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Study of Ion-Isotopic Self-Diffusion Reactions as a Function of Ionic Concentration and Temperature

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Radioactive isotope ^{82}Br has been used as a tracer to study the kinetics of ion-isotopic self-diffusion reactions. The study was carried out in the temperature range of 27.0–48.0°C using 0.010 M labelled bromide ion solution and 1.0 g of ion exchange resins in bromide from, to study the temperature effect on kinetics of self-diffusion reaction. The effect of bromide ion concentration in solution on kinetics of self-diffusion reaction was studied in the concentration range of 0.005–0.100 M labelled bromide ion solution, using 1.0 g of ion exchange resins in bromide form and at a constant temperature of 32°C.

Key Words: Kinetics, Isotope, Self-diffusion reaction.

INTRODUCTION

In recent years there has been a lot of development in the ion exchange techniques and a number of ion exchange resins have been synthesized and tailored to meet the ever growing need of industries. They are also equally important in rapid technical analysis and in separation of high level nuclear waste[1]. The present large and year by year increasing literature on ion exchangers shows the great importance of these substances. Furthermore, not only the fields of application are increasing but new ion exchange products afford new opportunities for both chemists and analysts[2].

Earlier investigators[3–12], in their study to understand the mechanism of ionic diffusion, observed that ionic diffusion proceeds either by film diffusion or particle diffusion mechanism which operates under different conditions of reaction thereby affecting the rate of reaction. The effect of temperature[13], resin particle size[14], degree of cross linking[15] indicates that the reaction rate generally increases with decrease in particle size, increase in porosity, temperature and are also greatly affected by nature of exchangeable species[16], composition of pore liquid[17], nature of functional group[18–21], swelling and mesh width of exchanger[17, 22] and concentration of external solution[23–25].

The present study of kinetics of ion-isotopic self-diffusion reaction was carried out using an industrial grade strongly basic anion exchanger Amberlite IRA-400, to investigate the effect of various operating parameters like concentration of ions

and temperature of external medium on efficienty of ion exchange resins which are being employed in wide range of industrial applications.

EXPERIMENTAL

Ion exchange resins Amberlite IRA-400 (supplied by Rohm and haas Co., USA) a strongly basic anion exchanger in chloride form were converted into bromide form using 10% potassium bromide solution. The complete conversion of ion exchange resins to bromide form was confirmed by potentiometric titration against 0.1 N $AgNO_3$. The resins were then air dried and preserved for further study of temperature and concentration effect on ion-isotopic self-diffusion reaction.

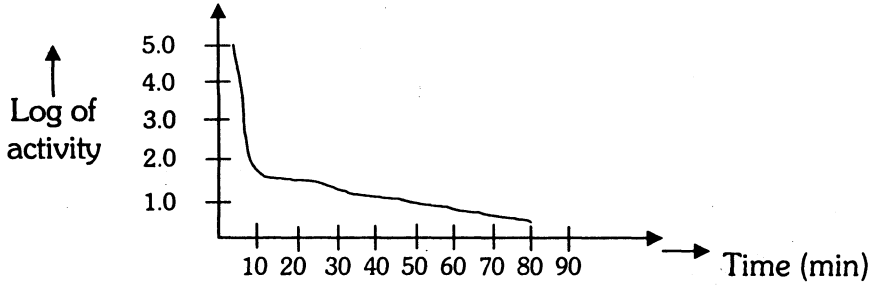
In the present investigation, potassium bromide solution of concentration 0.010 M was labelled with dilute ^{82}Br radio isotope using a micro syringe in such a way that 1.0 mL of potassium bromide solution had activity between 15,000–16,000 counts per min (CPM) as measured on γ-ray spectrometer having NaI (Tl) scintillation detector. To this labelled bromide ion solution (200 cm^3) in a stoppered bottle, ion exchange resins 1.0 g were added, the temperature of the system was maintained constant at 27°C (±0.1°C) under continuous and uniform mechanical stirring. The activity (in CPM) of the labelled solution was measured at a fixed interval of every 1 minute for initial 30 min and after that activity (in CPM) was measured at an interval of every 10 min, up to 90 min which gave the activity measured at infinite time. Similar experiments were performed to investigate the temperature effect up to 48°C. The experiment was also performed in the concentration range of 0.005–0.100 M bromide ion solution using 10 g of resin at 32°C , to study the effect of ionic concentration in solution on the kinetics of ion-isotopic self-diffusion reaction.

RESULTS AND DISCUSSION

It was observed that the activity of the solution goes on decreasing rapidly with time due to the rapid self-diffusion of labelled ^{82}Br radioactive isotope in solution and bromide ions on the ion exchange resin; after a certain time interval the diffusion rate decreases slowly due to the slow self-diffusion reaction taking place. Comparing the specific reaction rate of slow and rapid self diffusion reaction for any particular concentration of bromide ions in solution and for fixed temperature, as well as for same amount of ion exchange resin, the contribution of slow process to the overall rate of self-diffusion reaction is negligible was also observed. Hence for all calculations the specific reaction rate due to rapid self-diffusion process is taken into consideration.

From the measurement of specific reaction rate of rapid process for 1 g of ion exchange resin at various temperatures from 27 to 47°C and for different concentrations of bromide ion solution in the range of 0.005–0.100 M, it was observed that the specific reaction rate remains nearly constant for same temperature even through the bromide ion concentration is varied 20 times (Table-1). However, for same bromide ion concentration, the specific reaction rate of rapid process increases sharply with rise in temperature from 27 to 48°C

(Table-2) was observed, indicating that the present ion-isotopic self diffusion reaction is greatly influenced by the temperature as of ionic concentration of the external medium.



Concentration of bromide ions in solution = 0.0100 M
Amount of ion exchange resins in bromide form = 1 g
Temperature = 32.0°C
Fig. 1. Kinetics of ion-isotopic self-diffusion reaction
$R—Br + Br^*(aq) \rightleftharpoons R—Br^* + Br^-(aq)$

TABLE-1
EFFECT OF BROMIDE ION CONCENTRATION ON THE KINETICS OF SELF-DIFFUSION REACTION
$R—Br + Br^*(ag) \rightleftharpoons R—Br^* + Br^-(aq)$
IN AMBERLITE IRA-400

Amount of ion exchange resin in bromide form = 1 g
Volume of the labelled bromide ion solution = 200 cm^3
Temperature = 38°C

Concentration of labelled bromide ion in solution (M)	0.005	0.010	0.020	0.040	0.100
Millimoles of bromide ion in 200 cm^3 of solution	1.000	2.000	4.000	8.000	20.000
Specific reaction rate (min^{-1})	0.172	0.173	0.175	0.178	0.179

TABLE-2
EFFECT OF TEMPERATURE ON THE KINETICS OF THE SELF-DIFFUSION REACTION
$R—Br + Br^*(ag) \rightleftharpoons R—Br^* + Br^-(aq)$
IN AMBERLITE IRA-400

Concentration of the labelled bromide ion in solution = 0.010 m
Amount of the ion exchange resin in bromide form = 1.0 g

Temperature °C	27.0	32.0	38.0	43.0	48.0
Specific reaction rate (min^{-1})	0.152	1.162	0.173	0.193	0.222

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