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Energy Changes & Rates of Reactions

Definitions

- Heat of reaction (ΔH) is the net change of chemical potential energy of the system.
- Exothermic reactions are reactions which transform chemical potential energy into thermal energy.
- Endothermic reactions are reactions which transform thermal energy into chemical potential energy.
- Activation energy is the minimum energy required to start a chemical reaction OR the energy required to form the activated complex.
- The activated complex is a high energy, unstable, temporary transition state between the reactants and the products.
- Reaction rate is the change in concentration per unit time of either a reactant or product.
- Catalyst is a substance that increases the rate of the reaction but remains unchanged at the end of the reaction

Skills

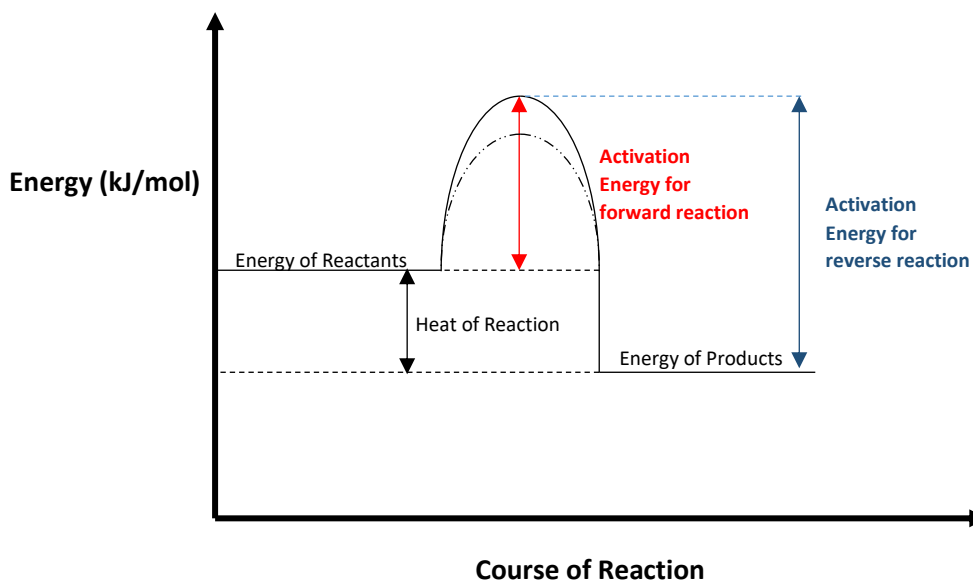
- Identify that bond breaking is endothermic and that bond formation is exothermic. (No calculations will be required).
- Identify that a stronger bond requires more energy to break and releases more energy when formed.
- Predict that $\Delta H > 0$ for endothermic reactions.
- Predict that $\Delta H < 0$ for exothermic reactions.
- Know that exothermic reactions release heat and thus increase the temperature of the reaction mixture.
- Know that endothermic reactions absorb heat and thus decrease the temperature of the reaction mixture.
- Draw and interpret potential energy profile graphs of catalysed and uncatalysed endothermic reactions and exothermic reactions (with reactants, products, activation energy, activated complex and ΔH labelled).
- Calculate average reaction rate, with appropriate units, in terms of change in mass, volume, or number of moles per unit time
- Distinguish between average and instantaneous reaction rates
- List the factors that affect the rate of chemical reactions.
- Explain that the collision theory is a model that explains that a reaction will only proceed when reactant particles collide effectively.
- Explain in terms of the collision theory that reaction rate is directly proportional to the number of effective collisions per unit time.
- Explain in terms of the collision theory how the various factors affect the rate of chemical reactions.
- Suggest and explain suitable experimental techniques for measuring the rate of a given reaction.
- Answer questions and interpret data (tables or graphs) on different experimental techniques for measuring the rate of a given reaction.
- Apply collision theory to explain the changes in the distribution of molecular energies (number of particles against their kinetic energy, i.e. Maxwell-Boltzmann distribution) due to changes in temperature, concentration of reactants and the presence of a catalyst.
- Use any other suitable graph (including e.g. energy profile graph, rate vs time or amount vs time) to show how changing concentration, pressure, surface area, or adding a catalyst affects the rate of reaction

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Concepts

- An effective (or successful) collision is one in which the colliding reactant particles have:
the correct orientation
sufficient energy, i.e. kinetic energy equal to or greater than the activation energy.

Energy Profile Curve for Exothermic Reaction

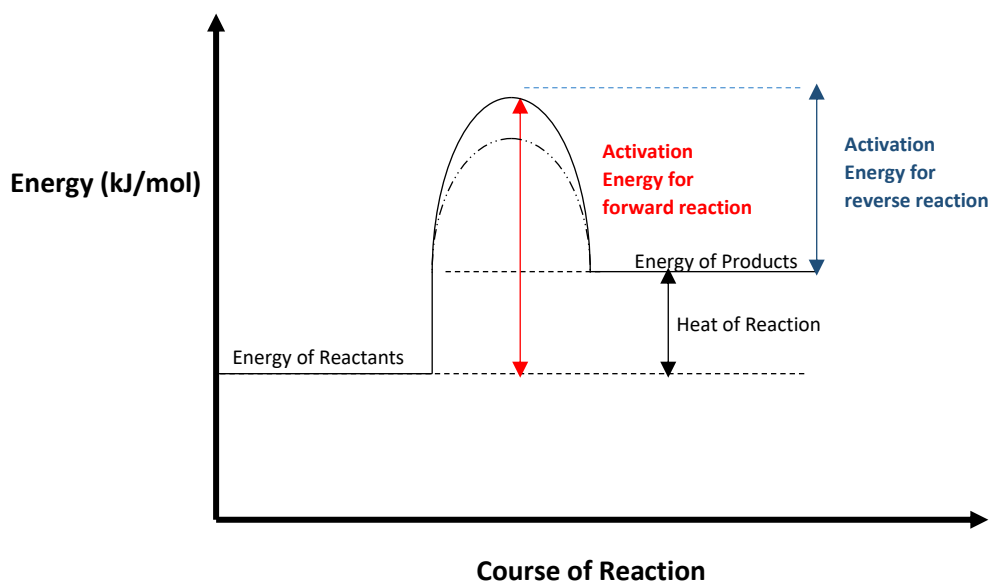


$$\Delta H = E_{\text{products}} - E_{\text{reactants}} < 0 \text{ for forward reaction}$$

$$\Delta H > 0 \text{ for reverse reaction, endothermic reaction}$$

----- Alternate path with catalyst

Energy Profile Curve for Endothermic Reaction

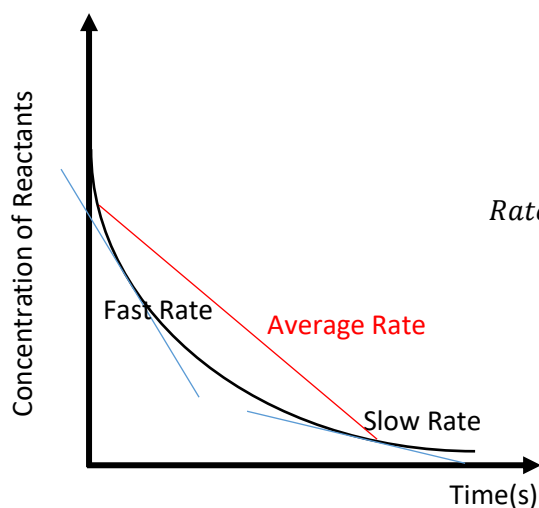


$$\Delta H = E_{\text{products}} - E_{\text{reactants}} > 0 \text{ for forward reaction}$$

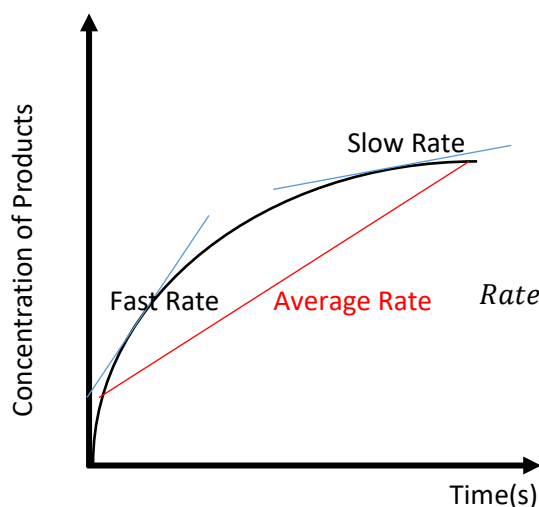
$$\Delta H < 0 \text{ for reverse reaction, exothermic reaction}$$

----- Alternate path with catalyst

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$$\text{Rate of Reaction} = \frac{\Delta \text{Concentration of Reactants}}{\Delta t}$$



$$\text{Rate of Reaction} = \frac{\Delta \text{Concentration of Products}}{\Delta t}$$

- The concentration of reactants/products can either be mass, volume or number of moles.
- The relevant units for rate of reaction will vary depending on how the quantity of the reactant/product is measured.
- When we measure the change in concentration of reactants/products over a long time interval this will give us the average reaction rate. (Red Line)
- When we measure the change in concentration of reactants/products over a short time interval this will give us the instantaneous reaction rate. (Blue Line)

Collision Theory

Reactant particles must collide effectively for the reactants to change into products.

To collide effectively the colliding reactant particles must:

1. Have the correct orientation: To break the existing bonds (in the reactants) and form new bonds (in the products).
2. Have sufficient energy: Kinetic energy equal to or greater than the activation energy.

More effective collisions will result in a higher rate of reaction.

Factor that affect the rate of a reaction

1. Nature of Reactants

- Bonds between reactants are broken.
- More particles have the correct orientation.
- Increase in the number of effective collisions per unit time.
- Higher reaction rate.

2. Surface area of solid

- A higher surface area means that there is a greater number of surface particles exposed to collisions.
- Increase in the number of collisions (between reactant particles) per unit time.
- Increase in the number of effective collisions per unit time.
- Higher reaction rate.

3. Concentration of solutions (aqueous)

- Increase in concentration, greater number of particles per unit volume.
- Increase in the number of collisions (between reactant particles) per unit time.
- Increase in the number of effective collisions per unit time.
- Higher reaction rate.

4. Pressure of a gas

- Increase in pressure, decreases volume, greater number of particles per unit volume.
- Increase in the number of collisions (between reactant particles) per unit time.
- Increase in the number of effective collisions per unit time.
- Higher reaction rate.

5. Temperature

- A higher temperature means that the particles have a greater average kinetic energy.
- Minor effect: there is an increase in the number of collisions per unit time.
Major effect: there is a greater proportion of particles with sufficient kinetic energy to overcome the activation energy.
- Increase in the number of effective collisions per unit time.
- Higher reaction rate.

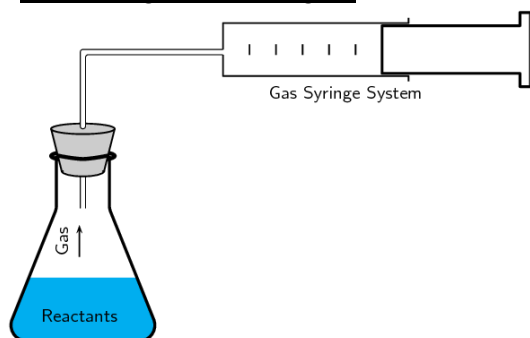
6. Catalyst

- A catalyst offers a reaction pathway of lower activation energy.
- There is thus a greater proportion of particles with sufficient kinetic energy to overcome the activation energy.
- Increase in the number of effective collisions per unit time.
- Higher reaction rate.

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measuring Rates of Reaction

1. Measuring volume of gas.

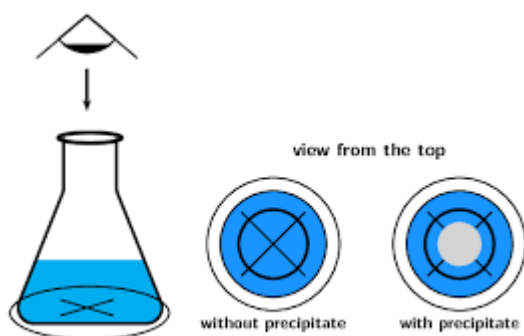


When a reaction produces a gas like CO_2 , the gas can be collected in a syringe using a delivery tube.

The volume of the gas is measured

The rate of the reaction can be calculated by taking the volume of gas formed divided by the time.

2. Measuring turbidity (Precipitation formation)

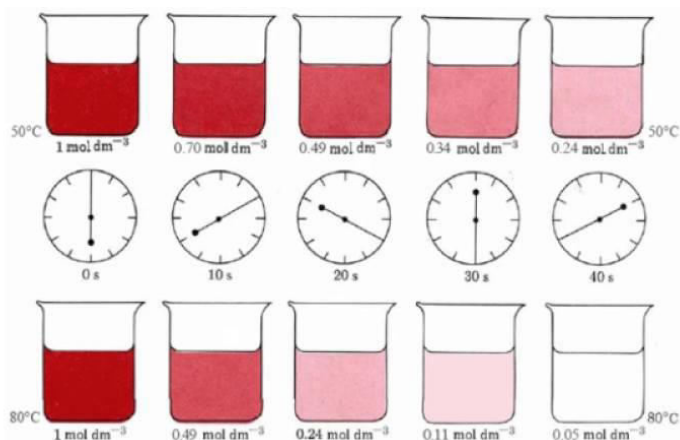


When a precipitate like sulphur is formed in the solution the turbidity can be used as a measure of products formed.

The time taken for the cross to disappear is recorded.

Since the amount of products formed in each case is constant, $1/\text{time}$ can be used as a measure of the rate of reaction.

3. Change of colour

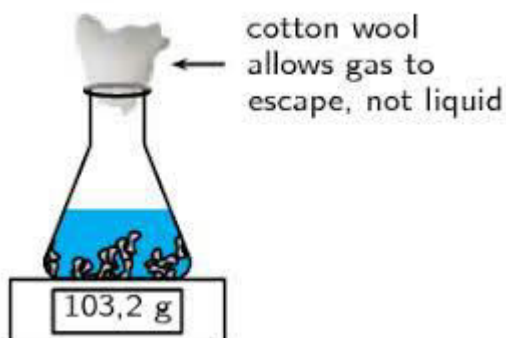


Using a spectrophotometer which measures the amount of light of a specific wavelength that is absorbed by the mixture.

Product formed can be quantified using the degree of colour.

The rate of reaction can be calculated by taking the degree of colour over time.

4. Change of mass

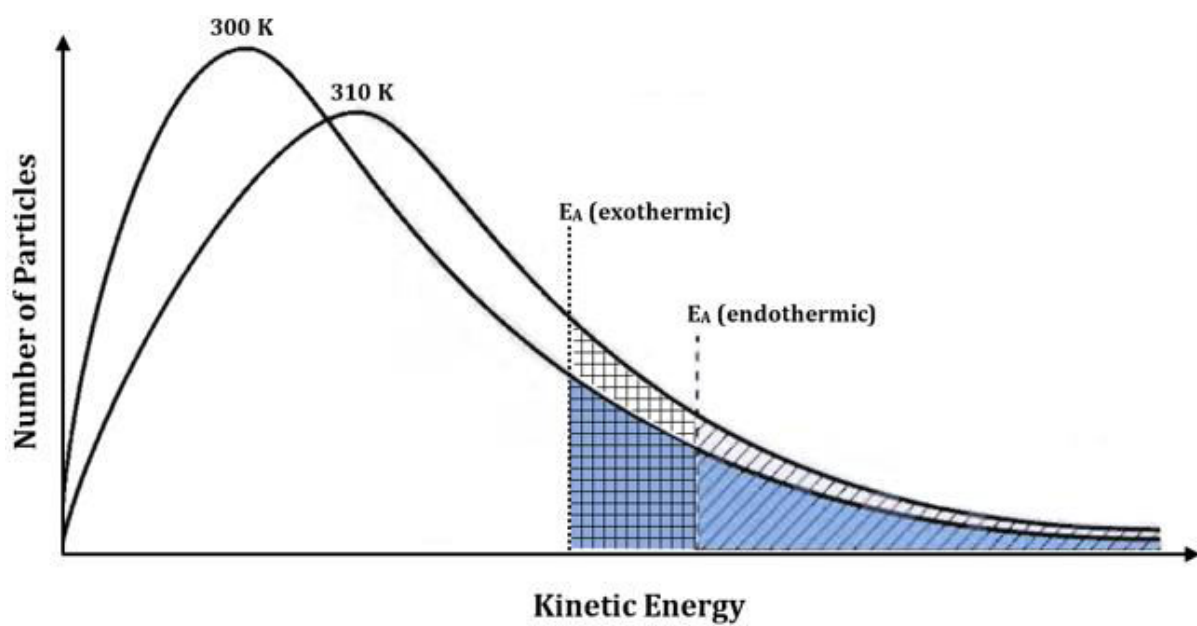


When one of the products is a gas like CO_2 , the mass of the contents decreases.

The decrease in mass is the amount of products formed.

The rate of reaction can be calculated by taking the loss in mass over time.

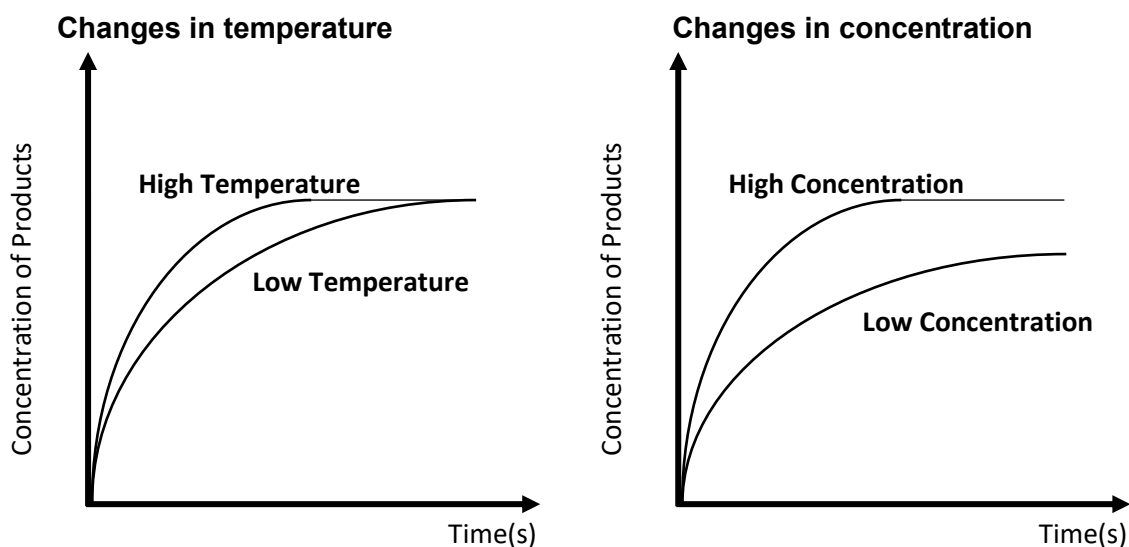
1. Maxwell-Boltzmann Distribution Curve



The higher the activation energy, the greater the percentage increase in the proportion of particles with $E_K > E_A$ (shaded area):

- Increase in temperature, peak moves right and moves down.
- Decrease in temperature, peak moves left and moves up.
- Increase in concentration, peak moves up.
- Decrease in concentration, peak moves down.

2. Graphical effect of factors affecting reaction rate.



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