Lesson 1 Rates of reaction

In order for a reaction to occur reactant particles must collide with enough energy to break bonds. These collisions are known as "Fruitful collisions".

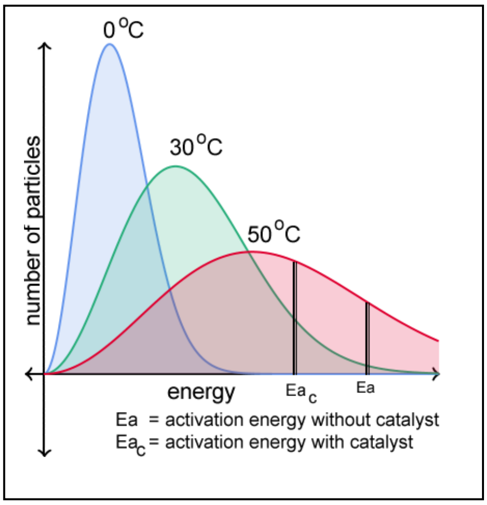
The rate of a chemical reaction depends on

- Surface area – the greater the surface area the more reactant particles that are exposed to undergo collisions.

- Concentration – the more particles per unit volume the greater the chance of fruitful collisions.

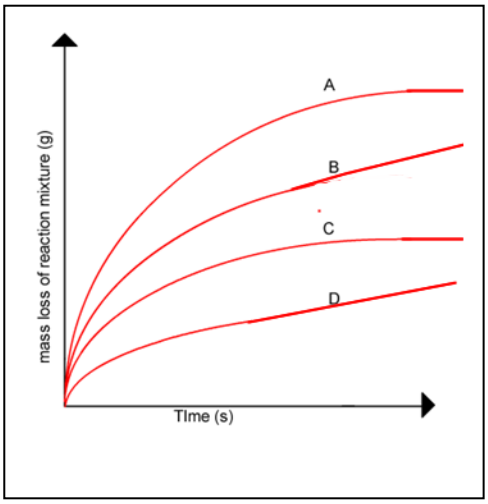
- Gas pressure – increasing the pressure of gas by decreasing the volume of the container at constant temperature is the same as increasing the concentration of the gas.

- Temperature – The higher the temperature the greater the average kinetic energy of the reactant particles hence greater number of collisions and greater energy at impact resulting in more fruitful collision.
  On the right is a Maxwell-Boltzman energy distribution curve at three different temps.
  Note – A molecule in a gas could have any one of a huge number of possible speeds.



- A catalyst - decreases the activation energy required for reactant particles to react. That means a greater proportion of particles have the required activation energy at the given temperature.

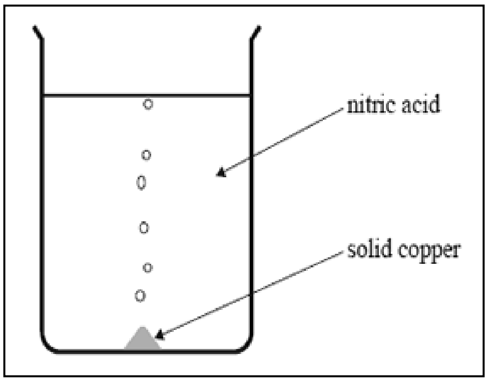
1) A student conducts four experiments by placing solid $CaCO_3$ in a solution of HCl . He is supplied with $CaCO_3$ powder and $CaCO_3$ chips, as well as 0.10 M HCl and 10.0 M HCl.
   $2HCl(aq) + CaCO_3(s) \rightarrow CO_2(g) + CaCl_2(aq) + H_2O(l)$
   The mass loss of the reaction mixture is measured and plotted on the set of axes on the right.
   a) In experiment A and B the student uses $CaCO_3$ powder with 0.10 M HCl solutions.
   What one factor could have caused the difference in graph A and graph B. Explain
   The rate of reaction A is higher than the rate of reaction B
   This could be achieved by A being at a higher temperature than B or a catalyst was used in reaction A and not in reaction B.



b) In experiment D and C the student used the 0.10 M HCl solution at 25°C. What factor could have caused the difference in graph D and graph C if the type of powder was the same in both experiments. Explain?

Catalyst was used in C and not in D

2) Copper metal reacts with nitric acid to produce nitrous oxide gas (NO). Which one of the following will not increase the rate of the reaction shown below? Explain why.



A. decreasing the size of the solid copper particles

This will increase the surface area and <u>will</u> increase the rate of reaction.

B. increasing the temperature of HNO_3 by 20 °C

Increasing the temperature will increase the average kinetic energy of the particles and hence more will have the necessary activation energy. This <u>will</u> increase the rate of a reaction.

C. increasing the concentration of HNO_3

Increasing the concentration will increase the rate of a reaction as it increases the number of collision assuming that enough activation energy is supplied.

D. allowing NO_2 gas to escape

Has no impact on the rate as it does not impact on the number of fruitful collisions.

3) In the above reaction, the number of successful collisions per second is a small fraction of the total number of collisions. The major reason for this is that

A. the nitric acid is ionised in solution.

B. some reactant particles have too much kinetic energy.

C. the kinetic energy of the particles is reduced when they collide with the container's walls. All collisions by gas particles are elastic, hence, no energy is lost.

D. not all reactant particles have the minimum kinetic energy required to initiate the reaction. Correct. All fruitful collisions require particles to have a minimum amount of energy upon collision, known as the <u>*activation energy.*</u>

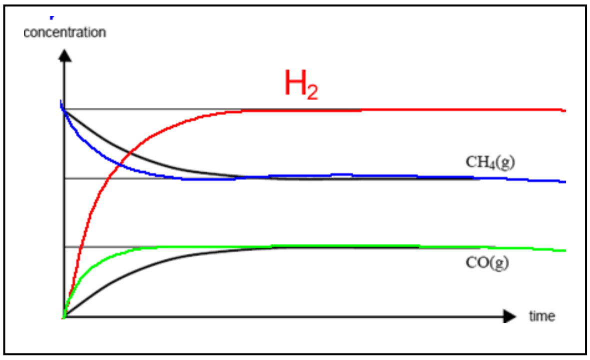
4) Explain how the number of fruitful collisions per second, in 3) above, can be increased.

Adding a catalyst which lowers the activation energy needed.

5) Carbon monoxide and hydrogen can be produced from the reaction of methane with steam according to the equation

$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$; $\Delta H = +206$ kJ mol^{-1}

Some methane and steam are placed in a closed container and allowed to react at a fixed temperature. The graph on the right shows the change in concentration of methane and carbon monoxide as the reaction progresses.

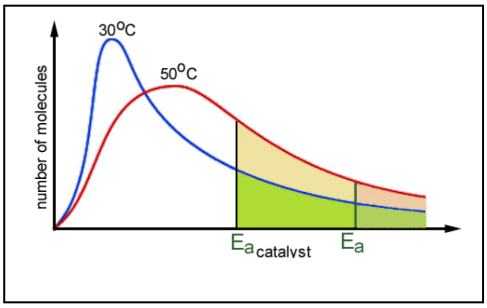


a) On the graph above, draw a line to show
the change in concentration of hydrogen gas as the reaction progresses. Label this line.
b) On the graph above, draw two lines to show how the usage of methane and the production of carbon monoxide would differ over time in the presence of a catalyst. Label these lines.

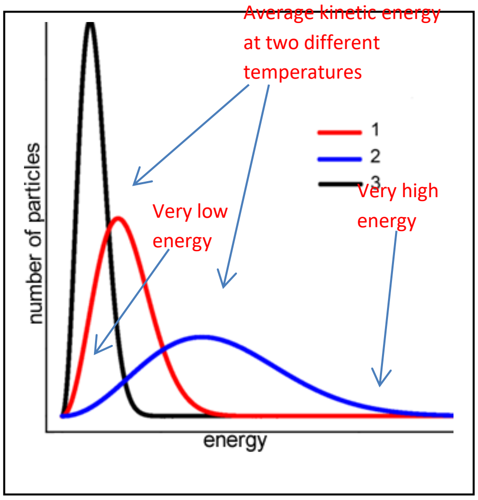
6) The two statements below give possible explanations for changes that occur when the temperature of a reaction mixture is increased.
i. At a higher temperature, particles move faster and the reactant particles collide more frequently.
ii. At a higher temperature, more particles have energy greater than the activation energy.
Which statement best explains why the observed reaction rate is greater at higher temperatures and why the other is not significant in determining the rate?
Collisions amongst reactant particles occur all the time, however, fruitful collisions involve particles with the minimum amount of energy, activation energy, to collide in order for a reaction to take place.

7) Explain how a catalyst increases the rate of a reaction using the Maxwell-Boltzmann distribution curve. Draw a diagram as part of your explanation.

A catalyst reduces the activation energy required for reactant particles to undergo fruitful collisions. At lower activation energies more molecules possess the necessary amount of energy to undergo fruitful collisions hence the rate of the reaction increases.



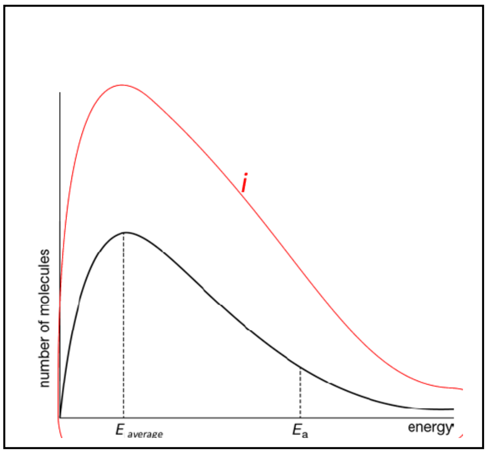
8) Consider the Maxwell-Boltzmann distribution curves shown on the set of axes on the right.
a) Label the axes
b) Place the curves 1, 2 and 3 in order of increasing temperature
3, 1, 2
c) Consider the statement below.
Indicate if it is true or false and give a reason using the graphs shown on the right.
" All molecules have higher kinetic energy at 100 °C than they do at 50°C".
False
At 50 °C or 100°C the shape of the Maxwell-Boltzmann energy distribution curve reveals that molecules exist at both temperatures that have very low kinetic energy and very high kinetic energy. The <u>average</u> kinetic energy, however, will be higher at 100°C than at 50°C .



9) The figure on the right shows the Maxwell-Boltzmann distribution curve of molecular energies of a gas at constant temperature.

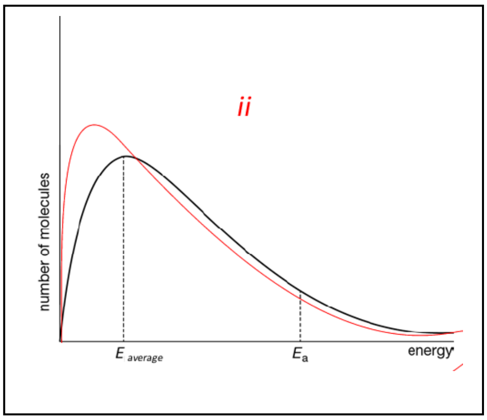
i. State how the average kinetic energy changes if the amount of gas is doubled at constant temperature.

The average kinetic energy possessed by the molecules in the gas does not change when more gas is added or gas is removed. Average kinetic energy changes only with temperature and increases at higher temperatures and decreases at lower temperatures.



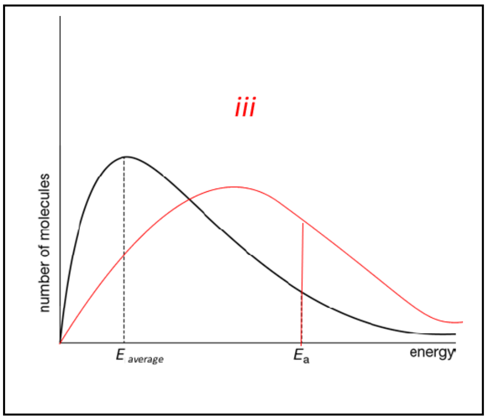
ii. State how the number of molecules with the average kinetic energy changes as the temperature is reduced.

The number of molecules with the average kinetic energy increases as the temperature is lowered.



iii. State what happens to the number of molecules with energy greater than the activation energy (E_a) changes as the temperature increases without an increase in the number of molecules.

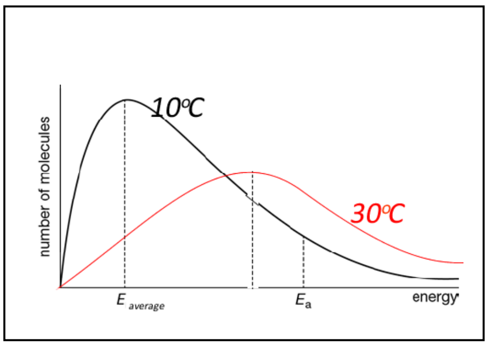
A greater number of molecules have energy greater than the activation energy at a higher temperature.



iv. State how the shape of the distribution curve changes as a result of adding a catalyst.

No change

10) A student was asked to draw the shape of the Maxwell-Boltzmann energy distribution curve of a sample of gas molecules at 30 °C given the curve at 10°C.
The student produced the curve in red as shown on the right. Is it accurate? Discuss. *No the curve should start at*



the origin as there are always molecules with very little kinetic energy even at high temperatures.