low surface area  →  high surface area

This means that there is an increased area for the reactant particles to collide with.

Smaller pieces have a larger surface area to volume ratio. This means more collisions and a greater chance of reaction.
Surface area and particle collisions

How does surface area affect particle collisions?

- Small surface area: 0
- Large surface area: 15

- Small surface area: 0
- Large surface area: 5
Reaction between a carbonate and acid

Marble chips are made of calcium carbonate. They react with hydrochloric acid to produce carbon dioxide.

$$\text{calcium carbonate} + \text{hydrochloric acid} \rightarrow \text{calcium chloride} + \text{water} + \text{carbon dioxide}$$

$$\text{CaCO}_3(s) + 2\text{HCl(aq)} \rightarrow \text{CaCl}_2(aq) + \text{H}_2\text{O(l)} + \text{CO}_2(g)$$

The effect of increased surface area on the rate of reaction can be measured by comparing how quickly the mass of the reactants decreases using marble chips of different sizes.
How does surface area affect rate of reaction?

The reaction between different sized marble chips and hydrochloric acid can be used to investigate the effect of surface area on rate of reaction.

Press "start" to find out how.
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How do different variables affect rate of reaction?

There are several variables that can affect the rate of a chemical reaction.

Click "start" to see how much you know about them.

start