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Practical- Chemical kinetics

B.Sc. I: Paper-III: Fundamentals of Chemistry for Biologist

What is Chemical Kinetics?

The branch of chemistry which deals with the study of the reaction rates is known as **Chemical Kinetics.**

In fact, in all chemical reactions, the reacting species move and collide to form the products. Chemical kinetics also involves the investigation of reaction mechanisms, the conditions of concentration, temperature, pressure, and catalyst which control the rates of different reactions.

Chemical kinetics, also called reaction kinetics, helps us understand the rates of reactions and how it is influenced by certain conditions. It further helps to gather and analyse information about the mechanism of the reaction and define the characteristics of a chemical reaction. In any chemical reaction, as the reaction proceeds, the amount of reactants decreases, whereas the amount of products increases. One has to understand that the rate of the overall reaction depends on the rate at which reactants are consumed or the rate at which the products are formed.

1) Rate of reaction (-dc/dt)

The rate of reaction refers to the speed at which the products are formed from the reactants in a chemical reaction. It gives some insight into the time frame under which a reaction can be completed. For example, the reaction rate of the combustion of cellulose in fire is very high and the reaction is completed in less than a second.

The rate of reaction or reaction rate is the speed at which reactants are converted into products. When we talk about chemical reactions, it is a given fact that rate at which they occur varies by a great deal. Some chemical reactions are nearly instantaneous, while others usually take some time to reach the final equilibrium.

2)Order of reaction:

The Order of reaction refers to the relationship between the rate of a chemical reaction and the concentration of the species taking part in it. In order to obtain the reaction order, the rate expression (or the rate equation) of the reaction in question must be obtained.

The order of reaction can be defined as the power dependence of rate on the concentration of all reactants. For example, the rate of a first-order reaction is dependent solely on the concentration of one species in the reaction. Some characteristics of the reaction order for a chemical reaction are listed below.

- Reaction order represents the number of species whose concentration directly affects the rate of reaction.
- It can be obtained by adding all the exponents of the concentration terms in the rate expression.
- The order of reaction does not depend on the stoichiometric coefficients corresponding to each species in the balanced reaction.

3) Molecularity of Reaction:

The number of reacting particles (molecules, atoms, or ions) that collide simultaneously in a rate determining step to form a product is called molecularity of a reaction.

In general, the molecularity of simple reactions is equal to the sum of the number of molecules of reactants involved in the balanced stoichiometric equation

Examples:

$PCl_5 \rightarrow PCl_3 + Cl_2$ (Unimolecular reaction)

$2SO_2 + O_2 \rightarrow 2SO_3$ (Trimolecular reaction)

$NO + O_3 \rightarrow NO_2 + O_2$ (Bimolecular reaction)

(i) Molecularity of a reaction is always in the whole number.

(ii) It is never fractional.

(iii) Molecularity is a theoretical concept.

(iv) Molecularity cannot be greater than three because more than three molecules may not mutually collide with each other.

- **Aim**: To study the specific reaction rate of hydrolysis of methyl acetate in presence of HCl.
- **Apparatus** : Burette, glass stoppered bottles, 5 ml pipette, conical flask, measuring cylinder, beaker, stop-watch etc.
- **Chemicals**: 0.5 N HCI, 0.1 N NaOH, methyl acetate, ice, phenolphthalein indicator.

Bottle no. 1 : 100 ml of 0.5 N HCL

Bottle no. 2: 5 ml of methyl acetate

- **Observations**:

In burette: 0.1 N NaOH solution

In conical flask: few ice pieces + 5 ml (cm^3) reaction mixture

Indicator: Phenolphthalein

End point: Colourless to pink

- **Procedure:**

(i) In to a stoppered bottle No. 1, take 100 ml 0.5 N HCI by measuring cylinder.

(ii) Into a stoppered bottle No. 2, take 5 ml methyl acetate.

(iii) Keep the bottles in a water bath for about 10 minutes to attain the room temperature.

(iv) Fill the burette with 0.1 N NaOH solution by removing the air bubble.

(v) Into a clean conical flask, take few pieces of ice or 5 ml (cm) ice-cold water and add 2 drops of phenolphthalein indicator. (The function of ice is to stop or arrest or freeze the reaction at that particular time).

(vi) Carefully transfer the whole of 0.5 N HCI from bottle No. 1 to bottle No. 2. shake well and note down the time of mixing (i.e. start the stop-watch).

(vii) Immediately pipette out 5 ml (cm^3) of the reaction mixture in a conical flask containing ice and phenolphthalein indicator and titrate it against 0.1 N NaOH solution till permanent pink colour (stable for 20 to 30 seconds) just develops. This is the zero minute reading and is designated as T_0.

(viii) Again fill the burette with 0.1 N NaOH solution and repeat the titrations by pipetting out the reaction mixture at the successive intervals of time viz. 10. 20, 30, 40 and 50 minutes from the start of the experiment. These readings are called T_t.

(x) Calculate the values of velocity constant, k by using the equation.

Reactions:

$$CH3COOCH3 + H_2O \xrightarrow{HCL} CH3COOH + CH3OH$$

$$HCl + NaOH \rightarrow NaCl + H_2O$$

$$CH3COOH + NaOH \rightarrow CH3COONa + H_2O$$

Equation for calculation of velocity constant:

$$\boldsymbol{k = \frac{2.303}{t} log_{10} \frac{a}{a - x}}$$

Observation table: $T_\infty = 51.9$ ml, $a = T_\infty - T_0 = 51.9 - 26.1 = 25.8$ ml

Time 't' in mins	Titration readings T_t (ml)	$X = T_t - T_0$	$a-x = T_\infty - T_t$	log (a-x)	log a/a-x	k min^{-1}
0	26.1	-	-	-	-	-
10	28.2	2	23.8	1.3765	0.03504	8.069×10^{-3}
20	29.5	3.4	22.4	1.3502	0.06137	7.0667×10^{-3}
30	30.2	4.1	21.7	1.3364	0.07514	6.894×10^{-3}
40	32.5	6.4	19.4	1.2878	0.1238	7.1277×10^{-3}
50	33.8	7.7	18.1	1.2576	0.1539	7.0886×10^{-3}

Result: The mean value of rate constant k = 7.24×10^{-3} min^{-1}

Reference:

1] A hand book of Practical Chemistry by Dr. S. J. Naik, Dr. R. V. Shejwal, Dr. U. B. More: B.Sc. I, Phadke Prakashan