Rates of reaction

Define the term *rate of reaction*. Describe suitable experimental procedures for measuring rates of reactions

Analyze data from rate experiments

Chemical Kinetics

- The study of rates of chemical reactions and the mechanisms (or steps) by which a chemical reaction takes place.
- Reaction rates vary greatly – some are very fast (burning) and some are very slow (disintegration of a plastic bottle in sunlight).

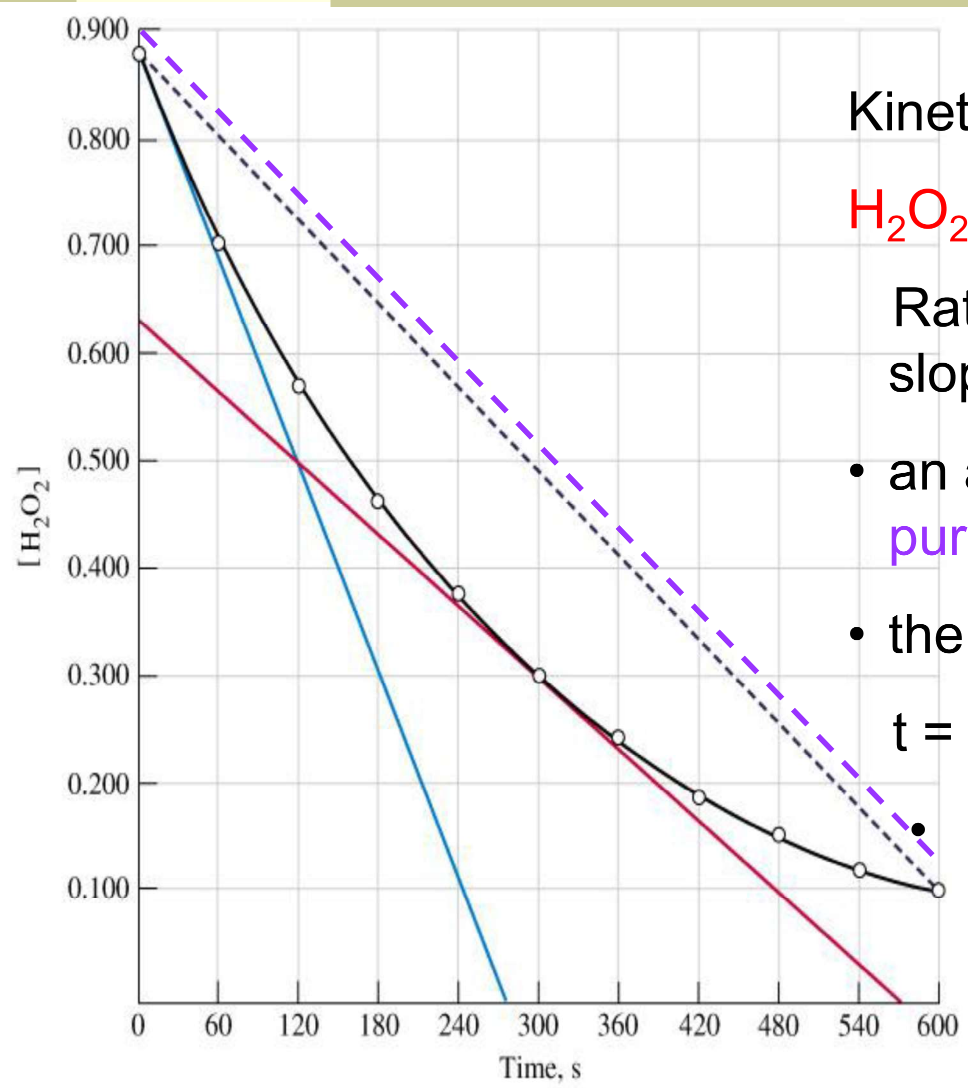
Rate of Reaction

- The **rate of a reaction** is the change in concentration of a product per unit of time (rate of formation of product).
- Also viewed as the *negative* of the change in concentration of a reactant per unit of time (- rate of disappearance of reactant).
- Rxn Rate (avg) = $\dfrac{\Delta\,[\text{reactant or product}]}{\Delta\,\text{time}}$
- [square brackets] = mol/L

Measuring Reaction Rates Decomposition of H_2O_2

Time, s	Accumulated mass O_2, g	$[H_2O_2]$, M
0	0	0.882
60	2.960	0.697
120	5.056	0.566
180	6.784	0.458
240	8.160	0.372
300	9.344	0.298
360	10.336	0.236
420	11.104	0.188
480	11.680	0.152
540	12.192	0.120
600	12.608	0.094

Some Kinetic Data



Kinetic data for the reaction:

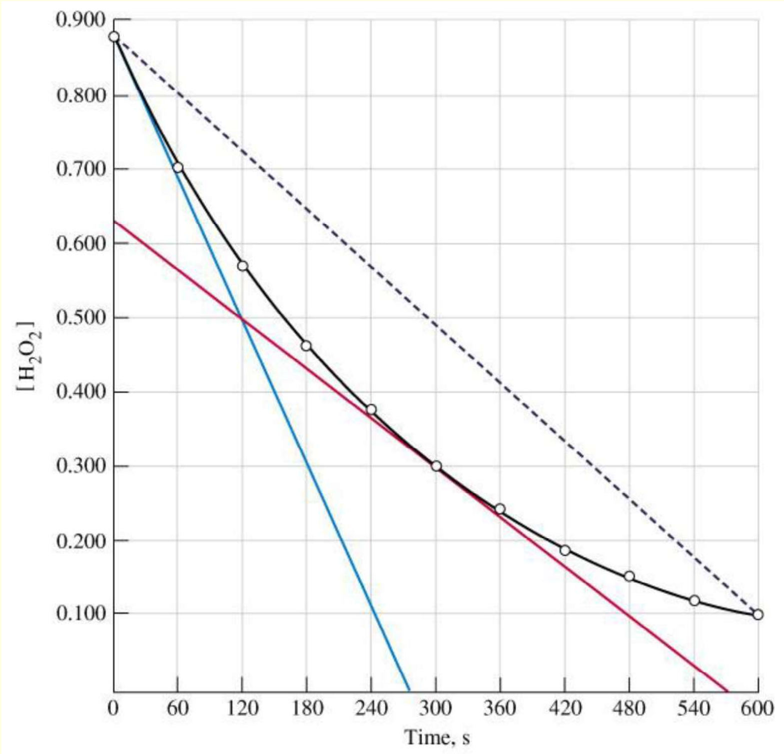
$H_2O_2(aq) \rightarrow H_2O(l) + ½\ O_2(g)$

Rates are obtained from the slopes of the straight lines:

- an average rate from the purple dotted line
- the instantaneous rate at t = 300 s from the red line
- the initial rate from the blue line.

Understanding the graph

- Concentration of reactant decreases with time, as it is being used up
- The rate is fastest when concentration of reactants is greatest; and slows when concentration of reactants are less.
- Decreasing numbers of reactants means less collisions producing new product.

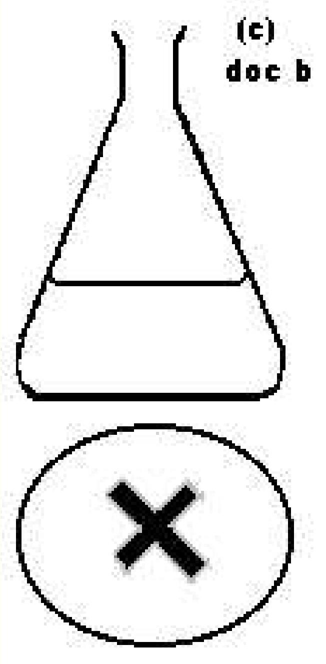


Measuring rate of reactions

- Any property that changes between the start and end of the reaction can in principle be used.
- The larger the changes the better the accuracy of its measurement.
- Any ideas of what we could measure?

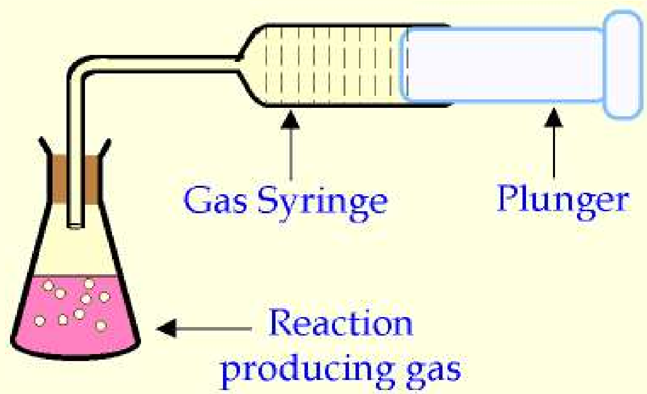
Light absorption

- If a reaction produces a precipitate (an insoluble compound) we can time how long it takes the formation of product to cloud the view of a mark made on a piece of paper placed under the reaction vessel.
- A spectrophotometer (measures wavelength of the color forming in solution)or a colorimeter (filters out a specific color) could also be used



Collecting an evolved gas

- The gas produced is collected in a syringe or in a graduated vessel over water (gas can’t be water soluble)
- The volume can be collected a different times and recorded



Other techniques

- **Electrical conductivity**
  - Presence of ions allows a solution to conduct. The reaction rate may be found from the changes in conductivity.
- **Titration**
  - Taking small samples throughout experiment and testing for amounts of product made at that time.
- **pH** (not great method) because dealing with small changes in concentration over the pH scale.

Collision theory

Describe the kinetic theory in terms of the movement of particles whose average energy is proportional to temperature in Kelvin's.

Define the term *activation energy, Ea*

Describe the collision theory

- Predict and explain, using the collision theory, the qualitative effects of particle size, temperature, concentration and pressure on the rate of a reaction.
- Describe the effect of a catalyst on a chemical reaction

Kinetic Molecular Theory

- Model of what happens to gas particles during experimentation
  - Large numbers of molecules in continuous motion
  - Attractive and repulsive forces are negligible
  - Energy is transferred between molecules during collisions, but average kinetic energy is unchanged (as long as temp is constant)
  - Kinetic energy of molecules is proportional to the absolute temperature. (in K)

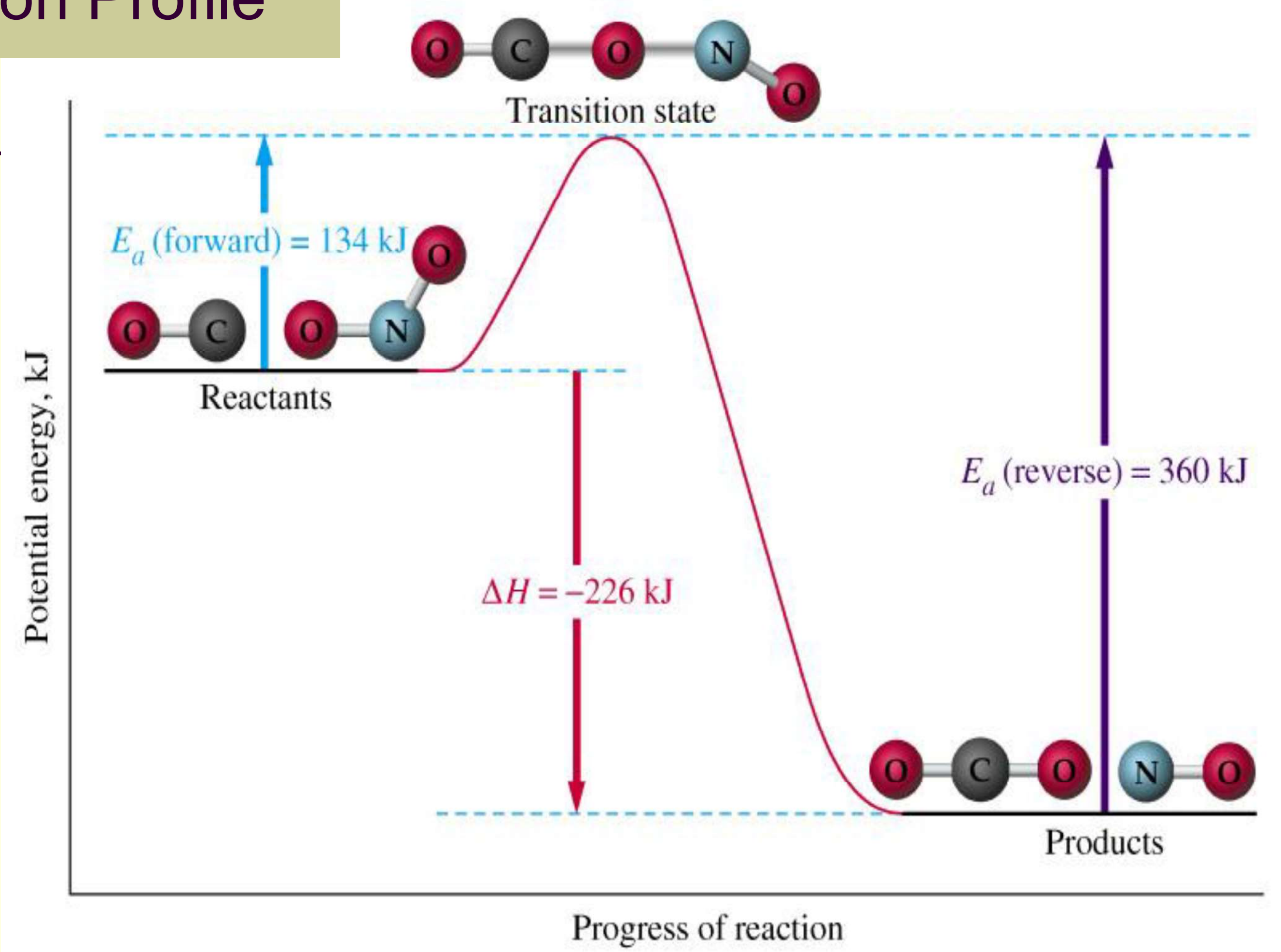
The Collision Theory

- is an explanation of what is necessary for a chemical reaction to occur.
- This theory states when a chemical reaction takes place, the reactant particles must…

1. collide with a certain minimum amount of energy, called *activation energy*.

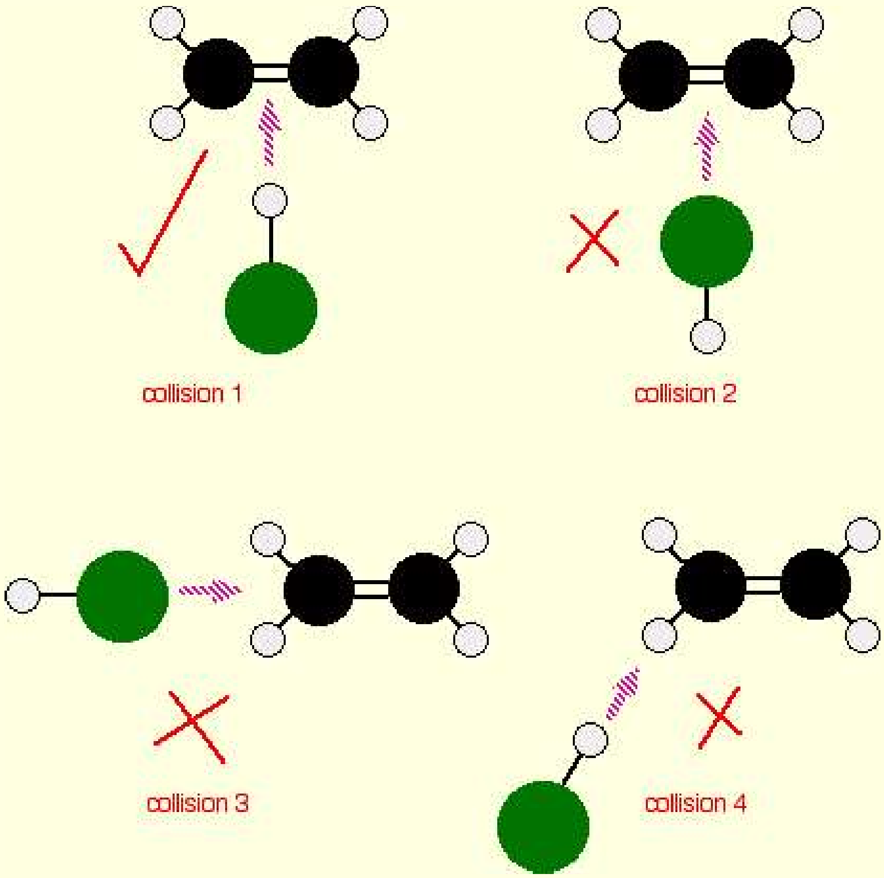
- This energy is required to break chemical bonds in the reactants.
- The energy of each particle is not important, it is the energy of the collision.

A Reaction Profile

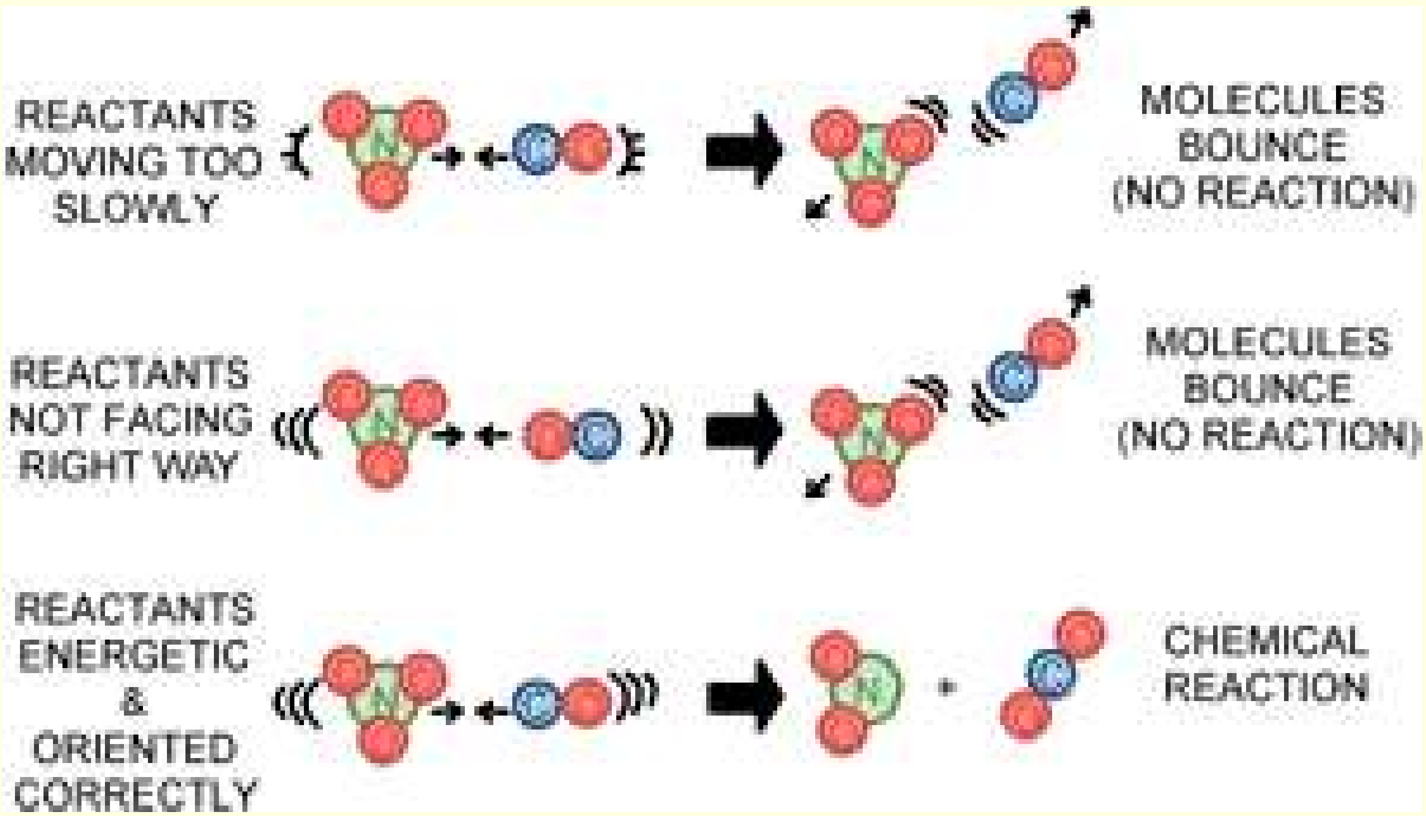


$$CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g)$$

2. Particles must collide with the proper geometry or orientation for atoms to come in direct contact and form the chemical bonds of the products. (steric factor)



- If both of these conditions are not met, particles will merely collide and bounce off one another without forming products.



http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/collis11.swf

- Although, the percentage of successful collisions is extremely small, chemical reactions still take place at a reasonable rate because there are so many collisions per second between reactant particles.

Factors that effect the rate of collision, effect the rate of reaction

- Concentration (and **pressure** with gases)
- Temperature
- Amount of surface area
- Catalysts

Concentration

- A higher concentration of reactants leads to more effective collisions per unit time, which leads to an increasing reaction rate
- We are not increasing the amount being made for a given balanced equation with limiting reactants, we are only speeding up how quickly those products are made.

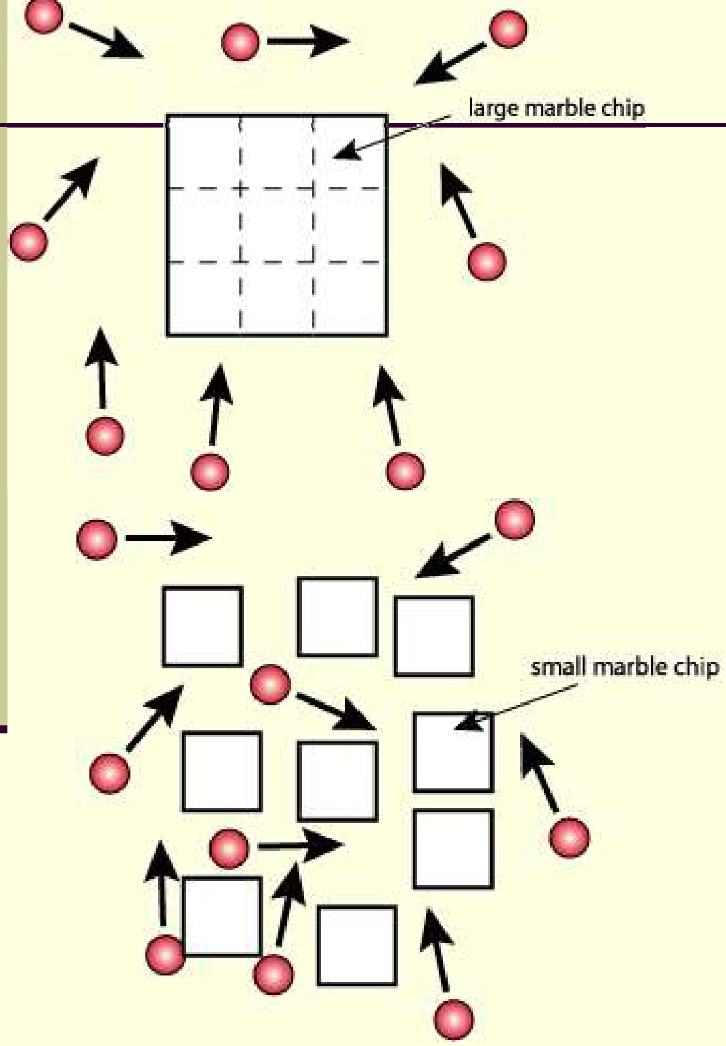
Pressure

- affects the rate of reaction, especially when you look at gases.
- When you increase the pressure, the molecules have less space in which they can move. That greater concentration of molecules increases the number of collisions.
- When you decrease the pressure, molecules don't hit each other as often. The lower pressure decreases the rate of reaction

Temperature

- Temperature is a measure of the kinetic energy of a system, so higher temperature implies higher average kinetic energy of molecules and more collisions per unit time.

Surface Area



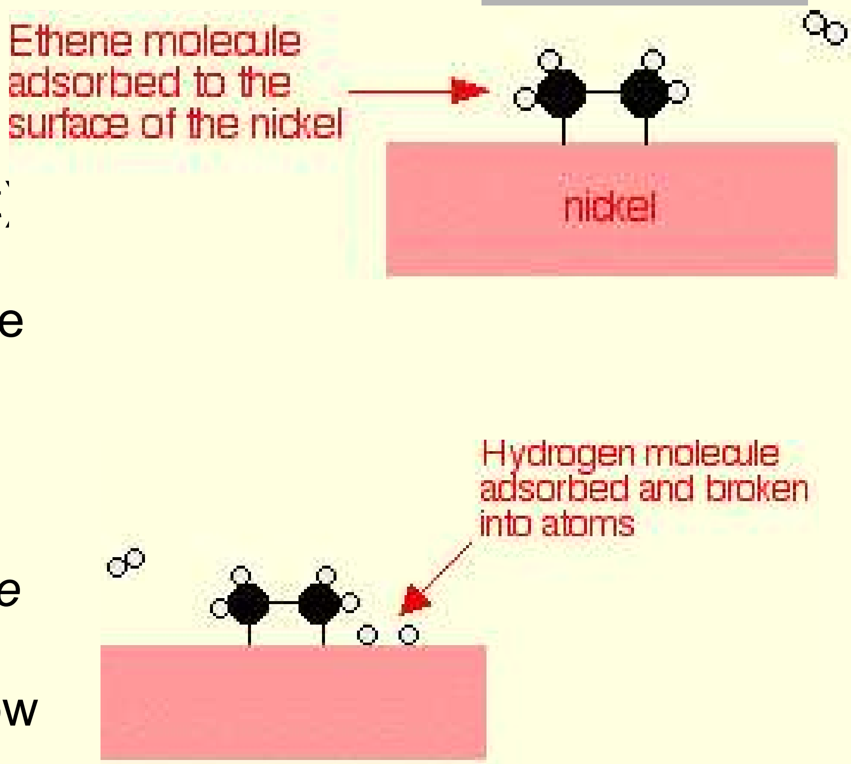
- **Reducing the size of particles increases the rate of a reaction because it increases the surface area available for collisions to take place**. This **increases** the number of collisions.

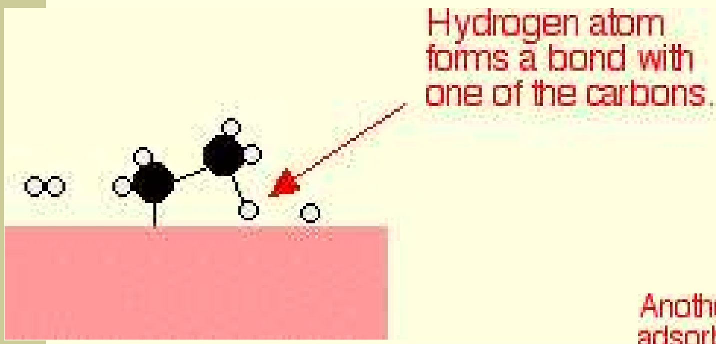
Catalysts

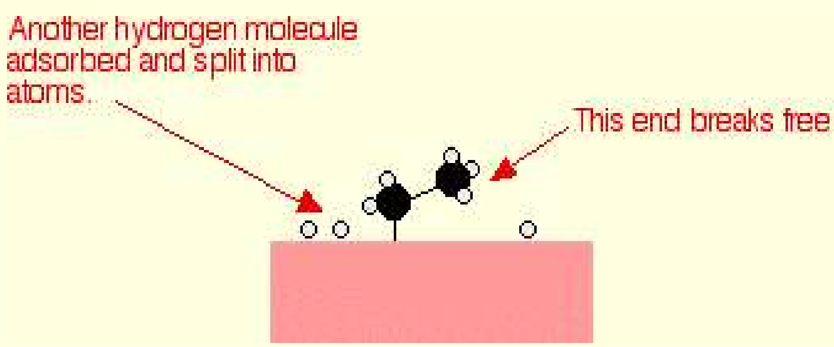
- A catalyst is a substance that speeds up a reaction **without being used up itself**.
- Some reactions have catalysts that can speed them up, but for many reactions there is no catalyst that works.
- How do they work?

1. A catalyst provides a surface on which the reaction can take place.

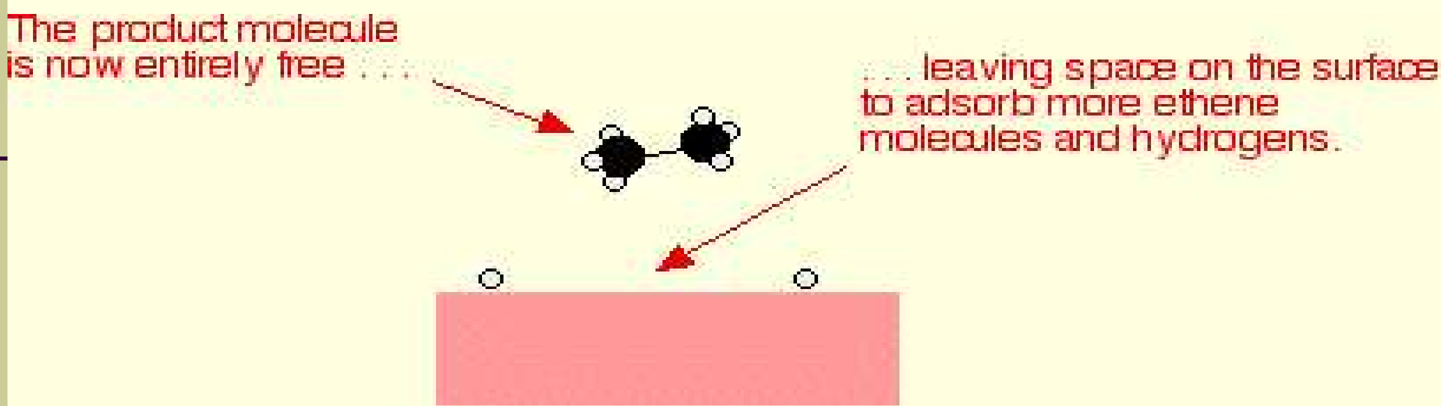
- One or more reactants are **adsorbed** to the surface (stick to it)
- Let's look at the example of ethene undergoing **hydrogenation** *(breaking double bond and making single bonds while adding hydrogen)*
- Usually VERY slow





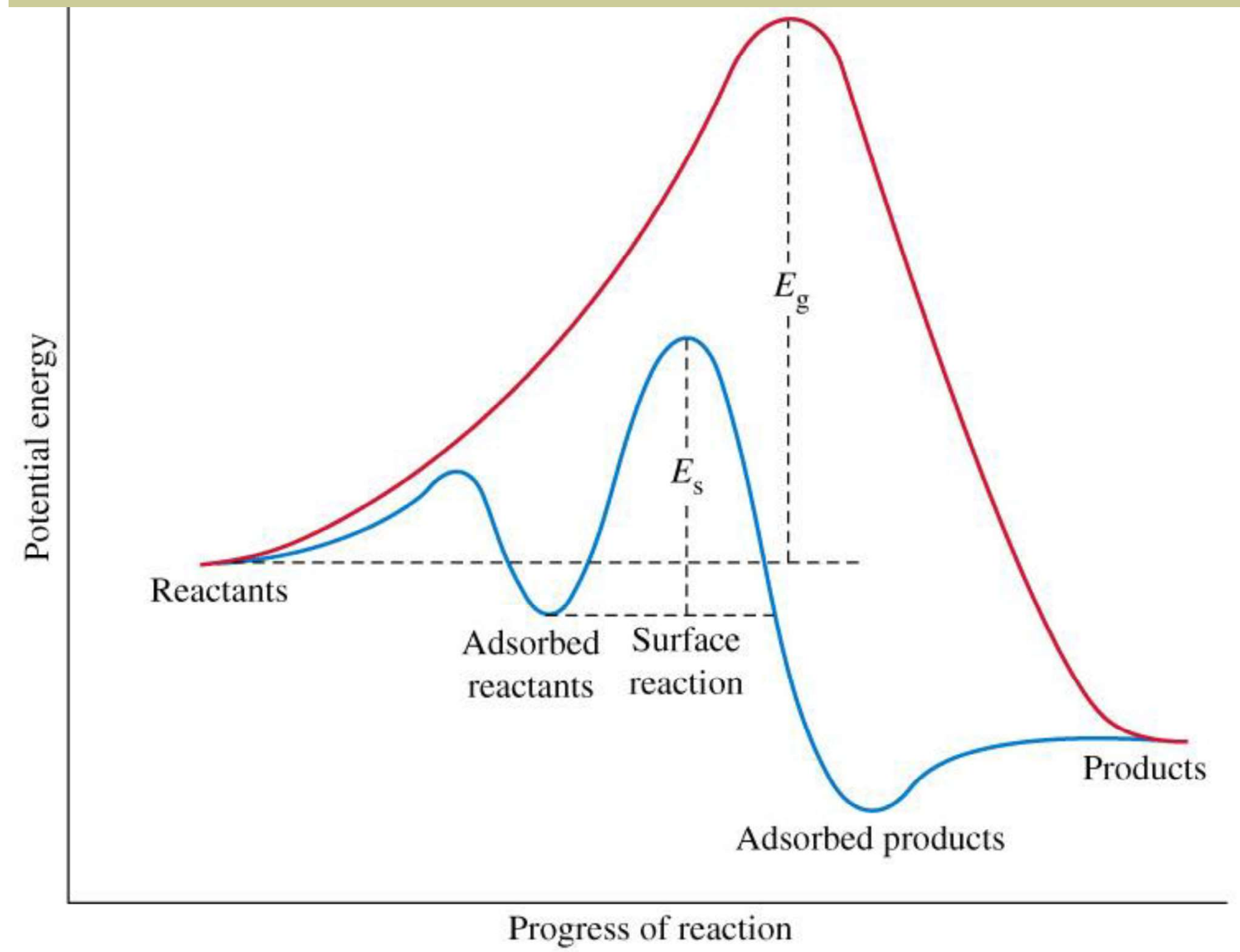


- Interaction between the catalyst and the reactant (maybe weakening bonds, or an actual reaction with the surface)
- The reactants may collide on the catalyst or one is prepared and then collide together

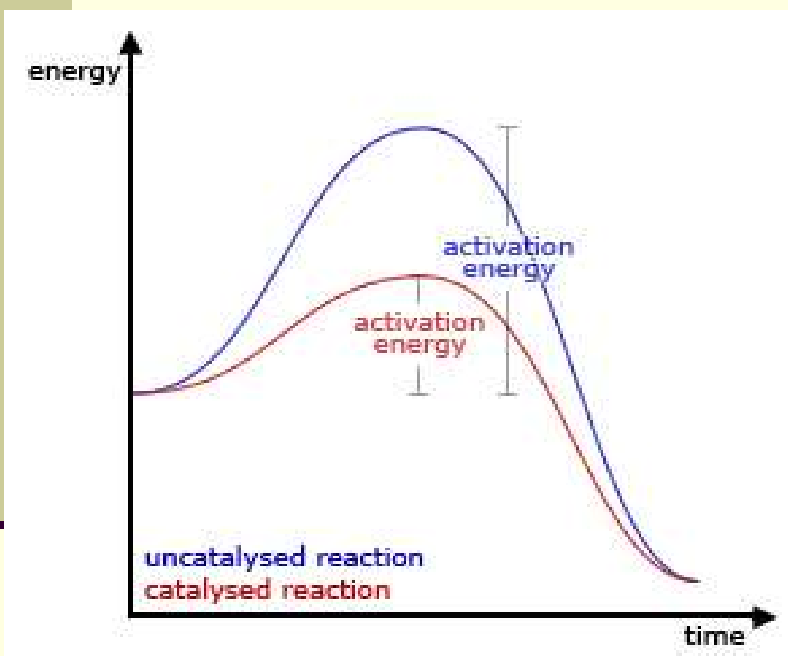


- The product is desorbed, breaks away from the catalyst once formed
- Nickel and platinum are excellent heterogeneous catalysts. They don't adsorbed too much or too little.
- Hydrogenation of vegetable oil to make margarine uses a nickel catalyst

A Surface-Catalyzed Reaction



2) A catalyst lowers the activation energy by…



- providing an **alternative mechanism** (step in the reaction)
- Reactants require less energy to react.
- *Sometimes catalysts seem to be used up, but they will regenerate at the end of the reaction*