Collision Theory & Reaction Rate

MCQs with Explanations

Key Idea

Reactions occur when particles collide with sufficient energy and the correct orientation.

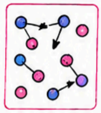
1

Statement: The number of collisions per unit volume of the reaction mixture is called:

(a) Collision energy
(b) Activation energy
(c) Collision frequency
(d) Collision force

Correct Answer: (c) Collision frequency

Explanation: Collision frequency is specifically defined as the number of collisions that occur per unit volume per unit time. It is a measure of how often reactant particles collide with each other.

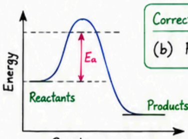


Collisions in unit volume

2

Statement: If the reactants possess an energy higher than the activation energy, then the reaction will be:

(a) Slow
(b) Fast
(c) Not affected
(d) Instantaneous



Correct Answer: (b) Fast

Explanation: Activation energy (Ea) is the minimum energy barrier that must be overcome for a reaction to take place. If reactant molecules have energy greater than this barrier, a significant proportion of their collisions will be successful, leading to a high reaction rate.

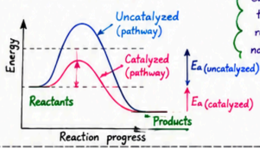
3

Statement: Which of the following explains the increase in the rate of reaction in the presence of a catalyst?

(a) Catalyst provides extra energy to the reactant molecules
(b) Catalyst provides an alternative pathway which lowers the activation energy.
(c) Catalyst increases the collision frequency
(d) Catalyst decreases the collision frequency

Correct Answer: (b) Catalyst provides an alternative pathway which lowers the activation energy.

Explanation: A catalyst provides a different mechanism (alternative pathway) with lower activation energy (Ea). Thus, more molecules have sufficient energy to react, which greatly increases the rate of reaction.



Catalyst changes the energy requirement, not the collision frequency.

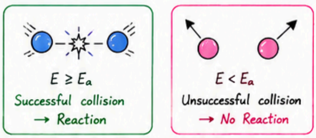
4

Statement: Which of the following statements is correct?

(a) Collisions with energy equal to or greater than the activation energy lead to reaction.
(b) Collision frequency is not related to the reaction rate.
(c) All collisions lead to a reaction.
(d) Collisions with energy less than the activation energy lead to the reaction.

Correct Answer: (a) Collisions with energy equal to or greater than the activation energy lead to reaction.

Explanation: For a collision to be successful, the particles must have minimum kinetic energy = activation energy. Collisions with energy less than Ea are ineffective and particles just bounce apart.



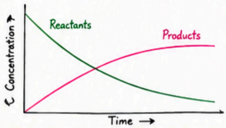
5

Statement: When a reaction proceeds ahead, how do the concentrations of reactants and products change?

(a) Concentration of reactants increases and that of the products decreases.
(b) Concentration of reactants decreases and that of the products increases.
(c) Concentration of both reactants and products decreases.
(d) Concentration of both reactants and products increases.

Correct Answer: (b) Concentration of reactants decreases and that of the products increases.

Explanation: As the reaction proceeds forward, reactants are consumed to form products. Therefore, reactant concentration decreases while product concentration increases.



This change in concentration defines the progress of reaction.

Quick Tip: More effective collisions (adequate energy + correct orientation) → Higher reaction rate!

Collision Theory & Reaction Rate

Short Questions (Section B)

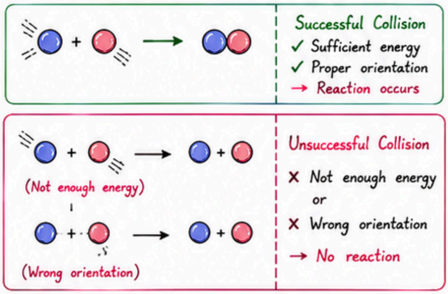
Remember! Reaction rate depends on the frequency of successful collisions.

17.1 What is a successful collision?

A successful collision is a collision between reactant particles that results in a chemical reaction. For a collision to be successful, it must meet two specific criteria:

1. **Sufficient Energy:** The colliding particles must possess energy equal to or greater than the activation energy.
2. **Proper Orientation:** The particles must collide in the correct geometrical alignment so that the reactive parts of the molecules actually come into contact.

Successful vs Unsuccessful Collisions

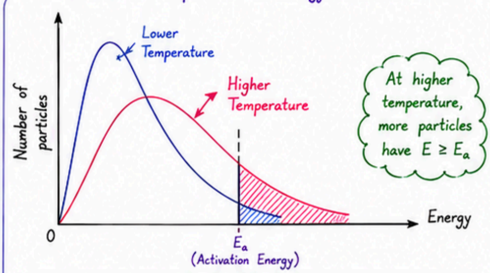


17.2 How does an increase in temperature increase the rate of a reaction?

Increasing the temperature boosts the reaction rate through two primary mechanisms:

1. **Increased Kinetic Energy:** Particles move faster, leading to more frequent collisions per unit of time.
2. **Increased Energy Factor (More Effective Collisions):** More importantly, a rise in temperature gives a greater proportion of particles the minimum energy required to overcome the activation energy barrier. This drastically increases the fraction of successful collisions, which has a more significant impact on the rate than just the collision frequency.

Effect of Temperature on Energy Distribution

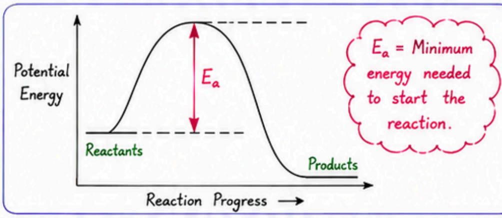


More particles with energy $\geq E_a$ → More effective collisions → Higher rate of reaction

17.3 Define activation energy.

Activation Energy (E_a) is defined as the minimum amount of energy required by reactant molecules to initiate a chemical reaction.

It is often visualized as the height of the "energy hill" that reactants must climb to transform into products.

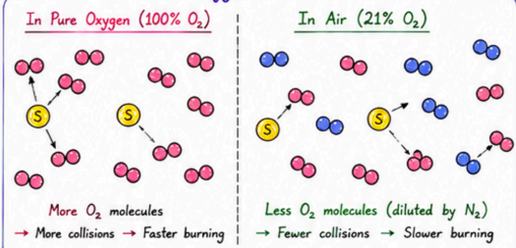


17.4 Why does the burning of sulphur proceed slower in air than in pure oxygen?

The rate of burning depends on the concentration of the reactant (oxygen).

- **Pure Oxygen:** Contains 100% oxygen particles, leading to a higher frequency of successful collisions between sulphur and oxygen molecules.
- **Air:** Contains only 21% oxygen; the remaining 79% is mostly nitrogen. The presence of nitrogen dilutes the oxygen, reducing the collision frequency between S and O_2 molecules, which slows down the reaction rate.

Pure Oxygen vs Air



Key Takeaway: The rate of a reaction depends on the number of successful collisions. Temperature, concentration, and catalysts all affect this!

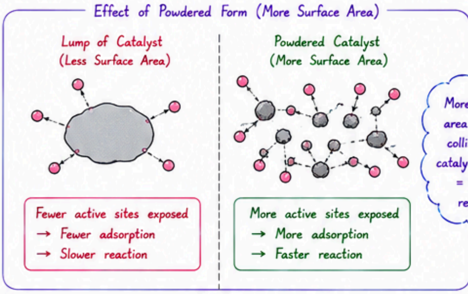
Collision Theory & Reaction Rate

> **Remember!**
> Anything that increases successful collisions increases the rate!

17.5 Why is a catalyst used in a reaction preferably taken in the powdered form?

A catalyst is taken in powdered form to increase its surface area. By breaking down a solid catalyst into a fine powder, the total surface area exposed to the reactants increases exponentially.

A larger surface area allows more reactant molecules to adsorb onto the catalyst's active sites simultaneously, thereby increasing the rate of reaction.



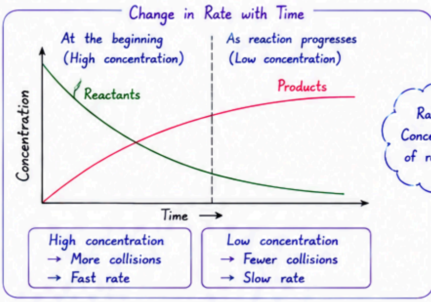
More surface area = More collisions on catalyst surface = Faster reaction!

17.6 Why is the rate of a reaction often very fast at the beginning of the reaction?

At the beginning of a reaction, the concentration of the reactants is at its maximum.

Since the rate of reaction depends on the concentration of the reactants (according to the collision theory), a higher concentration results in a higher frequency of collisions between reactant particles.

As the reaction progresses, the reactants are consumed, their concentration decreases, and consequently, the reaction rate slows down.



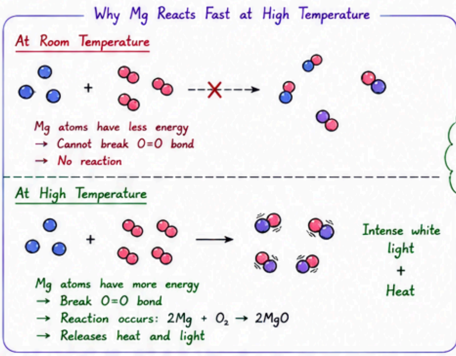
Rate ∝ Concentration of reactants

17.7 Magnesium does not react with air at room temperature but reacts very fast at high temperature giving intense white light. Explain.

This phenomnenon is related to Activation Energy.

★ **At Room Temperature:**
Magnesium atoms do not possess sufficient kinetic energy to overcome the high activation energy barrier required to break the strong bonds in O_2 molecules.

★ **At High Temperature:**
The heat energy supplies the necessary activation energy to the magnesium atoms. Once the particles have this energy, collisions become successful, initiating a highly exothermic reaction ($2Mg + O_2 \rightarrow 2MgO$) which releases intense heat and light.



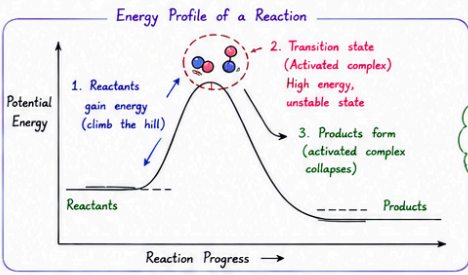
High temperature provides the activation energy!

17.8 What happens to the reactants after they climb the energy hill during a reaction?

When reactants climb the "energy hill" (overcome the activation energy), they reach a high-energy, unstable, temporary state known as the transition state (or activated complex).

At the peak of this hill, the old bonds begin to break, and new bonds start to form.

Once they pass this peak, the activated complex collapses, and the reactants are converted into products (which are usually at a lower energy state, releasing the excess energy).



Energy is released as products form!

> **Key Takeaway:** Rate of reaction depends on successful collisions.
> Increase energy, concentration, surface area or use a catalyst to speed it up!

Collision Theory & Reaction Rate

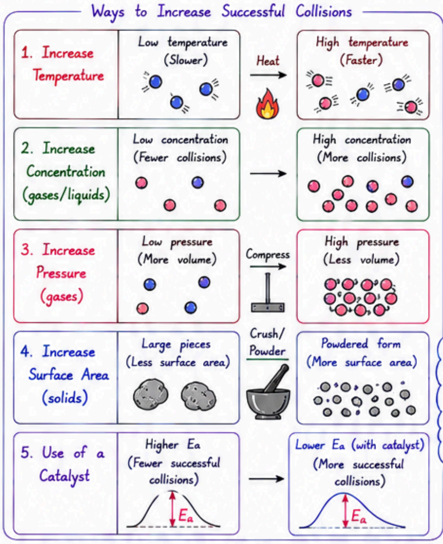
Constructed Response Questions (Section C)

Remember! More successful collisions → Higher reaction rate!

17.1 In what different ways can you increase the successful collisions between the particles of the reactants?

To increase successful collisions, we can manipulate the following factors:

1. **Increase Temperature:** Provides kinetic energy to particles.
2. **Increase Concentration (for gases/liquids):** Packs more particles into the same volume, increasing collision frequency.
3. **Increase Pressure (for gases):** Decreases the volume, bringing particles closer together.
4. **Increase Surface Area (for solids):** Crushing or powdering the solid exposes more particles for collision.
5. **Use of a Catalyst:** Provides an alternative pathway with a lower activation energy, meaning more collisions meet the energy requirement.



More frequent and more effective collisions = Faster reaction!

17.2 Give an example of a reaction which proceeds with the gain in mass.

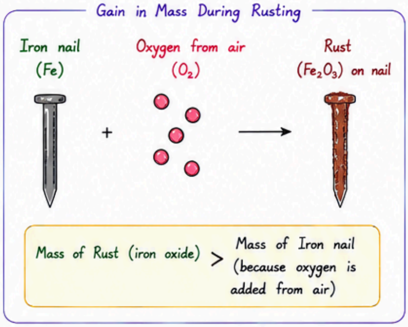
Any reaction involving the addition of oxygen (oxidation) or a combination reaction results in a gain in mass. The most classic example is:

Rusting of Iron (Oxidation):

$$4\,Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3$$

Iron + Oxygen → Iron oxide (Rust)

Here, iron combines with oxygen from the air to form iron oxide (rust). The mass of the rust produced is **greater** than the original mass of the iron because it includes the mass of the **absorbed oxygen gas**.



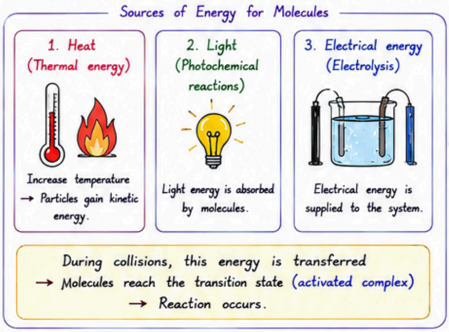
When oxygen is added, total mass increases!

17.3 From where do molecules get energy to attain a higher energy state?

Molecules attain a higher energy state (transition state) by absorbing energy from their surroundings. This energy can be supplied in the form of:

- **Heat (Thermal energy).**
- **Light (Photochemical reactions).**
- **Electrical energy (Electrolysis).**

The energy is transferred during collisions, where the **kinetic energy** of one molecule is transferred to another to raise it to the **activated complex** level.



Energy absorption leads to successful collisions!

Key Takeaway: More energy + More frequent collisions + Proper orientation = More successful collisions → **Higher reaction rate!**

Collision Theory & Reaction Rate

Constructed Response Questions (Section C)

Remember!
Lower E_a
→ Higher reaction rate!

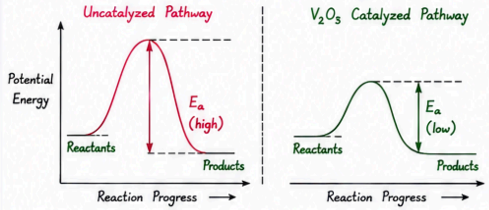
17.4 How does the presence of V_2O_5 catalyst lower the activation energy of the following reaction?

$$2SO_{2(g)} + O_{2(g)} \xrightarrow{V_2O_5} 2SO_{3(g)}$$

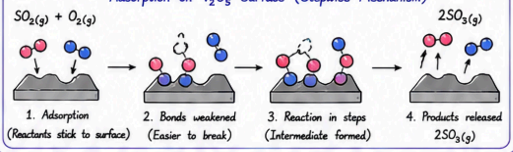
The V_2O_5 (Vanadium Pentoxide) catalyst lowers the activation energy by providing an alternative reaction pathway with a lower energy barrier.

- It works through adsorption: the gaseous reactants (SO_2 and O_2) are adsorbed onto the surface of the solid V_2O_5.
- This weakens the internal bonds of the reactants, making them easier to break.
- The reaction proceeds in steps involving intermediate compounds, requiring less initial energy than the uncatalyzed direct combination.

How V_2O_5 Lowers Activation Energy



Adsorption on V_2O_5 Surface (Stepwise Mechanism)

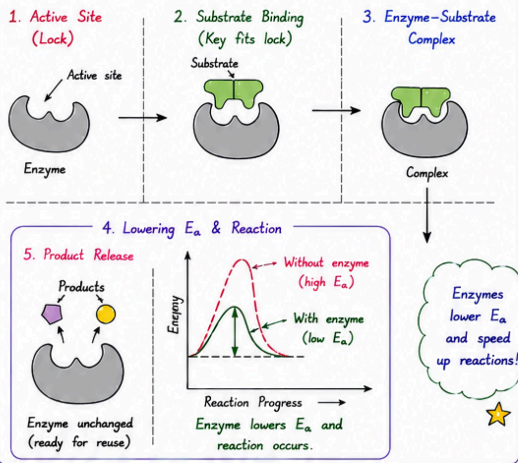


17.6 Explain the catalytic action of an enzyme.

Enzymes are biological catalysts (usually proteins) that speed up biochemical reactions in living organisms. Their catalytic action is explained by the "Lock and Key" Model:

1. **Active Site**: The enzyme has a specific active site (the lock) with a unique 3D shape.
2. **Substrate Binding**: The reactant molecule (substrate – the key) fits specifically into this active site.
3. **Enzyme–Substrate Complex**: When they bind, they form a complex. The active site changes shape slightly to perfectly embrace the substrate (Induced Fit).
4. **Lowering E_a**: The enzyme holds the substrate in the optimal orientation and creates a microenvironment that lowers the activation energy required for the reaction.
5. **Product Release**: The reaction occurs, products are formed, and because the products do not fit the active site anymore, they are released. The enzyme remains unchanged and ready to catalyze another reaction.

Enzyme Catalytic Cycle (Lock and Key Model)



17.7 If you desire to stop a reaction going on at 60°C, what action will you take?

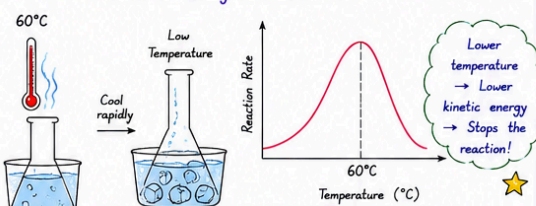
To stop the reaction, you need to lower the kinetic energy of the particles so they fall below the Activation Energy. The most effective action would be to:

Rapidly Cool the Reaction Mixture
(e.g., placing the reaction vessel in an ice bath).

This removes heat from the system. As the temperature drops below a certain threshold, the particles lose kinetic energy, collisions become less violent and less frequent, and the reaction effectively "freezes" or slows down to a near halt.

For enzyme-catalyzed reactions, this can also denature the enzyme, permanently stopping the reaction.

Effect of Cooling on Reaction Rate



What happens when we cool?
- ✔ Kinetic energy of particles decreases
- ✔ Fewer effective collisions (below E_a)
- ✔ Reaction rate decreases drastically
- ✔ Reaction stops or nearly stops

Key Takeaway: Increase successful collisions or lower activation energy → Faster reaction.
Lower temperature or remove energy → Slower or stop the reaction.