AS level Rates of Reaction

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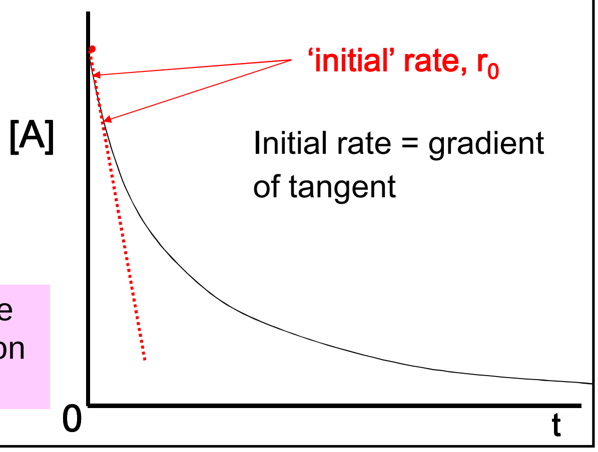
Rate of Reaction

The rate of reaction is defined as the change in concentration of a substance in unit time

Its usual unit is mol $dm^{-3}s^{-1}$

When a graph of concentration of reactant is plotted vs time, the gradient of the curve is the rate of reaction.

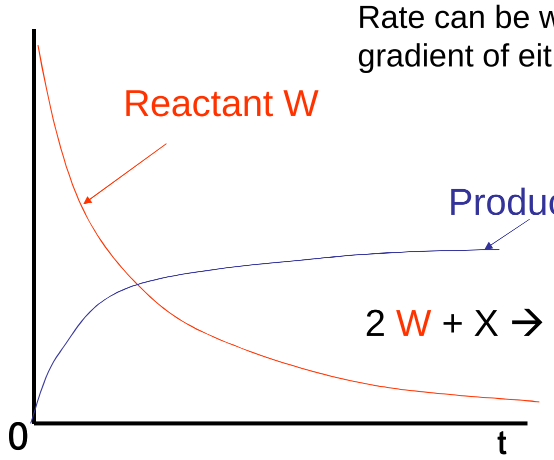
The initial rate is the rate at the start of the reaction where it is fastest



Plotting concentration of products and reactants

Graphs of concentration of reactants or products can be drawn

Rate can be worked out from the gradient of either graph

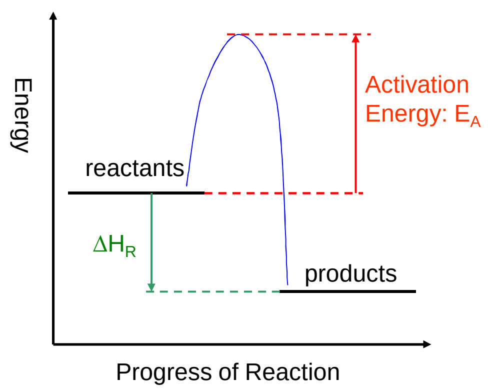


Collision theory

Reactions can only occur when collisions take place between particles having sufficient energy.

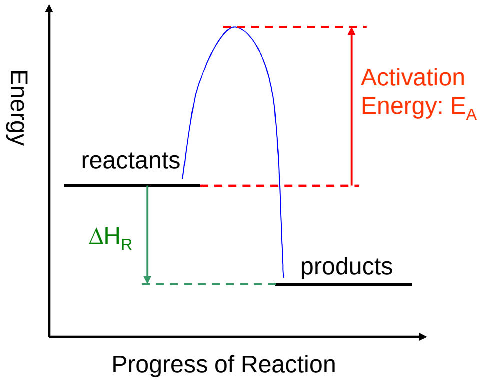
This minimum energy is called the **Activation Energy**

The **Activation Energy** is defined as the minimum energy which particles need to collide to start a reaction

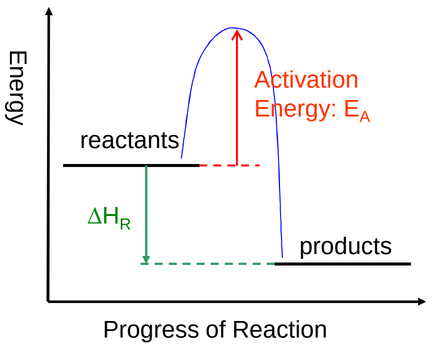


Activation Energy

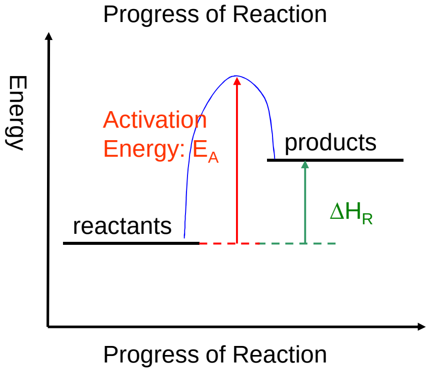
Molecules will only react if they collide with enough energy to break the relevant bonds in one or either of the reactant molecules. This is the minimum energy required and is called the activation energy.



The activation energy is usually equal to the energy required to break the relevant bonds in the reactants.



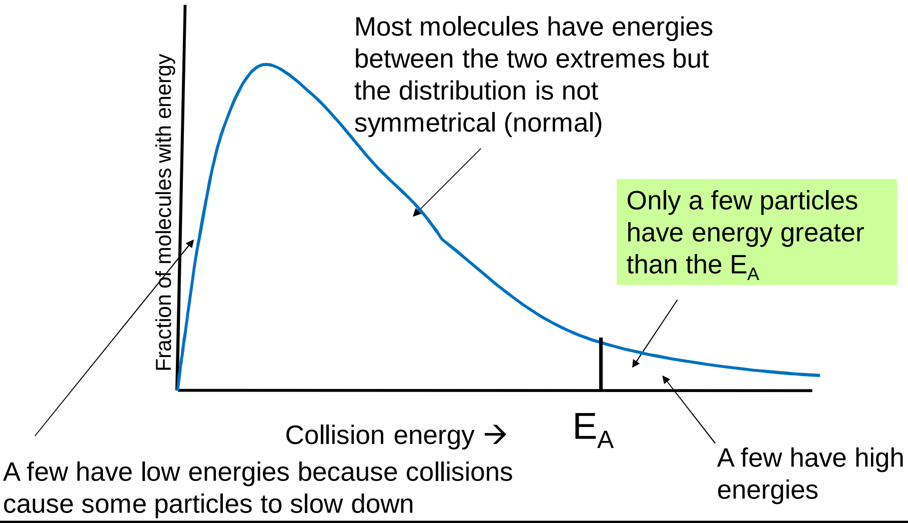
Reaction profile for an EXOTHERMIC reaction



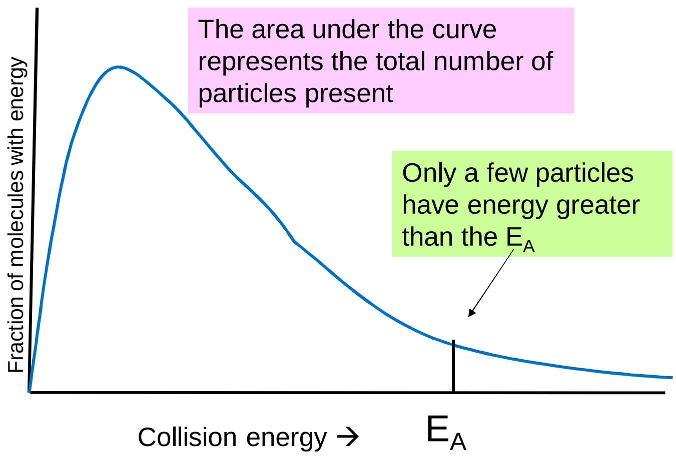
Reaction profile for an ENDOTHERMIC reaction

Maxwell Boltzmann Distribution

The Maxwell-Boltzmann energy distribution shows that any one temperature the molecules in a gas have a range of different energies.



Maxwell Boltzmann Distribution



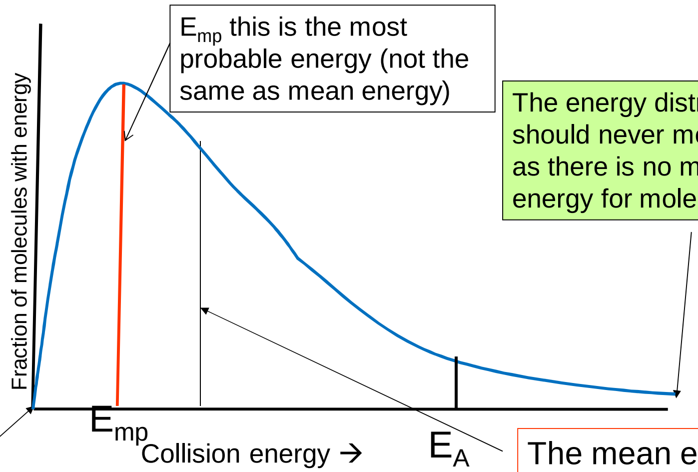
How can a reaction go to completion if few particles have energy greater than Ea?

Particles can gain energy through collisions

Drawing Maxwell Boltzmann Distributions

E_{mp} this is the most probable energy (not the same as mean energy)

The energy distribution should never meet the x axis, as there is no maximum energy for molecules

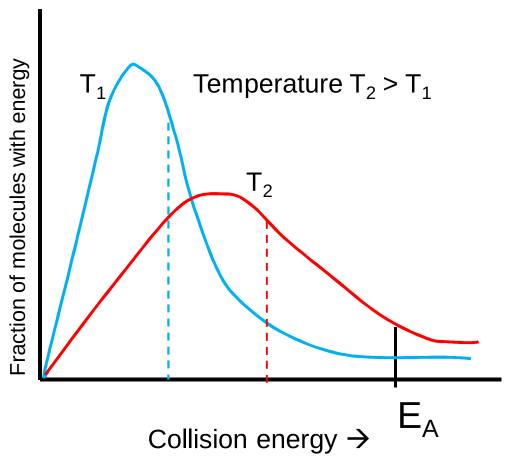


The energy distribution should go through the origin because the are no molecules with no energy

The mean energy of the particles is not at the peak of the curve

Maxwell-Boltzmann Energy Distribution

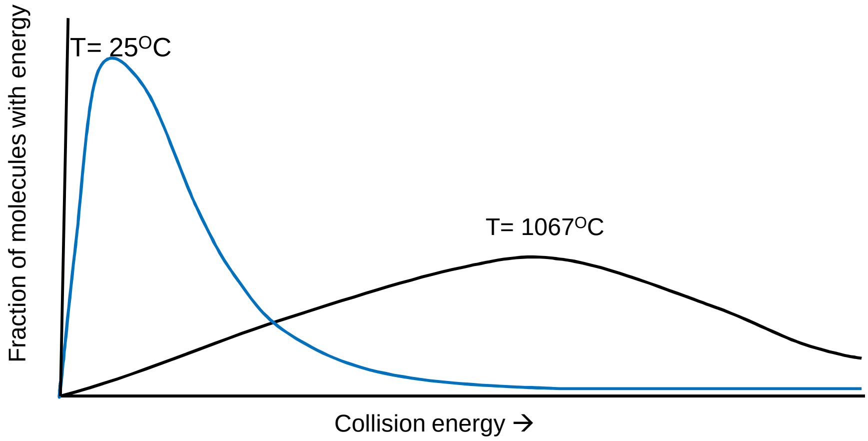
Each curve shows the distribution of molecular energies for the molecules of a gas at a particular temperature.



As the temperature increases the distribution shifts towards having more molecules with higher energies

The total area under the curve should remain constant because the total number of particles is constant

Energy Distributions for large temperature differences



At higher temperatures the molecules have a wider range of energies than at lower temperatures.

Effect of Increasing Concentration

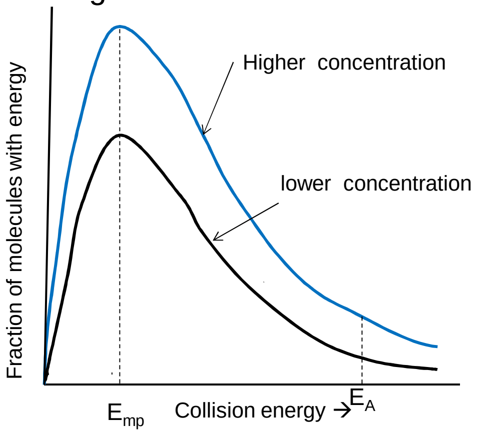
At higher concentrations there are more **particles per unit volume** (or more crowded) and so **the particles collide with a greater frequency** and there will be a **higher frequency of effective collisions**

If a question mentions a **doubling** of concentration/rate then make sure you mention **double** the number of particles per unit volume and **double** the frequency of effective collisions.

Effect of Increasing Concentration on Energy Distribution

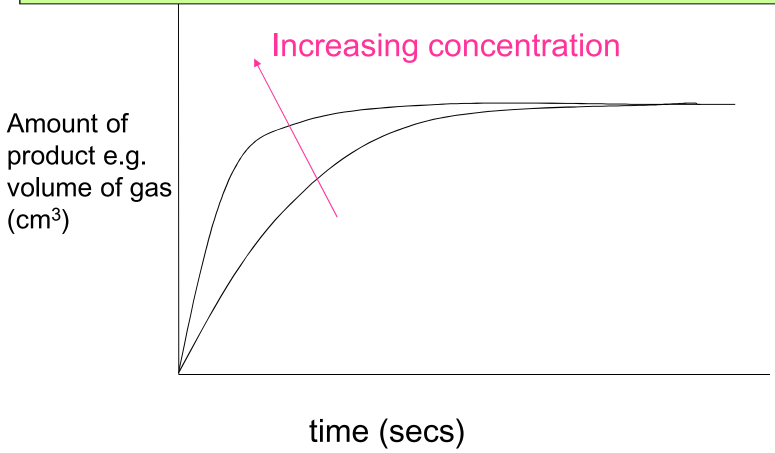
If concentration increases, the shape of the energy distribution curves do not change (i.e. the peak is at the same energy)

They curves will be higher, and the area under the curves will be greater because there are more particles

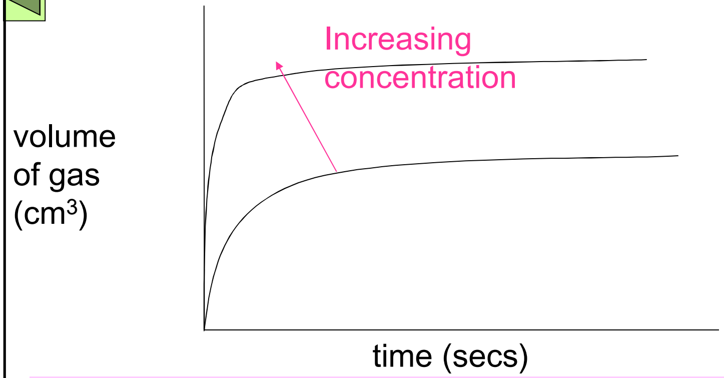


More molecules have energy > E_A (although not a greater proportion)

Effect of increasing concentration on rate graphs



These graphs show what would happen between a solid reactant and excess solution whose concentration is increased

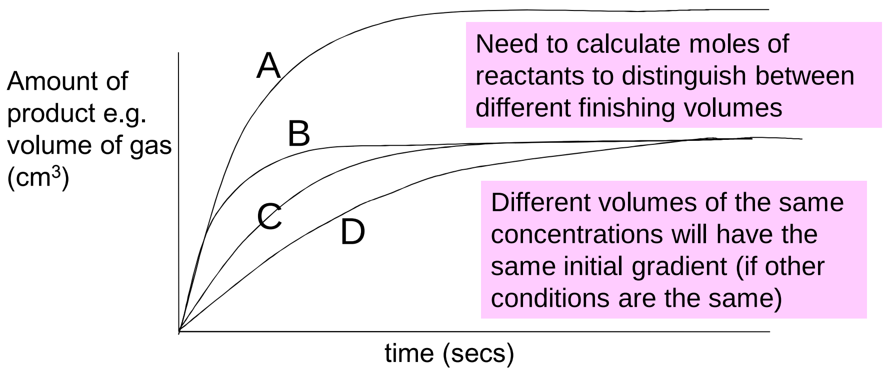


If the solid reactant is in excess, then increasing concentration or increasing the volume of 'acid' will increase the total volume of product produced.

The final amount of product will be proportional to the moles of reactant that is not in excess

Moles = conc X vol

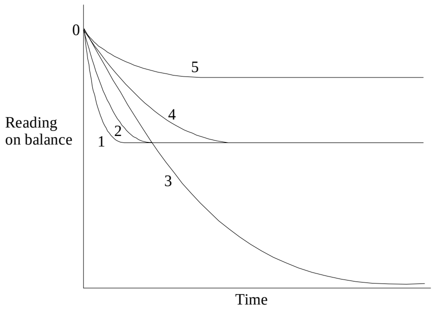
Comparing reaction curves



1. 50 cm^3 of 0.1M HCl and small marble chips
2. 50 cm^3 of 0.2 M HCl and small marble chips
3. 25 cm^3 of 0.2 M HCl and small marble chips
4. 50 cm^3 of 0.1M HCl and medium marble chips

Which curve belongs to which experiment?

1.(a) An excess of calcium carbonate was added to some hydrochloric acid in a flask on a balance which was immediately set at zero. The mass reading on the balance was then recorded over a period of time. Other similar experiments were performed at the same temperature.



The reaction of lumps of calcium carbonate with 100 cm^3 of 0.1 M hydrochloric acid gave curve 4. Which one of the curves, labelled 1-5, could have been produced using the following mixtures? Each curve may be used once only.

(i) 100 cm^3 of 0.1 M hydrochloric acid with finely powdered calcium carbonate?

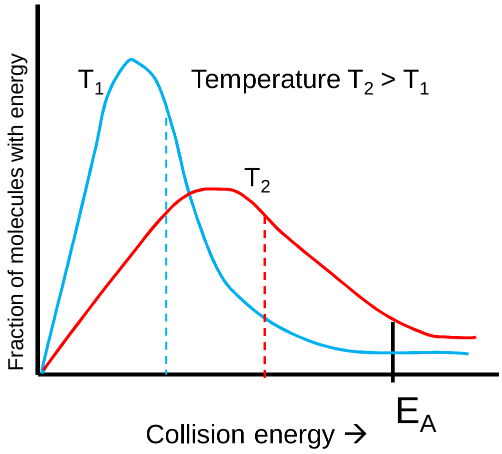
(ii) 50 cm^3 of 0.1 M hydrochloric acid with lumps of calcium carbonate?

(iii) 50 cm^3 of 0.2 M hydrochloric acid with lumps of calcium carbonate?

Increasing Temperature

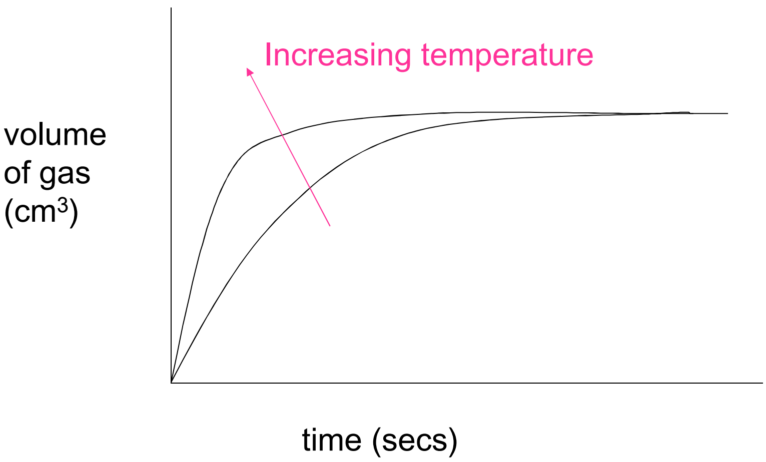
Increasing temperature increases the rate of reaction. At higher temperatures the energy of the particles increases. They collide more frequently and more often with energy greater than the activation energy. More collisions result in a reaction

Effect of increasing Temperature



As the temperature increases, the graph shows that a **significantly bigger** proportion of particles have **energy greater than the activation energy**, so the **frequency of successful collisions increases**

Note that most collisions do not result in reactions



These graphs show what would happen between magnesium and acid when temperature is increased

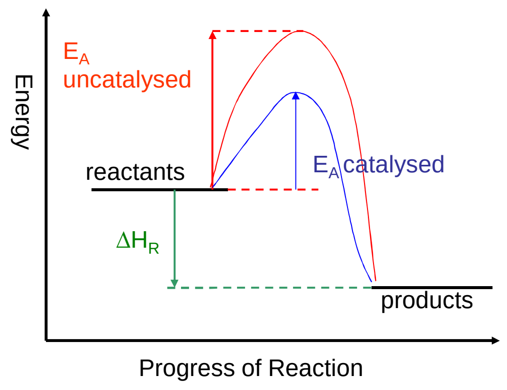
Effect of Surface Area

Increasing surface area will cause collisions to occur more frequently between the reactant particles and this increases the rate of the reaction.

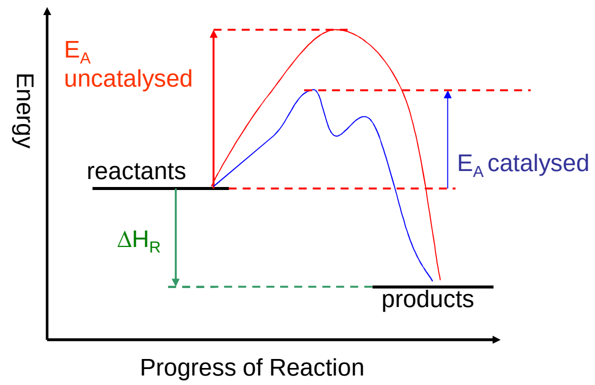
Catalysts

Catalysts increase reaction rates without getting used up. They do this by providing an alternative route with a lower activation energy

Comparison of the activation energies for an uncatalysed reaction and for the same reaction with a catalyst present.

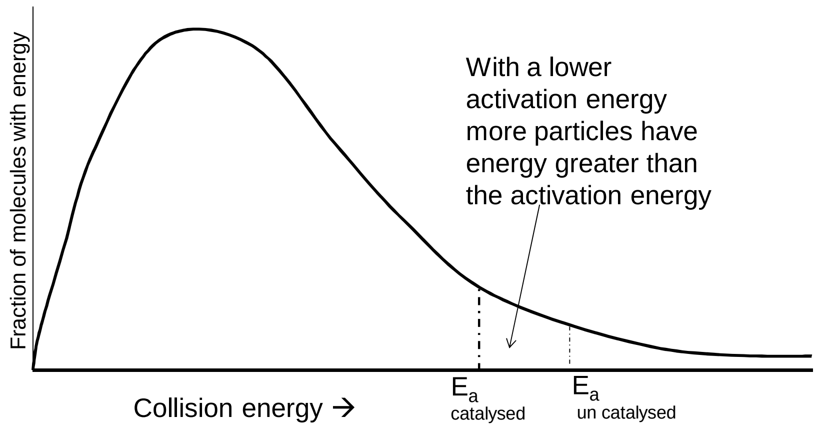


Energy level diagram for a catalysed reaction

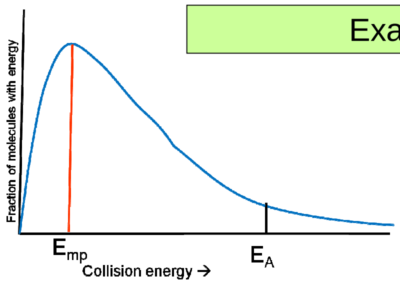


Energy distribution for a catalysed reaction

If the activation energy is lower, more particles will have energy > E_A, so there will be a higher frequency of effective collisions and a faster rate



Exam Question

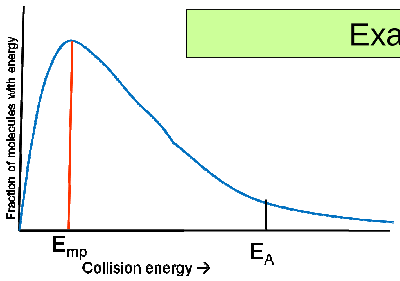


Consider the following change:
(i) The number of molecules is increased at constant temperature.

State how, if at all, the following would vary:

- the value of the most probable energy, E_{mp} no change
- the number of molecules with the most probable energy, E_{mp} increases
- the area under the molecular energy distribution curve increases
- the number of molecules with energy greater than the activation energy, E_a increases

Exam Question

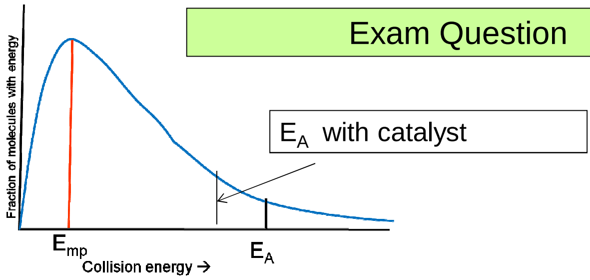


Consider the following change:
The temperature is decreased without changing the number of molecules.

State how, if at all, the following would vary:

- the value of the most probable energy, E_{mp} decreases
- the number of molecules with the most probable energy, E_{mp} increases
- the area under the molecular energy distribution curve No change
- the number of molecules with energy greater than the activation energy, E_a decreases

Exam Question

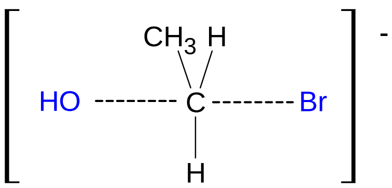


Consider the following change:
A catalyst is introduced without changing the temperature or number of molecules. State how, if at all, the following would vary:

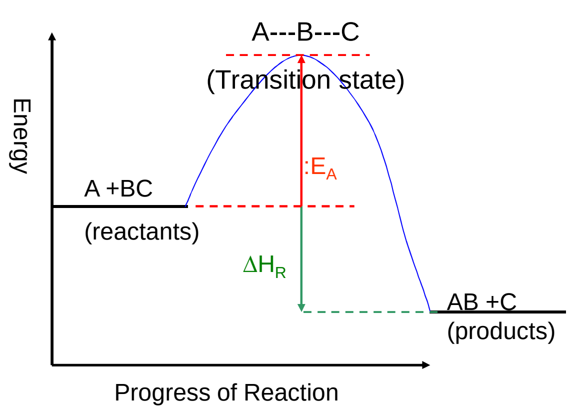
- the value of the most probable energy, E_{mp} No change
- the number of molecules with the most probable energy, E_{mp} No change
- the area under the molecular energy distribution curve No change
- the number of molecules with energy greater than the activation energy, E_a increases

Transition State Theory

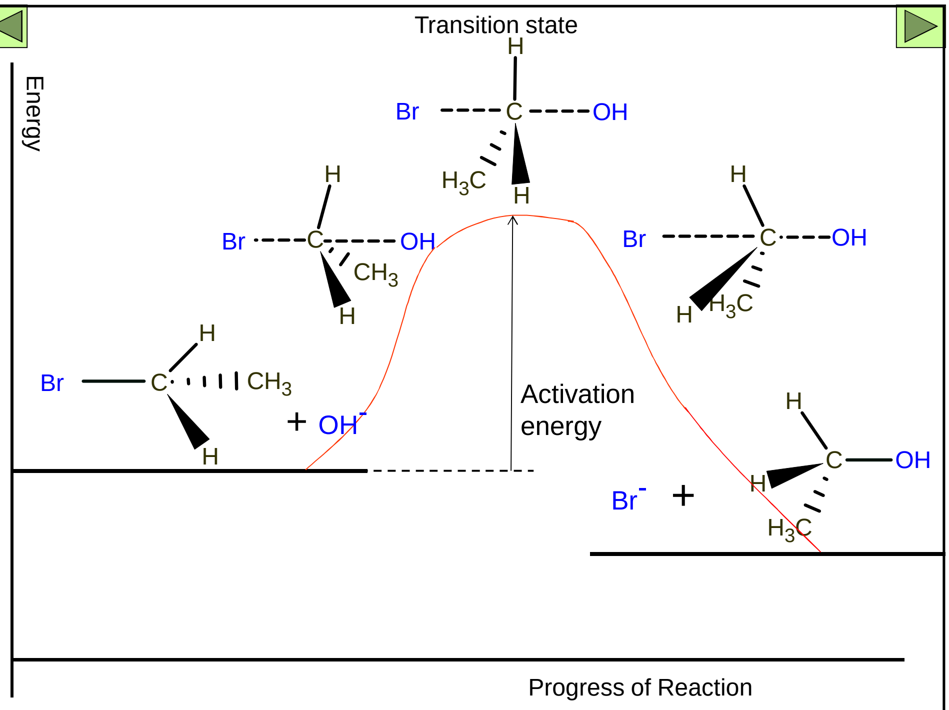
During a chemical reaction, reactants do not suddenly convert to products.
The formation of products is a continuous process of bonding breaking and forming.
At some point, a transitional species is formed containing "partial" bonds.
This species is called the transition state.



•At the top of the hump the reactants are at a stage where the old bonds are not quite broken and the new bonds are not quite made.
•This is the point of maximum potential energy and is called the transition state.



•The activation energy is therefore the energy needed to reach the transition state



Reversible Reactions