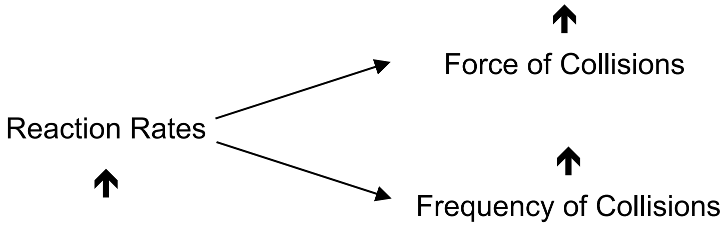
CONTENTS

CHANGING REACTION RATES



FACTORS THAT INCREASE THE FREQUENCY OF COLLISIONS

Factors that increase the **frequency of collisions** result in faster reaction rates.

Therefore, any event that enables more reacting particles to come in contact with one other will result in greater opportunities for collisions to occur.

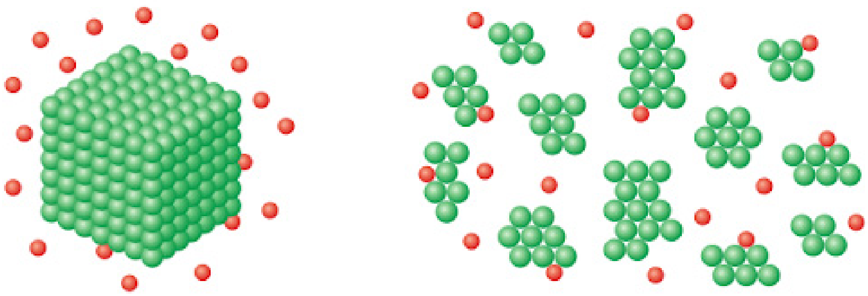
The probability of a **successful collision** increases, and therefore, reaction rates increase.

Factors that increase the frequency of collisions include:

- **Increasing the surface area of the reacting particles (keeping temperature constant).**

  As the surface area increases, more of the reacting particles come into contact with one other; resulting in more frequent collisions, a greater probability of a successful collision occurring and therefore, the reaction rate increases.

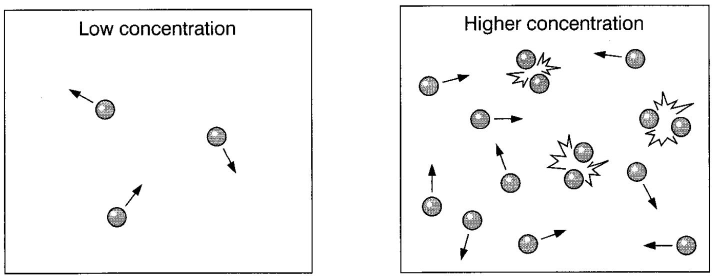
  Surface areas may be increased by grinding solids into powders, or by coating substances onto larger surfaces.



Low Exposed Surface Area **High Exposed Surface Area**

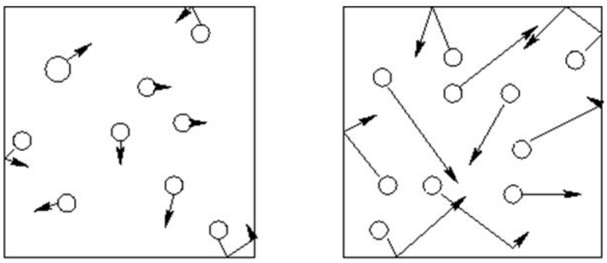
- **Increasing reactant concentrations (keeping volume and temperature constant).**

  As the concentration of a reactant increases (keeping volume and temperature constant), more of the reacting particles come into contact with one other. This results in more frequent collisions, a greater probability of a successful collision occurring, and hence the reaction rate increases.



- **Increasing the temperature.**

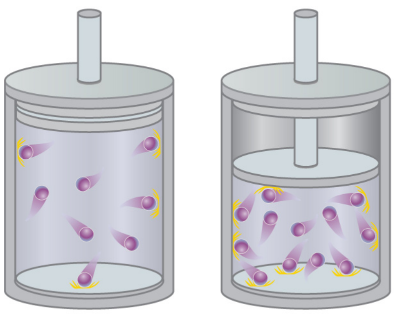
  At higher temperatures, particles move faster. This means that the probability of contact increases, resulting in a greater chance of successful collisions occurring and therefore, an **<u>increase</u>** in reaction rates.



Low Temperature **High Temperature**

Note: Not all reaction rates increase as the temperature of a system increases.

- **Increasing the pressure by decreasing the volume of the reaction mixture (keeping temperature constant).**



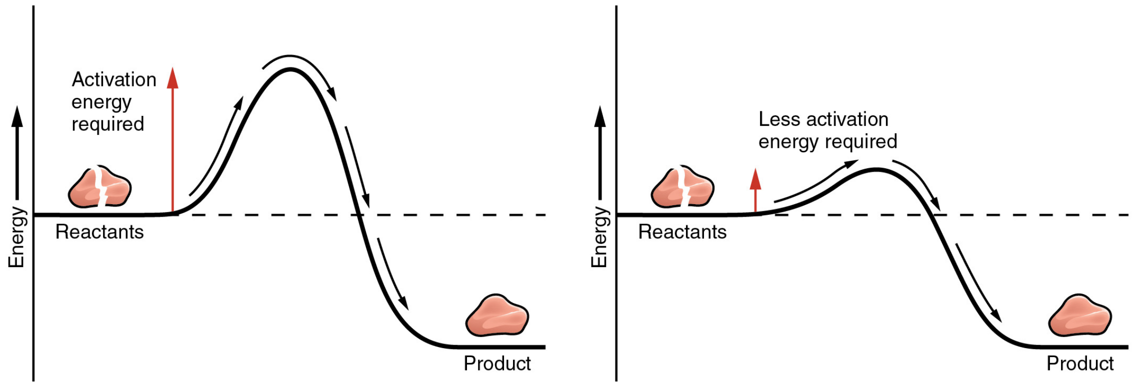
Low pressure High pressure

When the pressure is increased by decreasing the volume of a container at constant temperature, the reacting particles are forced to move more closely to one another. This increases the probability of a successful collision occurring, and therefore, reaction rates are increased.

- **Adding catalysts.**

  A catalyst is a substance that increases the rate of a chemical reaction without being consumed during the process.

  Catalysts function by providing an alternative, lower energy pathway for the formation of the activated complex, thereby lowering the activation energy requirement for the reaction. Greater numbers of particles will now have the kinetic energy needed to react.



Reaction Without a Catalyst **Reaction With a Catalyst**

Note:

The effects of catalysts can be compounded by coating them onto materials with a high surface area. The high surface area ensures that more reactants are in contact with the catalysts, and therefore, reaction rates are increased. For example, in the production of sulfuric acid, the catalyst V_2O_5 is spread out across large beds so as to maximise the exposed surface area.

IMPORTANT NOTE:

Each of the described changes affects the forward and back reaction rates to the same extent.

FACTORS THAT INCREASE THE ENERGY OF COLLIDING PARTICLES

Factors that increase the **energy of colliding particles** (e.g. temperature) will also result in faster reaction rates.

At higher temperatures, the kinetic energy of particles increases, meaning that collisions occur with a greater force. This results in greater numbers of particles having the minimum activation energy required to react – and a **substantial increase** in a reaction rate.

This can be explained using the Maxwell-Boltzmann Distribution curve.

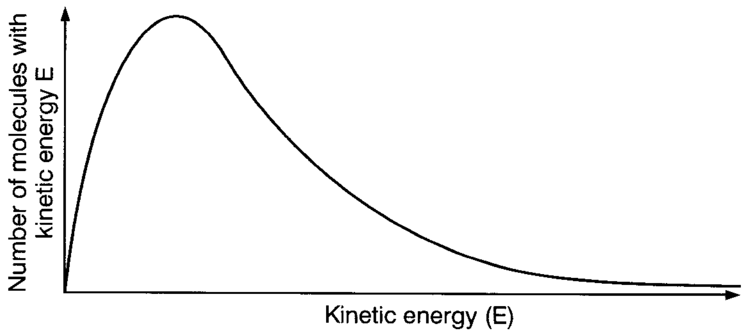
Note:

Not all reaction rates increase as the temperature of a system increases.
For example: The production of nitric acid.

THE MAXWELL-BOLTZMANN DISTRIBUTION CURVE

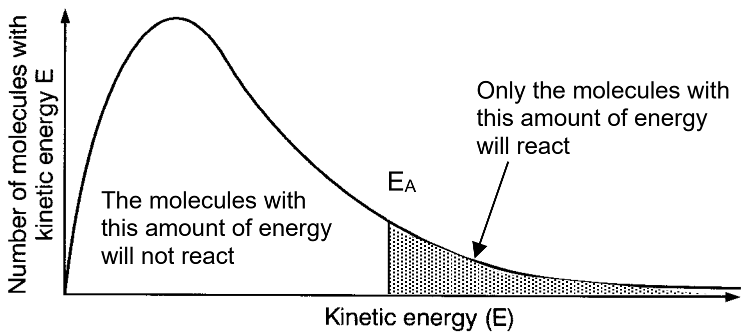
The distribution of kinetic energies in a gas at a given temperature is modelled by the Maxwell-Boltzmann distribution, which is shown below.

The vertical axis of the distribution graph gives the number of gas molecules per unit speed whereas the horizontal axis represents the kinetic energy or speed. The area under the curve represents the total number of molecules in the gas.

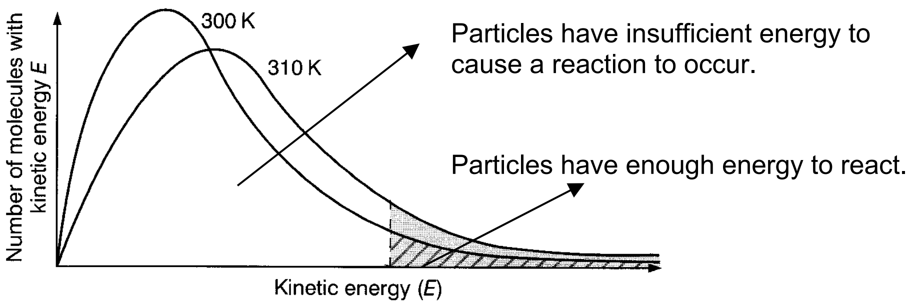


As shown in the graph above, particles have different kinetic energies or speeds at a given temperature. Some gas molecules will be moving very fast, some will be moving at moderate speeds, and some will hardly be moving at all. Therefore, temperature is a measure of the **average** kinetic energy of the system.

In order for a reaction to occur, the kinetic energy of a reacting particle must be equal to or greater than the activation energy requirement for that reaction. The number of particles with energy greater than the activation energy (E_A) for a particular reaction is represented by the shaded area under the curve below. Only those particles with energies in the shaded region can react.



As the temperature increases, more energy is available and therefore, more particles move at higher speeds, and the shaded region under the graph increases in size. This means that the proportion of particles that now have the energy needed to react has increased, resulting in faster reaction rates.



Note:

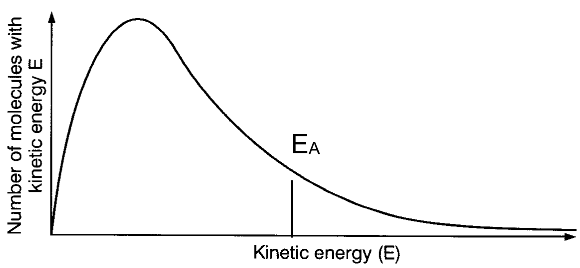
Increasing the temperature doesn't make much of a difference to the energy of each individual particle, but it does have a large impact on the proportion of particles with enough energy to react.

The area under the Maxwell-Boltzmann curve at different temperatures is the same.

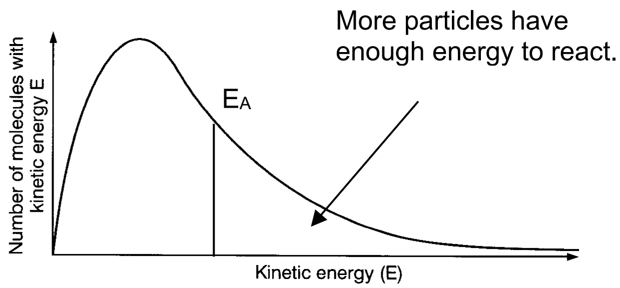
CATALYSTS AND THE MAXWELL-BOLTZMANN DISTRIBUTION CURVE

Adding a catalyst has no effect on the shape of the Maxwell-Boltzmann Distribution curve. The minimum amount of energy needed to react, however, decreases, enabling more particles to react. The probability of a successful collision increases and therefore, the reaction rate increases as well.

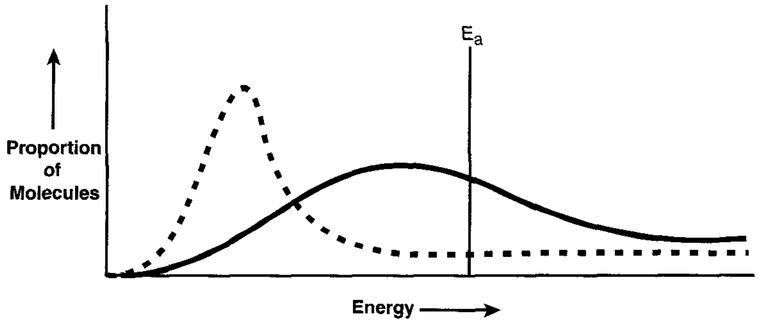
No Catalyst:



Catalyst Present:



QUESTION 3
The distribution of kinetic energies in a gaseous mixture at two different temperatures is given below.



(a) Which curve would best represent the reaction system at the higher temperature?

(b) Which curve best describes the reaction with the slowest reaction rate? Give a reason for your answer.

QUESTION 4
In a particular reaction system, a 5% increase in temperature resulted in the doubling of the rate of reaction.

(a) Provide a reason why such a large increase in reaction rate was observed with such a small change in temperature.

(b) What changes would be observed in the rate of a back reaction as the result of such change?