Stage 2 Chemistry

**Managing Chemical Processes:** Rates of Reaction

**Science Understanding**

* The rates of a reaction at different times can be compared by considering the slope of a graph of quantity or concentration of reactant or product against time.
  + Draw and interpret graphs representing changes in quantities or concentration of reactants or products against time.
* Rates of reaction can be influenced by a number of factors, including the presence of inorganic and biological catalysts (enzymes).
  + Predict and explain, using collision theory, the effect on rates of reaction due to changes in:
    - concentration
    - temperature
    - pressure (for reactions involving gases)
    - surface area
    - the presence of a catalyst
* Energy profile diagrams can be used to represent the relative enthalpies of reactants and products, the activation energy, and the enthalpy change for a chemical reaction.
  + Draw and interpret energy profile diagrams.

**Rates of Reaction**

Chemical reactions take place at a variety speeds. For example:

* precipitation reactions are usually very fast,
* some organic preparations are much slower, varying from minutes to hours, eg esterification
* rusting of iron is a very slow reaction and may take years.

When designing an industrial process it is important to know how quickly a reaction occurs and how to change the speed of a reaction.

**How are rates of reaction measured?**

* How fast or slow a reaction takes place is called the “rate” of a reaction. It is measured as the change in concentration or amount of a reactant or a product during a chemical reaction per unit time.
* To find the rate of a reaction means measuring:
  + the amount/concentration of reactant used up per unit time, OR
  + the amount/concentration of product formed per unit time.
* Graphs of concentration vs time or mass vs time can be used to calculate the rate of a chemical reaction.
* Using the slope of the graph, the rate can be expressed as an instantaneous rate at a given time or an average rate of reaction.
* Graphs of concentration vs time or mass vs time can also show the factors that affect the rate of reaction.

**SUPPORTING QUESTON 1:**

The data shown in the table below shows the volume of hydrogen formed with time in the reaction of magnesium with dilute hydrochloric acid.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Time (sec) | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 |
| Vol of H2 (mL) | 0 | 29 | 53 | 67 | 73 | 77 | 79 | 80 | 80 |

1. Write an equation for the reaction.
2. Which variable would be the independent variable in this experiment? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

1. Draw a graph of volume of H2 against time.
2. Describe how the slope of the graph changes with time and hence how the rate changes with time.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Use the graph to calculate the instantaneous rate of reaction at t = 75 sec. (*Include units*)

1. Use the graph to calculate the average rate of reaction over the first 250 sec.
2. At what time does the reaction stop?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

State what feature of the graph indicates the completion of the reaction.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Factors affecting the rate of reaction**

Rates of a reaction are affected by the following factors:

* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of reactants,*
* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of the reaction mixture,*
* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of the reaction mixture, (if products and reactants are gases),*
* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, ie state of subdivision of reactants,*
* *the presence of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, including enzymes*

**Collision theory**

The effects of the above factors can be explained in terms of the **Collision Theory** of chemical reactions. Collision Theory says that for a reaction to occur:

1. The reactant particles must **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.**
2. The colliding particles must have sufficient energy to overcome the **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** energy which is an energy requirement for a reaction to proceed.

For every chemical reaction, there is a certain minimum energy needed in the collisions before a reaction can take place. This minimum energy is called the “activation energy” of the reaction.

1. The particles must have the correct **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** when they collide. This is significant for big molecules only.

Collisions can be: **productive collisions**, which result in the formation of products or

**unproductive collisions**, not resulting in the formation of products.

The collision theory can explain why the rate of a reaction is changed by the 5 factors listed above. In terms of collision theory, the rate of reaction is dependent on:

* the *magnitude of the activation energy*,
* the *frequency of collisions* between reactant particles,
* the *energy of collisions* of particles relative to the activation energy,
* the *orientation* of reactant particles.

Therefore we can explain the increase in rate caused by the 5 factors using collision theory

1. Concentration: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Temperature: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

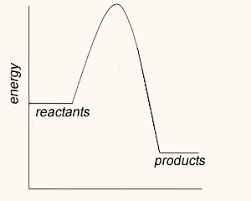
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Pressure: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Surface Area: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. Catalyst: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Energy Profile Diagrams**

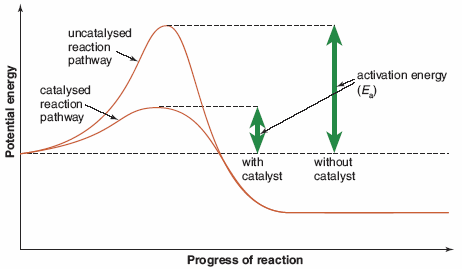
In energy terms, the course of a chemical reaction can be represented as an energy profile diagram. It shows the relative potential energy values for reactants and products. In order for products to form, the kinetic energy of reacting particles must exceed the activation energy.



* Activation energy is from the reactant energy to the peak of the curve
* Enthalpy is the difference between the reactant and product energies

When reactant energy is higher, the reaction is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

When product energy is higher, the reaction is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Draw a fully labelled diagram of an exothermic reaction
2. Draw a fully labelled diagram of an endothermic reaction
3. With reference to the diagram, explain how the presence of a catalyst may increase the rate of a reaction

**Supporting Question 2**

Hydrogen peroxide solution can be used as a bleaching agent. However over time, it decomposes as shown by the equation:

2H2O2(aq) 2H2O(l) + O2(g)

An experiment was carried out to monitor the decomposition of hydrogen peroxide. Data collected shows the concentration of hydrogen peroxide remaining at the end of each time interval:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time (min) | 0 | 10 | 20 | 30 | 40 | 50 |
| Hydrogen peroxide concentration (mol L-1) | 2.32 | 1.49 | 0.98 | 0.62 | 0.39 | 0.25 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

1. Calculate the instantaneous rate of reaction at t = 35 min
2. On the same set of axes, sketch the graph expected if the experiment was carried out at a lower temperature.
3. On the same set of axes, sketch the graph expected if a catalyst had been added at the start of the experiment.
4. Use Collision Theory to explain why the concentration of hydrogen peroxide fell more rapidly in the first 5 minutes than it did in the last 5 minutes. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_