

CHEMISTRY 203

Hydrolysis of Ethyl Acetate

Purpose

1. To **study** experimentally the kinetics of a chemical reaction: **hydrolysis of ethyl acetate**.
2. To determine the **rate constant** and the **activation energy**, E_a , for the **base-catalyzed hydrolysis of ethyl acetate**.

Chemical Kinetics: is the area of chemistry concerned with the speeds, or rates, at which a chemical reaction occurs.

Reaction rate is the **change** in the concentration of a reactant or a product with time (M/s).

In general, the **rate** of a chemical reaction depends on several factors:

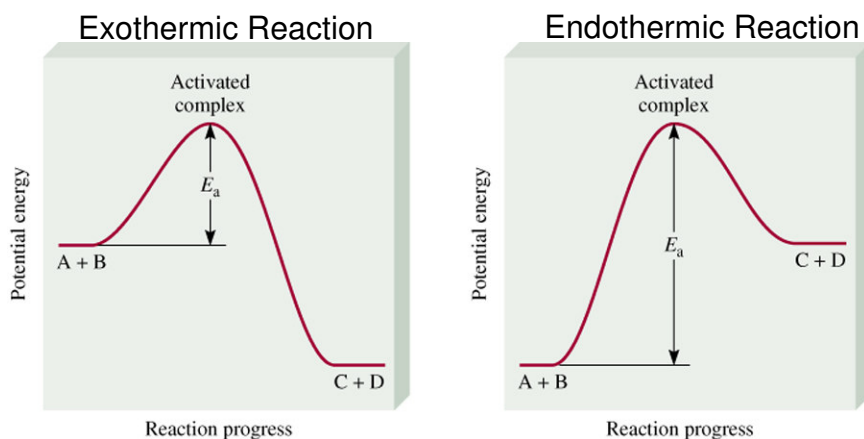
- The **nature** of the reaction
- The **concentrations** of reactants
- The **surface area**
- The **temperature**
- The presence of a **catalyst**.

The first three listed factors were investigated in the previous experiment.

The effect of temperature on a reaction will be investigated in this experiment.

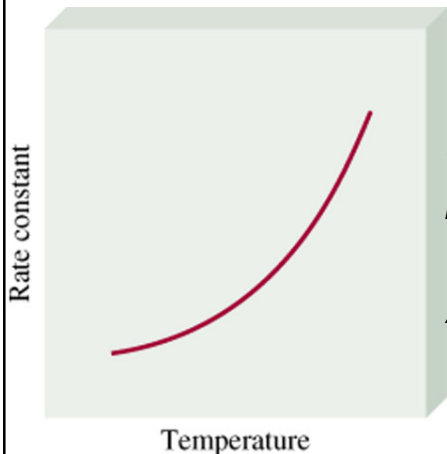
The rate of a reaction most of the time increases with temperature. An often cited rule, but only approximately correct is: "A 10 °C rise in temperature will double the rate".

Activation Energy (E_a): $A + B \longrightarrow C + D$



The **activation energy (E_a)** is the **minimum** amount of energy required to initiate a chemical reaction.

Temperature Dependence of the Rate Constant (*Arrhenius equation*)



$$k = A \cdot e^{(-E_a/RT)}$$

E_a is the activation energy (J/mol)

R is the gas constant (8.314 J/K•mol)

T is the absolute temperature

A is the frequency factor

$$\ln k = -\frac{E_a}{R} \frac{1}{T} + \ln A$$

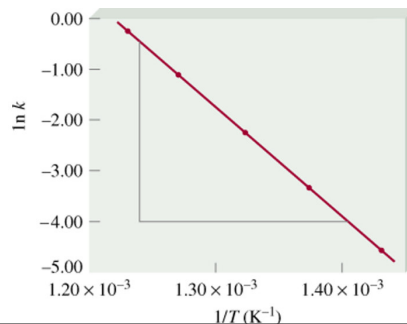
Activation Energy E_a : is the *minimum* amount of energy required to initiate a chemical reaction, in order to react, the reactant species must have a total kinetic energy equal to or greater than the activation energy.

$$\ln k = -\frac{E_a}{R} \left(\frac{1}{T} \right) + \text{constant}$$

Activation energy can be determined from:

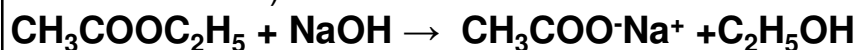
- the **slope** of the line obtained by measuring k at different temperatures, then plotting $\ln k$ versus $1/T$
- the values of k at **two** different temperatures using the formula

$$\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$



Basic hydrolysis of ethyl acetate

Hydrolysis is the breaking down of an **ester** to its corresponding **organic acid** and **alcohol** (in basic media, to its corresponding **sodium salt** of the acid and to the **alcohol**).



This reaction is often called **saponification**.

This hydrolysis is a **second order** reaction (bimolecular) in which the rate is directly proportional to the concentration of both reactants (whose initial concentrations are the same).

The **rate law** and the **integrated rate law** for this second order reaction are given by:

$$\text{rate} = k [\text{A}]^2$$

$$\frac{1}{[\text{A}]} = \frac{1}{[\text{A}]_0} + kt$$

Experimentally

Equal amounts of **ethyl acetate** and **NaOH** will be mixed at two different temperatures.

At **different time intervals**, certain volume of the reaction will be pipetted out of the solution into an Erlenmeyer flask filled with **HCl**, which will **quench** the reaction by reacting with the remaining **NaOH** and thus, **no more NaOH will be available for the hydrolysis to continue**.

The **excess HCl** will be **back-titrated** with a standardized **NaOH** solution using **phenolphthaleine** as an indicator.

Calculations

The number of moles and the concentration **A** of ethyl acetate (same as that of NaOH) at time **t** will be determined from the **back-titration of excess HCl**

By plotting **1/A vs. t** for the two different temperatures, the two **rate constants** are determined (slope of the line).

The **activation energy** of the reaction is then calculated from

$$\ln \frac{k_1}{k_2} = - \frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$