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KINETICS AND EQUILIBRIUM STUDY OF ION EXCHANGE REACTION ON ION EXCHANGE RESIN DUOLITE A 102–D USING TRACER ISOTOPE ^{82}Br

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ABSTRACT

Bromide ion exchange reaction between resin and solution phase has been studied. ^{82}Br radioactive tracer isotope has been used for the present study. The exchange of radioactive bromide ions and inactive bromide ions takes place reversibly. In the present investigations, kinetics of forward and backward reaction has been investigated.

Key words : Kinetics and Equilibrium study, Resin Duolite, Tracer ^{82}Br

INTRODUCTION

Recently, much more development has taken place in the field of ion exchangers. Number of new ion exchangers have been synthesized and upgraded to meet the growing demands of industries. First worthwhile attempt was made by Gans[1] in 1913 for softening of water and decolorisation of sugar solution by Reents[2].

The use of ion exchangers followed by decolorisation and vaccum evaporation for glycerin purification. In recent years, resins are widely in use in chemical industries. For effective use of resins even at high flow rate, a knowledge of rate of ion exchange and factors affecting rate of ion exchange is required. In the present investigations, ^{82}Br isotope was used as a tracer to study the rate of ion exchange reaction at different temperatures, different concentrations of bromide ions and at different amount of ion exchange resin.

EXPERIMENTAL

A strongly basic anion exchange resin Duolite A 102 D was obtained from Auctel Products (India) Pvt. Ltd., Ratnagiri, Maharashtra. The supplied anion exchanger was in chloride form. It was converted into bromide form by conditioning the resin in column using 10% KBr solution. The conditioned resin was then air dried and used for further experiments.

The kinetic study was carried out to understand the forward exchange between radioactive bromide ions in solution and bromide ions on exchanger phase. The reaction can be reprsented as –

$$R - Br + \bar{Br}^{*}_{aq} \longrightarrow R - Br^{*} + Br^{-}_{aq}$$

For kinetic study of forward reaction, bromide ion solutions of different concentrations ranging from 0.005 M to 0.10 M were taken. These solutions were labeled with diluted ^{82}Br solution by microsyringe such that 1.0 *l* of bromide ion will have initial activity between 15000 to 16000 cpm. To this bromide ion solution of known initial activity, fixed amounts of ion exchange resin (1.0 g) in bromide form is added to the labelled bromide ion solution, which is kept in a water bath maintained at constant temperature at 25°C and under constant stirring of solution activity cpm of 1.0 mL of solution is measured on Gamma ray scintillation counter at an interval of every two minutes. Due to rapid exchange of bromide ions, activity of solution decreases rapidly with time for initial period of time and after some interval of time, the activity of solution remains nearly constant. The graph of log activity against time in minute is plotted giving a composite curve, which includes activity exchanged due to rapid as well as slow process. By resolving the composite curve, specific reaction rate in min^{-1} of rapid exchange process is calculated. Such experiments are carried out at different temperatures from 25°C to 45°C and for varying amount of ion exchange resin from 1.0 g to 5.0 g.

The reversed ion exchange reaction can be represented by

$$R - Br^{*} + Br^{-}_{aq} \longrightarrow R - Br + Br^{-*}_{aq}$$

In this the exchange is studied between radioactive bromide ions on the resin and bromide ions in the solution. In the reverse exchange study, ion exchange resin is labeled by placing it in radioactive bromide ion solution for 24 hours and are then air dried. These air dried resins are then used to study exchange rates at different concentrations of bromide ion solution from 0.0025 M to 0.02 M for different temperatures ranging from 25°C to 45°C and for varying amount of ion exchange resin samples from 0.25 g to 2.0 g. In this also, activity in solution increases rapidly during initial stage and after some time, the activity remains nearly constant. Composite curve of log activity against time in minute is obtained and resolved for calculating specific reaction rate in min^{-1} of the rapid ion exchange process. Temperature of the water bath during the experiment was maintained constant with the deviation ± 0.1°C using insurf water bath having automatic on – off control system.

RESULTS AND DISCUSSION

The kinetics of forward and reverse exchange reaction is carried out in two sets of experiments. It is observed that the specific reaction rate increases as the temperature of the electrolytic KBr solution.

With increase in temperature of eletrolyte, the number of collisions between bromide ions in the solution and bromide ions on ion exchanger resin increases thereby causing the reaction rate to increase with rise in temperature as shown in Tables 1 and 2. However, as the amount of ion exchange resin increases, the number of exchangeable ions increases. So the specific reaction rate increases much more sharply with increase in amount of ion exchange resin as shown in Tables 3 and 4. In these two sets of experiments, it is observed that irrespective of whether the initial step is the exchange of radioactive bromide ions from the resin into the solution or from solution into the resin, the two processes should occur, simultaneously. It was confirmed by the fact that under similar conditions of experiment with 1.0 g of resin at 25°C and 0.01M potassium bromide solution, the specific reaction rates were observed to be 0.084 min^{-1}, and 0.084 min^{-1}, respectively, which is identical as seen in Table 1 and Table 4. For both sets of experiments, the amount of bromide ion exchanged in millimoles increases with increase in concentration of potassium bromide solution, although this increase takes place at same specific reaction rate with temperature and amount of ion exchange resin remains constant as shown in Table 5 and 6.

Table 1. Effect of temperature on specific reaction rate of forward ion exchange reaction

$$R - Br + Br^{*-}_{aq} \longrightarrow R - Br^{*} + Br^{-}_{aq}$$

Concentration of labelled bromide ion solution 0.01 M

Amount of ion exchange resin 1.0 g

Temperature (°C)	25	30	35	40	45
Specific reaction rate (min^{-1})	0.084	0.102	0.120	0.142	0.160

Table 2 : Effect of temperature on specific reaction rate of reverse ion exchange reaction

$$R–Br^{*} + Br^{-}_{aq} \longrightarrow R–Br + Br^{*-}_{aq}$$

Concentration of labeled bromide ion solution 0.01 M

Amount of ion exchange resin 0.5 g

Temperature (°C)	25	30	35	40	45
Specific reaction rate (min^{-1})	0.061	0.081	0.100	0.119	0.160

Table 3. Effect of amount of ion exchange resin on specific reaction rate of forward ion exchange reaction

$$R - Br + Br^{*-}_{aq} \longrightarrow R - Br^{*} + Br^{-}_{aq}$$

Concentration oif labelled bromide ion solution 0.005 M

Temperature 30°C

Amount of ion exchange resin (g)	1.0	2.0	3.0	4.0	5.0
Specific reaction rate (min^{-1})	0.103	0.151	0.219	0.250	0.272

Table 4. Effect of amount of ion exchange resin on specific reaction rate of reverse ion exchange reaction

Amount of ion exchange resin (g)	0.5	1.0	1.5	2.0	2.5
Specific reaction rate (min^{-1})	0.062	0.084	0.108	0.130	0.153

Table 5. Variation of amount of bromide ion exchange with concentration of potassium bromide solution in forward ion exchange reaction

$$R - Br + Br^{*-}_{aq} \longrightarrow R - Br^{*} + Br^{-}_{aq}$$

Amount of ion exchange resin 1.0 g

Temperature 25° C

Concentration of bromide ion solution (M)	Specific reaction rate (min^{-1})	Millimoles of bromide ions in 200 cm^3	Amount of bromide ions exchanged (millimoles)
0.005	0.082	1.0	0.470
0.010	0.084	2.0	0.911
0.020	0.083	4.0	1.778
0.040	0.084	8.0	3.420
0.100	0.083	20.0	7.936

Table 6. Variation of amount of bromide ion exchange with concentration of potassium bromide solution in reverse ion exchange reaction

$$R - Br^{*} + Br^{-}_{aq} \longrightarrow R - Br + Br^{*-}_{aq}$$

Amount of ion exchange resin 0.5 g

Temperature 25° C

Concentration of bromide ion solution (M)	Specific reaction rate (min^{-1})	Millimoles of bromide ions in 200 cm^3	Amount of bromide ions exchanged (millimoles)
0.005	0.062	1.0	0.384
0.010	0.061	2.0	1.246
0.020	0.060	4.0	2.904
0.040	0.062	8.0	6.912
0.100	0.061	20.0	17.820

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