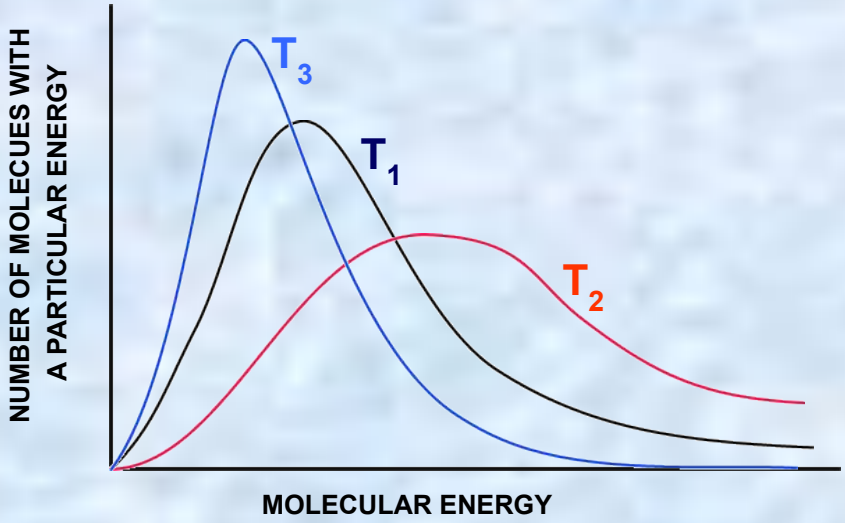
RATES OF REACTION - 1

A guide for A level students



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2015
SPECIFICATIONS

RATES OF REACTION

INTRODUCTION

This *Powerpoint* show is one of several produced to help students understand selected topics at AS and A2 level Chemistry. It is based on the requirements of the AQA and OCR specifications but is suitable for other examination boards.

Individual students may use the material at home for revision purposes or it may be used for classroom teaching if an interactive white board is available.

Accompanying notes on this, and the full range of AS and A2 topics, are available from the KNOCKHARDY SCIENCE WEBSITE at...

www.knockhardy.org.uk/sci.htm

Navigation is achieved by...

either clicking on the grey arrows at the foot of each page

or using the left and right arrow keys on the keyboard

RATES OF REACTION

CONTENTS

RATES OF REACTION

Before you start it would be helpful to…

- know how the energy changes during a chemical reaction
- know the basic ideas of Kinetic Theory
- know the importance of catalysts in industrial chemistry

CHEMICAL KINETICS

Introduction

Chemical kinetics is concerned with the dynamics of chemical reactions such as the way reactions take place and the rate (speed) of the process.

One can look at the QUALITATIVE and the QUANTITATIVE aspects of how the rate (speed) of a reaction can be changed.

Chemical kinetics plays an important part in industrial chemistry because the time taken for a reaction to take place and the energy required are of great economic importance. The kinetic aspect of chemistry is often at odds with the thermodynamic side when considering the best conditions for industrial production.

The concepts met in this topic can be applied throughout the theoretical and practical aspects of chemistry.

The basis of the study is COLLISION THEORY...

COLLISION THEORY

Collision theory states that...

- particles must **COLLIDE** before a reaction can take place
- not all collisions lead to a reaction
- reactants must possess at least a minimum amount of energy – **ACTIVATION ENERGY**

plus

- particles must approach each other in a certain relative way - **STERIC EFFECT**

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According to collision theory, to increase the rate of reaction you need...

more frequent collisions increase particle speed or have more particles present

more successful collisions give particles more energy or lower the activation energy

INCREASING THE RATE

The following methods may be used to increase the rate of a chemical reaction

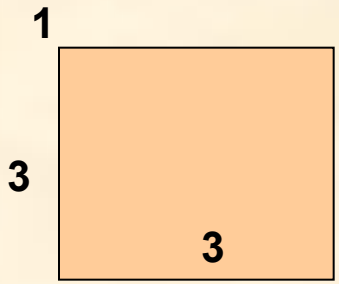
- **INCREASE THE SURFACE AREA OF SOLIDS**
- **INCREASE TEMPERATURE**
- **SHINE LIGHT**
- **ADD A CATALYST**
- **INCREASE THE PRESSURE OF ANY GASES**
- **INCREASE THE CONCENTRATION OF REACTANTS**

INCREASING SURFACE AREA

- **Increases chances of a collision - more particles are exposed**
- **Powdered solids react quicker than larger lumps**
- **Catalysts (e.g. in catalytic converters) are finely divided for this reason**

+

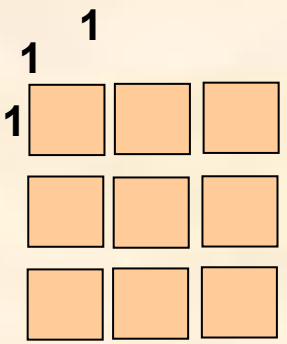
In many organic reactions there are two liquid layers, one aqueous, the other non-aqueous. Shaking the mixture increases the reaction rate as an emulsion is often formed and the area of the boundary layers is increased giving more collisions.



SURFACE AREA

9+9+3+3+3+3 = 30 sq units

CUT THE SHAPE INTO SMALLER PIECES



SURFACE AREA

9 x (1+1+1+1+1+1) = 54 sq units

INCREASING TEMPERATURE

Effect increasing the temperature increases the rate of a reaction
particles get more energy so can overcome the energy barrier
particle speeds also increase so collisions are more frequent

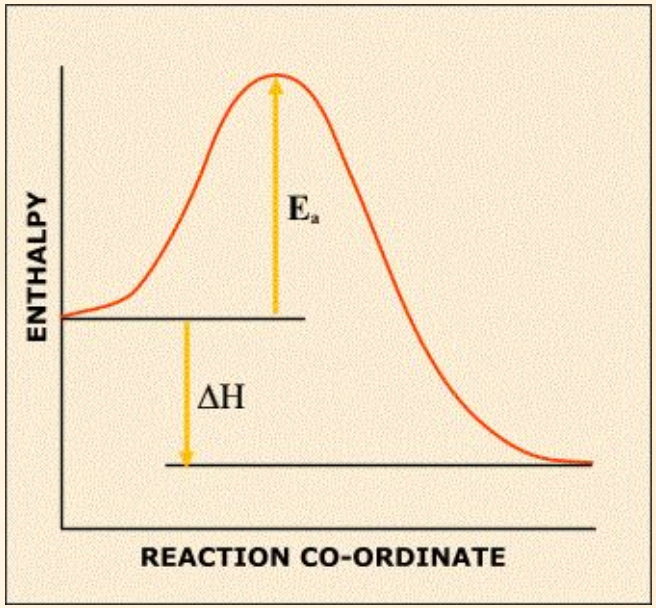
ENERGY CHANGES DURING A REACTION

As a reaction takes place the enthalpy of the system rises to a maximum, then falls

A minimum amount of energy is required to overcome the ACTIVATION ENERGY (E_a).

Only those reactants with energy equal to, or greater than, this value will react.

If more energy is given to the reactants then they are more likely to react.



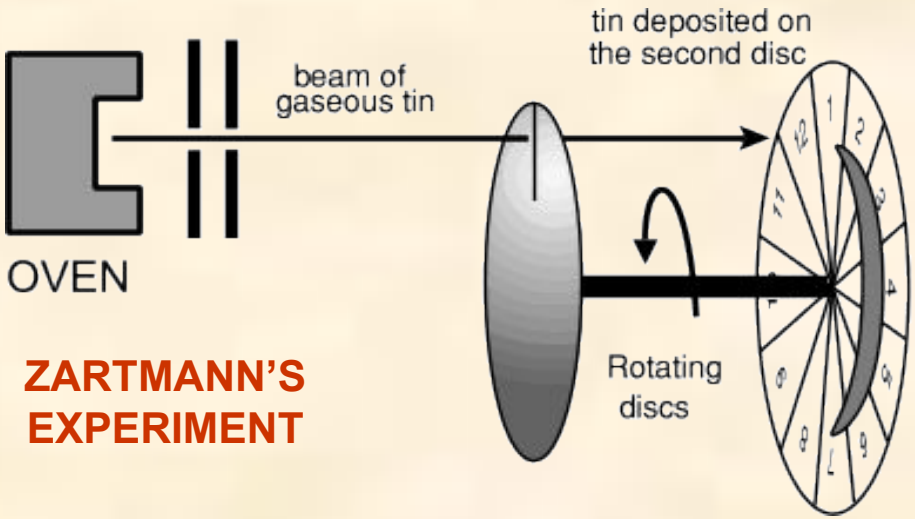
Typical energy profile diagram for an exothermic reaction

INCREASING TEMPERATURE

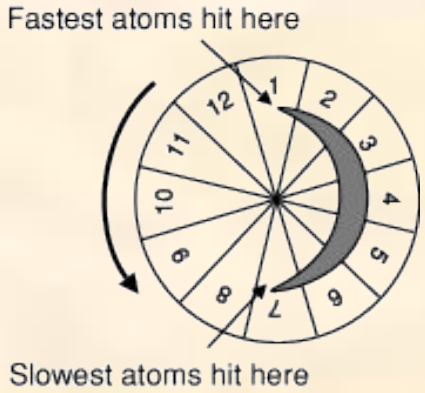
According to KINETIC THEORY, all particles must have energy; the greater their temperature, the more energy they possess. The greater their KINETIC ENERGY the faster they travel.

ZARTMANN heated tin in an oven and directed the gaseous atoms at a rotating disc with a slit in it. Any atoms which went through the slit hit the second disc and solidified on it. Zartmann found that the deposit was spread out and was not the same thickness throughout.

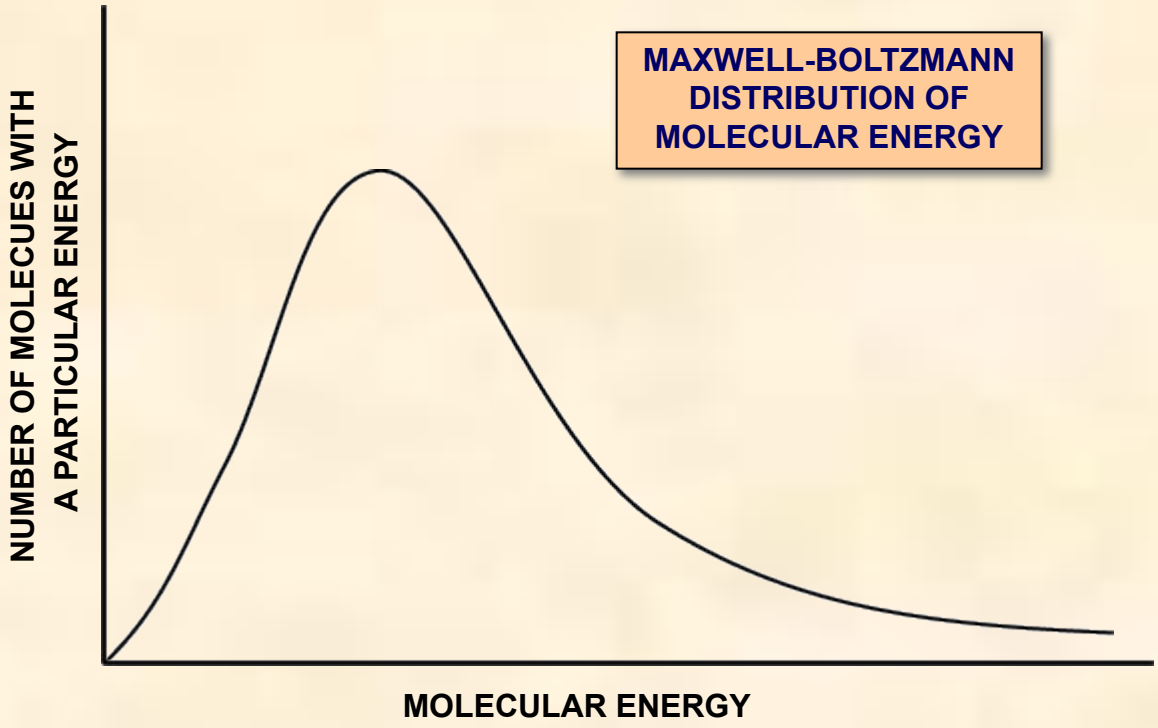
This proved that there was a spread of velocities and the distribution was uneven.



ZARTMANN'S EXPERIMENT



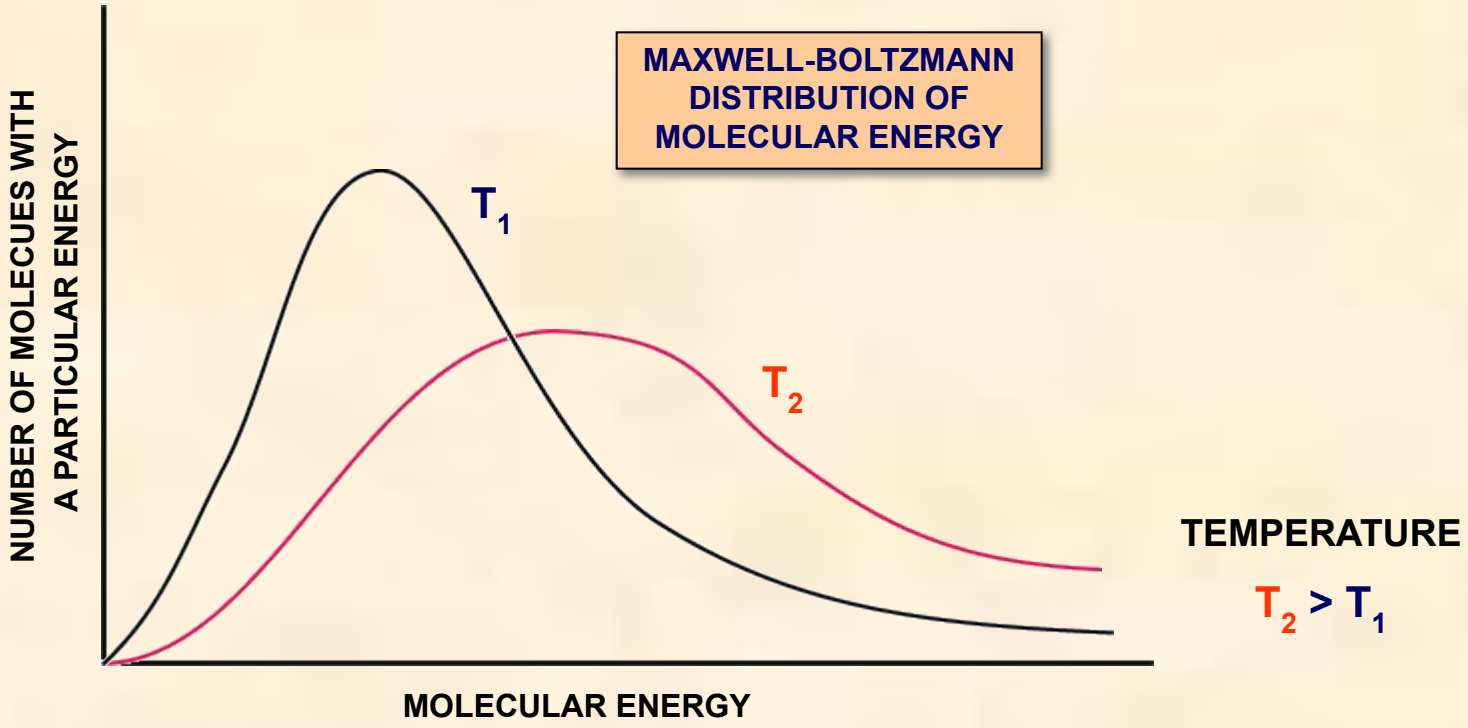
INCREASING TEMPERATURE



Experiments showed that, due to the many collisions taking place between molecules, there is a spread of molecular energies and velocities.

no particles have zero energy/velocity
some have very low and some have very high energies/velocities
most have intermediate velocities.

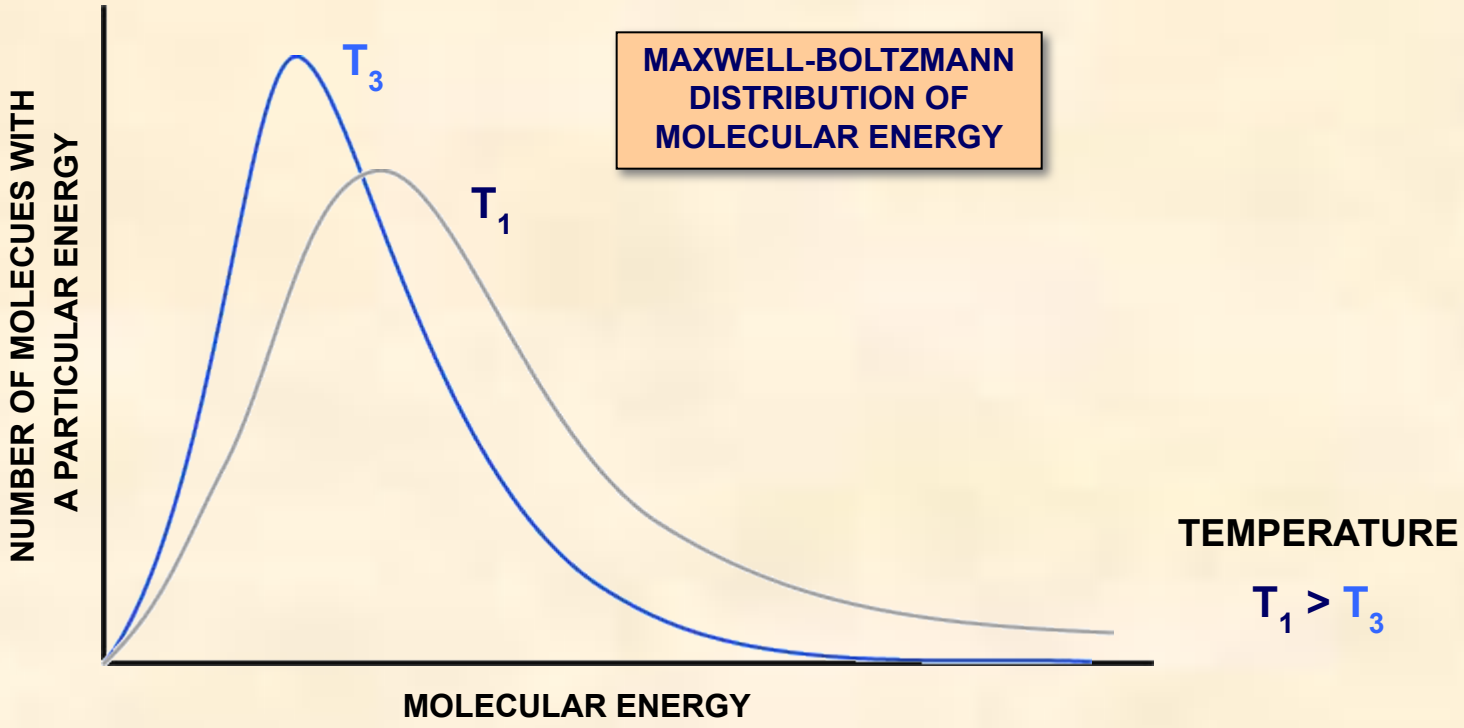
INCREASING TEMPERATURE



Increasing the temperature alters the distribution

- get a shift to higher energies/velocities
- curve gets broader and flatter due to the greater spread of values
- area under curve stays constant - corresponds to the total number of particles

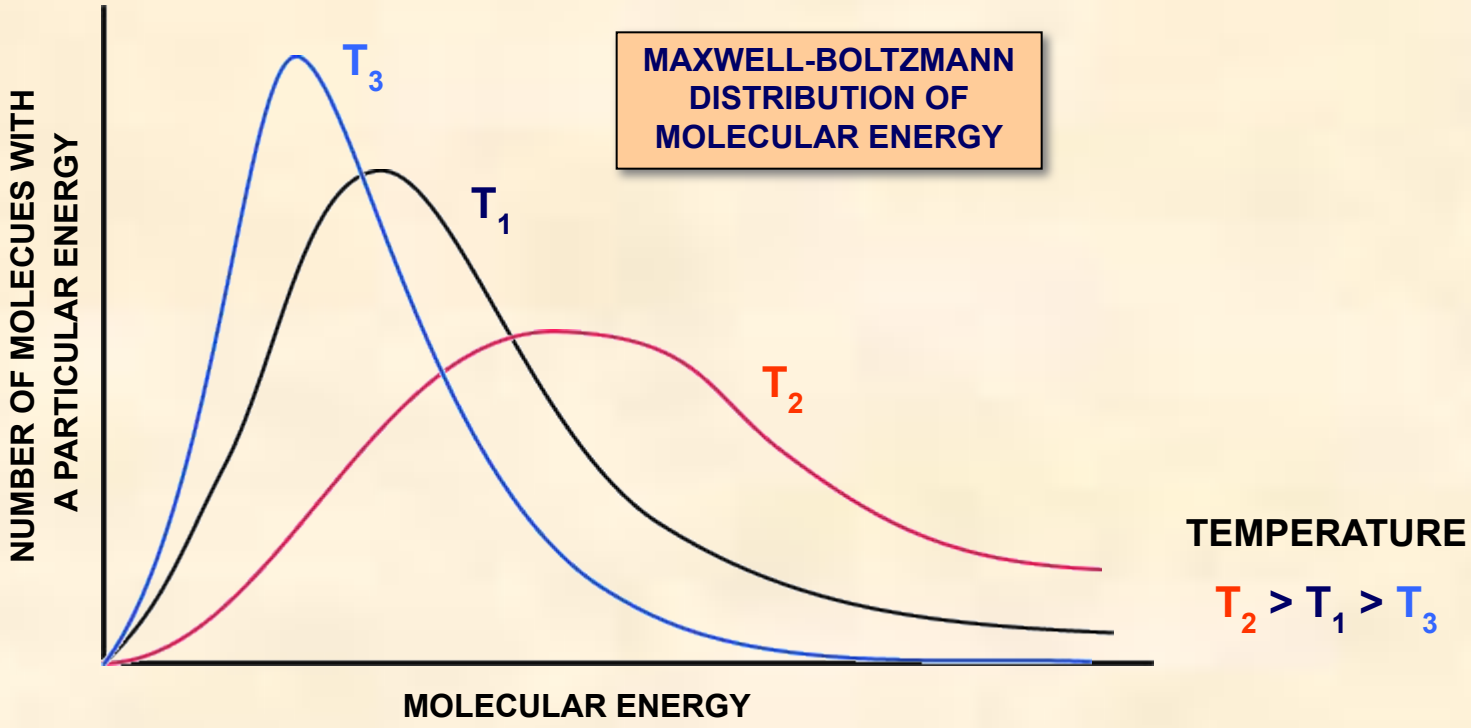
INCREASING TEMPERATURE



Decreasing the temperature alters the distribution

- get a shift to lower energies/velocities
- curve gets narrower and more pointed due to the smaller spread of values
- area under curve stays constant

INCREASING TEMPERATURE



REVIEW

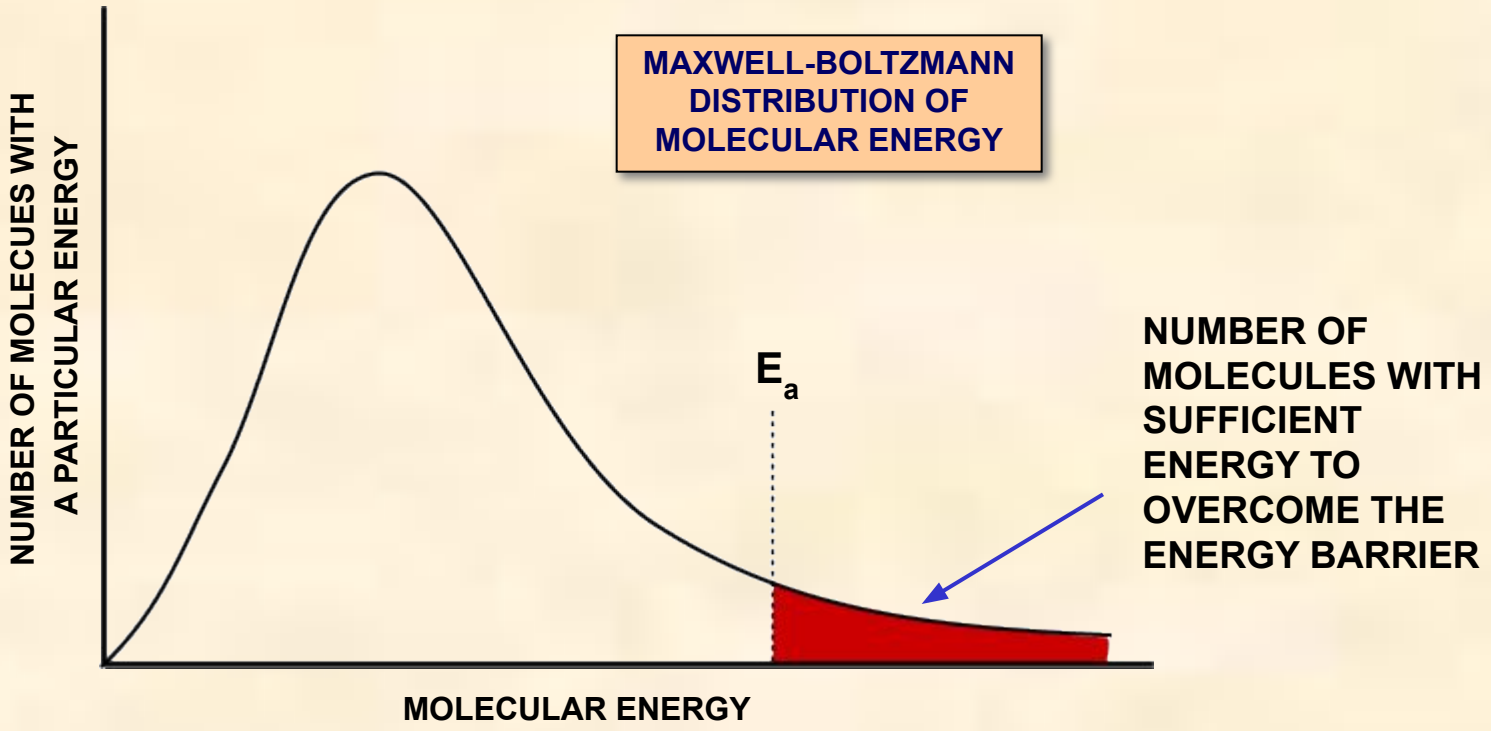
no particles have zero energy/velocity

some particles have very low and some have very high energies/velocities

most have intermediate velocities

as the temperature increases the curves flatten, broaden and shift to higher energies

INCREASING TEMPERATURE

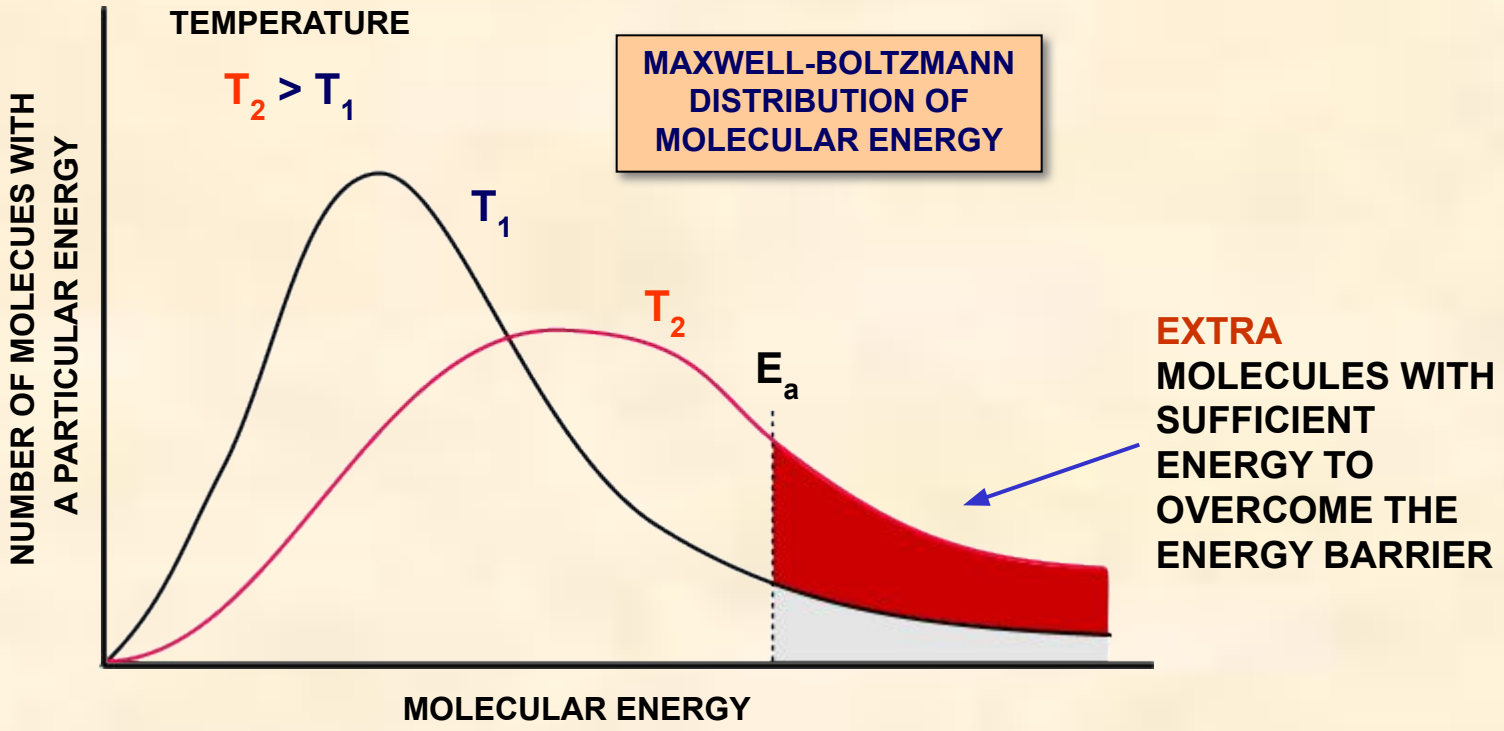


ACTIVATION ENERGY - E_a

The Activation Energy is the minimum energy required for a reaction to take place

The area under the curve beyond E_a corresponds to the number of molecules with sufficient energy to overcome the energy barrier and react.

INCREASING TEMPERATURE



Explanation

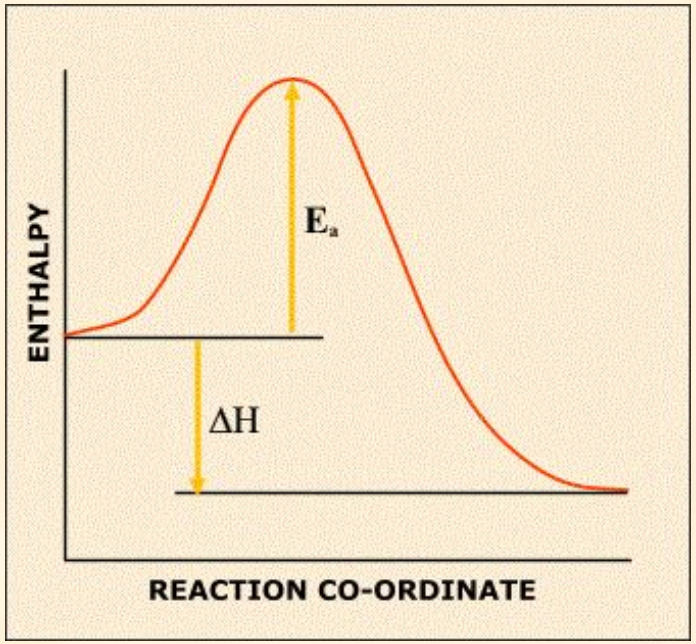
increasing the temperature gives more particles an energy greater than E_a

more reactants are able to overcome the energy barrier and form products

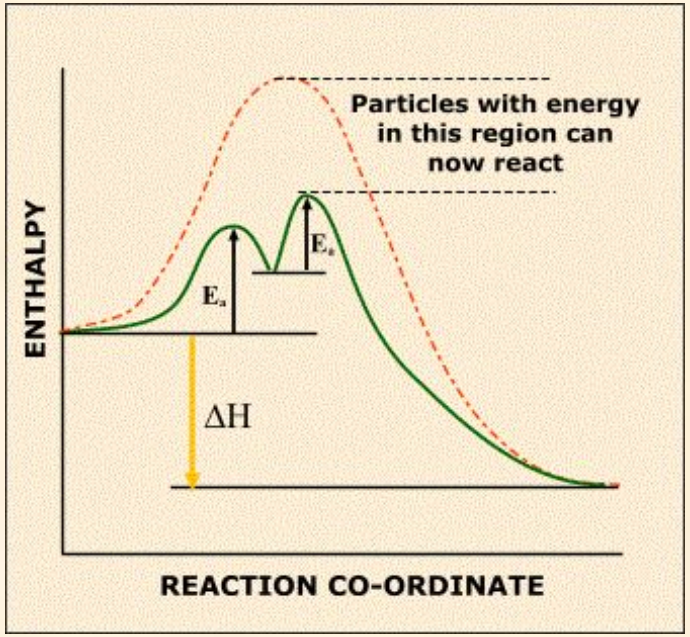
a small rise in temperature can lead to a large increase in rate

ADDING A CATALYST

- Catalysts provide an alternative reaction pathway with a lower Activation Energy (E_a)
- Decreasing the Activation Energy means that more particles will have sufficient energy to overcome the energy barrier and react
- Catalysts remain chemically unchanged at the end of the reaction.

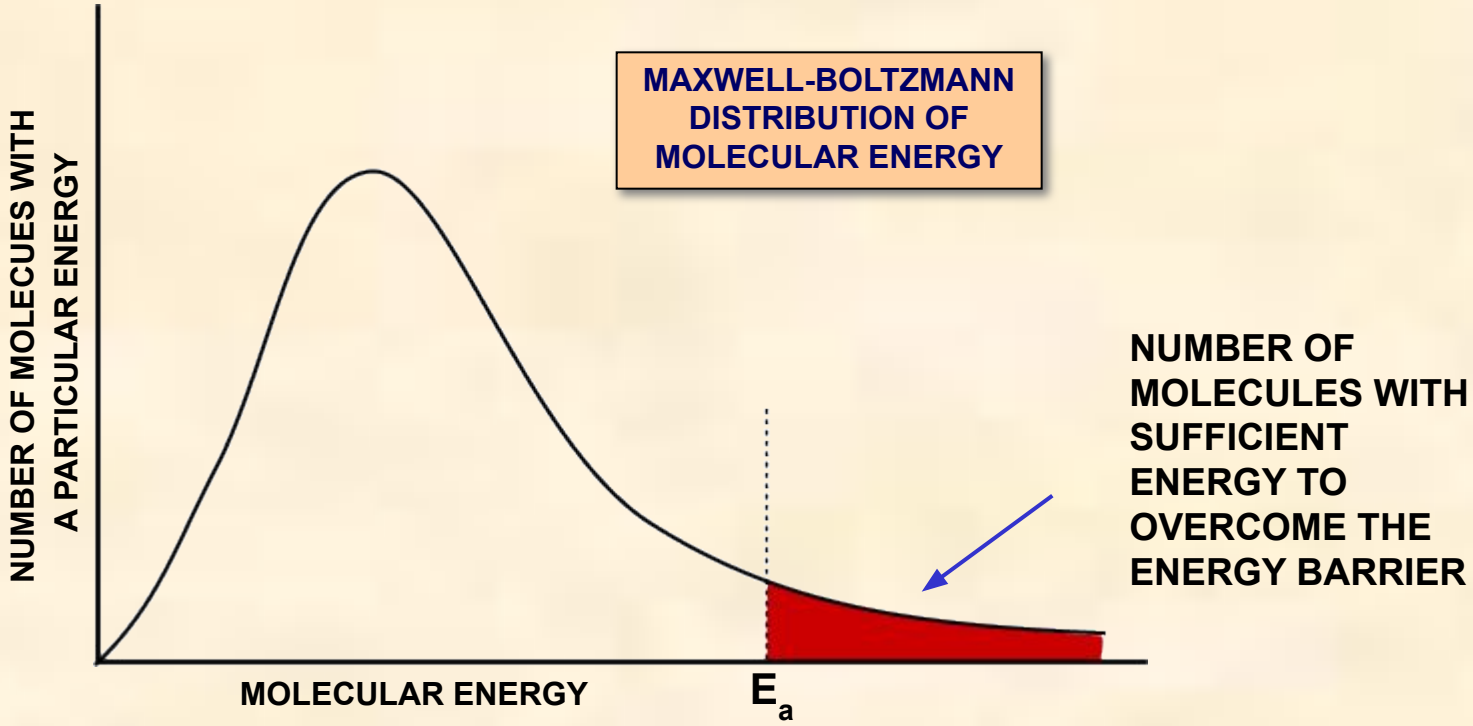


WITHOUT A CATALYST



WITH A CATALYST

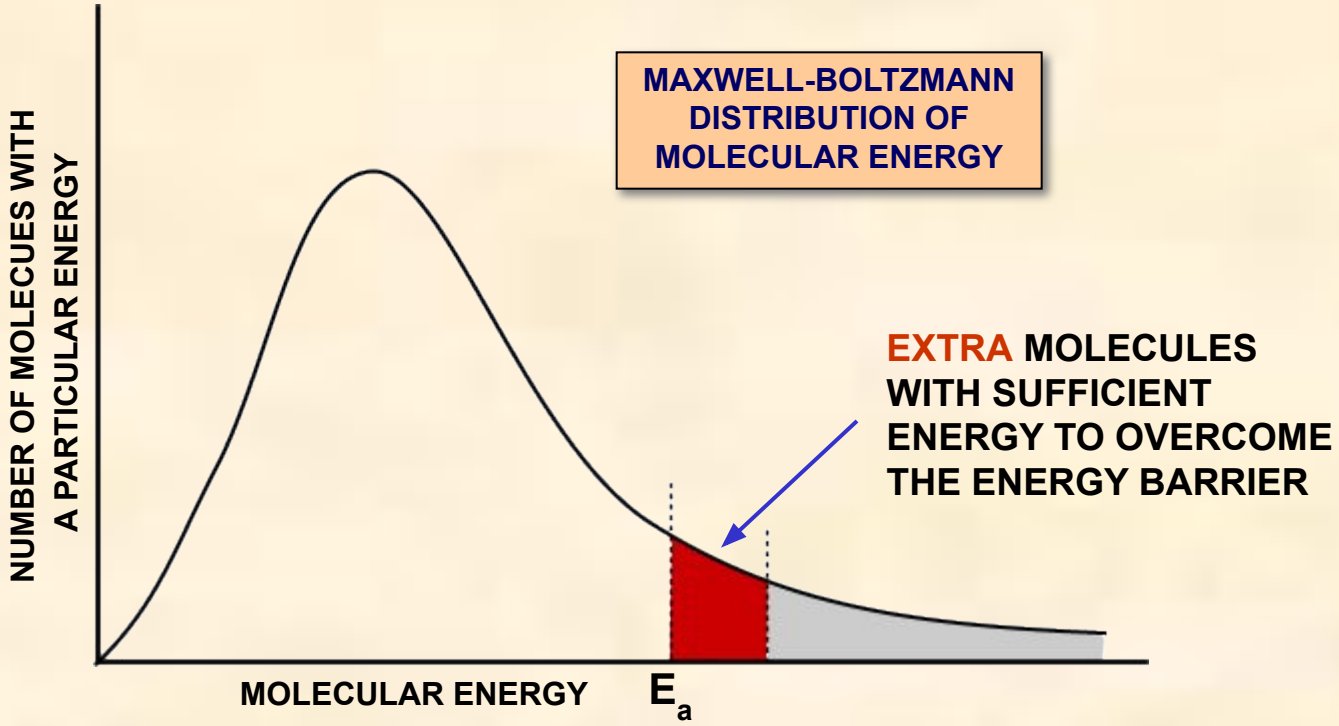
ADDING A CATALYST



The area under the curve beyond E_a corresponds to the number of molecules with sufficient energy to overcome the energy barrier and react.

If a catalyst is added, the Activation Energy is lowered - E_a will move to the left.

ADDING A CATALYST



The area under the curve beyond E_a corresponds to the number of molecules with sufficient energy to overcome the energy barrier and react.

Lowering the Activation Energy, E_a, results in a greater area under the curve after E_a showing that more molecules have energies in excess of the Activation Energy

CATALYSTS - A REVIEW

- work by providing an alternative reaction pathway with a lower Activation Energy
- using catalysts avoids the need to supply extra heat - safer and cheaper
- catalysts remain chemically unchanged at the end of the reaction.

Types	Homogeneous Catalysts	Heterogeneous Catalysts
	same phase as reactants	different phase to reactants
	e.g. CFC's and ozone	e.g. Fe in Haber process

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CATALYSTS DO NOT AFFECT THE POSITION OF ANY EQUILIBRIUM

- **but they do affect the rate at which equilibrium is attained**
- **a lot is spent on research into more effective catalysts - the savings can be dramatic**
- **catalysts need to be changed regularly as they get 'poisoned' by other chemicals**
- **catalysts are used in a finely divided state to increase the surface area**

CATALYSTS - WHY USE THEM?

Catalysts are widely used in industry because they…

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can reduce pollution **CATALYTIC CONVERTERS**

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can reduce pollution CATALYTIC CONVERTERS

SHINING LIGHT

certain reactions only

- shining a suitable light source onto some reactants increases the rate of reaction
- the light - often U.V. - provides energy to break bonds and initiate a reaction
- the greater the intensity of the light, the greater the effect

Examples a) the reaction between methane and chlorine - *see alkanes*

b) the darkening of silver salts - *as used in photography*

c) the reaction between hydrogen and chlorine

Equation $H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$

Bond enthalpies H-H 436 kJ mol^{-1} Cl-Cl 242 kJ mol^{-1}

Mechanism

$Cl_2 \longrightarrow 2Cl\bullet$ - - - - - INITIATION

$H_2 + Cl\bullet \longrightarrow HCl + H\bullet$ - - - - - PROPAGATION

$H\bullet + Cl_2 \longrightarrow HCl + Cl\bullet$

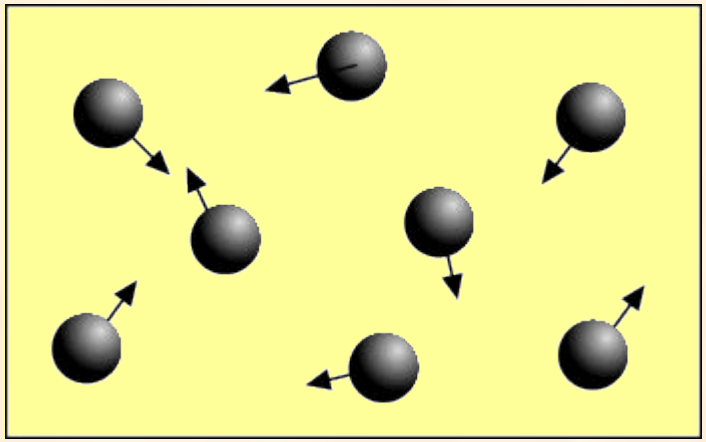
$2Cl\bullet \longrightarrow Cl_2$ - - - - - TERMINATION

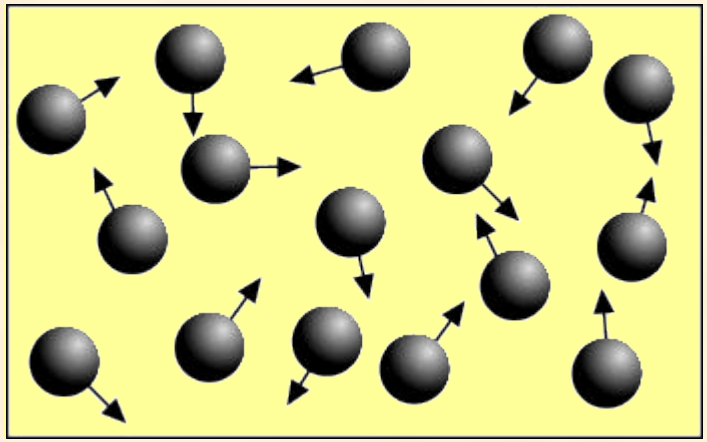
$2H\bullet \longrightarrow H_2$

$H\bullet + Cl\bullet \longrightarrow HCl$

INCREASING THE PRESSURE

- increasing the pressure forces gas particles closer together
- this increases the frequency of collisions so the reaction rate increases
- many industrial processes occur at high pressure to increase the rate... but it can adversely affect the position of equilibrium and yield

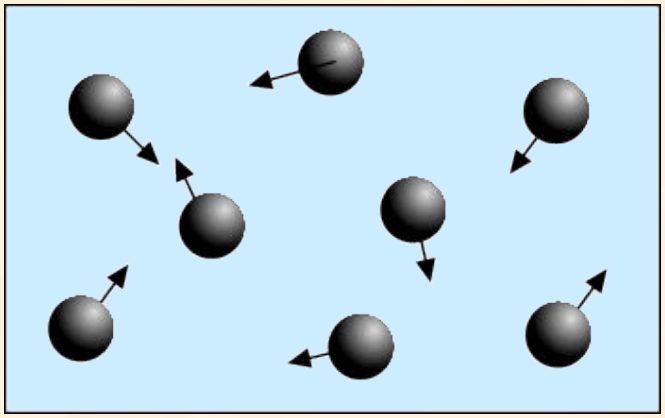




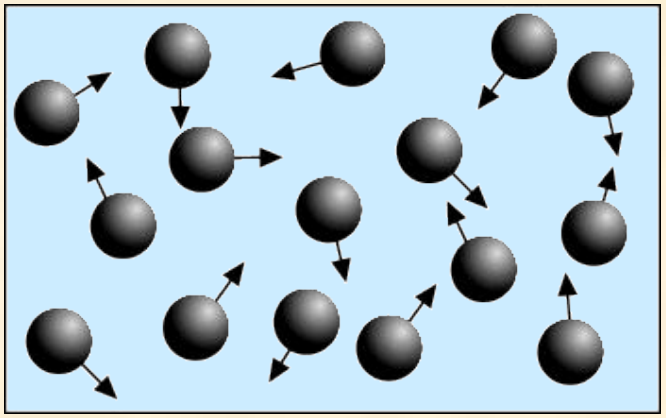
The more particles there are in a given volume, the greater the pressure
The greater the pressure, the more frequent the collisions
The more frequent the collisions, the greater the chance of a reaction

INCREASING CONCENTRATION

Increasing concentration = more frequent collisions = increased rate of reaction



Low concentration = fewer collisions



Higher concentration = more collisions

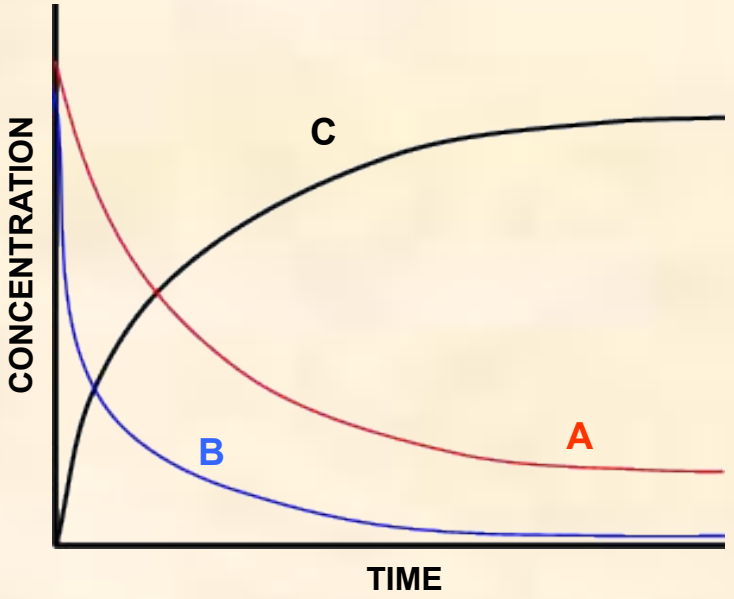
However, increasing the concentration of some reactants can have a greater effect than increasing others

RATE CHANGE DURING A REACTION

Reactions are fastest at the start and get slower as the reactants concentration drops.

In a reaction such as A + 2B ——> C the concentrations might change as shown

Reactants (A and B)
Concentration decreases with time
Product (C)
Concentration increases with time



- **the steeper the curve the faster the rate of the reaction**
- **reactions start off quickly because of the greater likelihood of collisions**
- **reactions slow down with time as there are fewer reactants to collide**

MEASURING THE RATE

Experimental Investigation

- the variation in concentration of a reactant or product is followed with time
- the method depends on the reaction type and the properties of reactants/products

e.g. Extracting a sample from the reaction mixture and analysing it by titration.
- this is often used if an acid is one of the reactants or products

Using a colorimeter or UV / visible spectrophotometer.

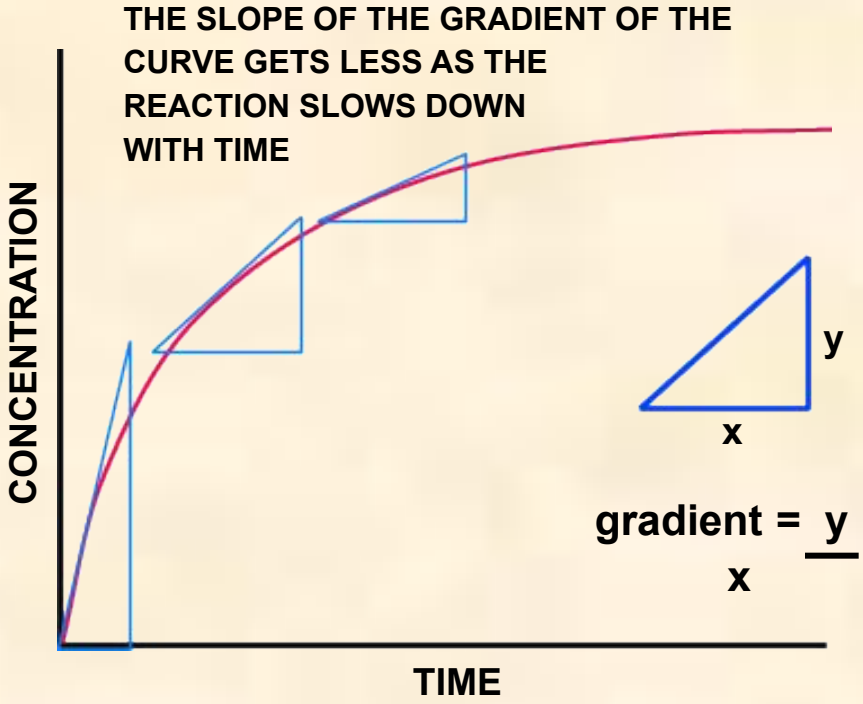
Measuring the volume of gas evolved.

Measuring the change in conductivity.

More details of these and other methods can be found in suitable text-books.

MEASURING THE RATE

RATE How much concentration changes with time. It is the equivalent of velocity.



- the rate of change of concentration is found from the slope (gradient) of the curve
- the slope at the start of the reaction will give the INITIAL RATE
- the slope gets less (showing the rate is slowing down) as the reaction proceeds

REVISION CHECK

What should you be able to do?

Recall and understand the statements in Collision Theory

Know six ways to increase the rate of reaction

Explain qualitatively how each way increases the rate of reaction

Understand how the Distribution of Molecular Energies is used to explain rate increase

Understand how the importance of Activation Energy

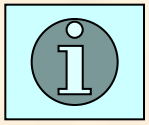
Recall and understand how a catalyst works by altering the Activation Energy

Explain how the rate changes during a chemical reaction

CAN YOU DO ALL OF THESE? YES NO

You need to go over the relevant topic(s) again

Click on the button to return to the menu



WELL DONE!

Try some past paper questions

RATES OF REACTION - 1

The End