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Comparative Study of Forward and Reverse Ion Exchange Reaction in Amberlite IRA -400 by Application of Tracer Isotope-^{131}I

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Iodide ion exchange reaction between the resin and solution phase can be represented by $RI + I^*_{(aq)} \rightleftharpoons RI^* + I_{(aq)}$ where RI is the resin phase having exchangeable iodide ion, I* is the radioactive ^{131}I tracer isotope. This exchange of radioactive iodide ions and inactive iodide ions takes place reversibly. In the present investigation, kinetics study of forward and reverse ion exchange reaction was carried out in two sets of experiments: (1) exchange between radioactive iodide ions in solution and iodide ions on ion exchanger (forward exchange), (2) exchange between radioactive iodide ions on ion exchanger and iodide ions in solution (reverse exchange). This exchange study was performed at different temperatures from 27°C to 48°C, for different concentrations of potassium iodide solution from 0.0025 to 0.1 M and for different amounts of ion exchange resin ranging from 0.250 g to 5.00 g. The forward and reverse ion exchange reaction rates were observed to be 0.123 min^{-1} and 0.122 min^{-1} under identical conditions of 1 g ion exchanger at 27°C and 0.01 M iodide ion solution indicating that forward and reverse ion exchange reaction occurs simultaneously.

INTRODUCTION

In recent years there has been lot of development in the ion exchange technique and a number of ion exchange resins have been synthesized and tailored to meet the ever growing need of industries. As regards utilisation of ion exchangers for industrial purposes the first worth while attempt was made by Gans[1] in 1913 for softening water and decolourising sugar solution. Reents[2] reported the use of ion exchangers followed by decolourisation and vacuum evaporation for glycerine purification.

Now-a-days, resins are an integral part of many chemical industries. For effective operations of resins even at high flow rate, a knowledge of rate of ion exchange and factors influencing that rate of ion exchange is a prerequisite for industrial applications of resins. In the present investigation ^{131}I was applied to study the rates of ion exchange reaction (min^{-1}) for different temperatures, concentrations of iodide ions and for different amount of ion exchange resins, since it is observed that tracer technique only serves as an effective and relatively convenient and sensitive analytical tool.[3]

EXPERIMENTAL

Amberlite IRA-400 used for kinetic study in the present investigation is a strongly basic anion exchanger in chloride form which is converted into iodide form in a conditioning column by using 10% potassium iodide solution. The conditioned resins were then air dried and used for further kinetic experiments. The kinetic study was carried out to study the forward exchange between radioactive iodide ion in solution and iodide ions on ion exchanger phase. Ion exchange reaction can be represented as

$$RI + I^*_{(aq)} \rightleftharpoons RI^* + I_{(aq)}.$$

For studying this forward ion exchange reaction, iodide ion solutions of different concentrations from 0.005 M to 0.1 M were taken. By using microsyringe this solutions were labelled with diluted ^{131}I solution such that 1.0 mL of iodide ion solution will have initial activity between 15,000 c.p.m. to 16,000 c.p.m. (counts per minute). To this iodide ion solution of known initial activity, fixed amount of conditioned ion exchange resin (1.0 g) in iodide form is added to the labelled iodide ion solution which is kept in a water maintained at constant temperature (27°C) and under condition of constant stirring of solution, activity in c.p.m. of 1.0 mL of solution is measured on γ-ray spectrometer at an interval of every 1.0 min. Due to rapid exchange of iodide ions, activity of solution decreases rapidly with time for intial period of time, and after some time interval the activity of solution remains nearly constant. The graph of log activity against time (min.) is plotted giving a composite curve which includes activity exchanged due to rapid as well as slow process. By resolving this composite curve specific reaction rate (min^{-1}) of rapid exchange process is calculated. Such experiments are carried for different temperatures from 27°C to 48°C and for varying amounts of ion exchange resins from 1.0 g to 5.0 g.

The reverse ion exchange reaction can be represented by

$$RI^* + I_{(aq)} \rightleftharpoons RI + I^*_{(aq)}$$

in which the exchange is studied between radioactive iodide ions on the resins and iodide ions in solution. In this reverse exchange study ion exchanger resins are labelled by placing them in radioactive iodide ion solution for 24 h and are then air dried. These air-dried labeled resins are then used to study the exchange rates for different concentrations of iodide ion solutions from 0.0025 M to 0.0200 M, for different temperatures 27°C to 48°C and for varying amounts of ion exchange resins from 0.250 g to 2.00 g, similar to that of previous experiments. In this reverse ion exchange study due to rapid exchange of radioactive iodide ions on exchanger phase with iodide ions in solution, activity (c.p.m.) of solution will increase rapidly with time during initial time interval and after some time interval the activity remains constant; so a composite curve of log activity against time (min) is obtained. The curve is resolved similar to that of previous experiment for calculating specific reaction rates (min^{-1}) of rapid ion exchange process. Temperature of solution during the experiment is maintained with temperature deviation of ± 0.1°C using in surf water bath having automatic on-off control system.

RESULTS AND DISCUSSION

Kinetic study of forward and reverse ion exchange reaction as carried in two sets of experiments shows similar results. In both sets of experiments, specific reaction rate increases with increase in temperature of electrolyte (potassium iodide solution).

With increase in temperature of electrolyte the number of collision between iodide ions in solution and iodide ion exchange resins increases thereby causing the reaction rates to increase with rise in temperature (Table 1, 2). However as the amount of ion exchange resins increases the number of exchangeable ion increases; so the specfic reaction rate increases much more sharply with increase in amount of ion exchange resins (Tables 3, 4). It was observed in two sets of experiments that irrespective of whether the initial step is the exchange of radioactive iodide ions from the resins into the solution or from solution into the resins, the two processes should occur simultaneously, which was confirmed by the fact that under similar conditions of experiment with 1.0 g of resins at 27°C and 0.010 M of potassium iodide solution, the specific reaction rates were observed to be 0.123 min^{-1} and 0.122 min^{-1} respectively which are nearly equal (Tables 1, 4). For both sets of experiments, the amount of iodide ions exchanged in millimoles increases with increase in concentration of potassium iodide solution, although this increase takes place at the same specific reaction rate with temperature and amount of ion exchange resins remaining constant (Tables 5, 6).

TABLE-1
EFFECT OF TEMPERATURE ON REACTION RATES OF FORWARD ION EXCHANGE REACTION

$$RI + I^{*}_{(aq)} \rightleftharpoons RI^{*} + I_{(aq)}$$

Concentration of labeled iodide ion solution 0.010 M
Amount of ion exchange resins 1 g

Temperature (°C)	27.0	32.0	38.0	43.0	48.0
Specific reaction rates (min^{-1})	0.123	0.143	0.155	0.166	0.175

TABLE-2
EFFECT OF TEMPERATURE ON SPECIFIC REACTION RATE OF REVERSE ION EXCHANGE REACTION

$$RI^{*} + I_{(aq)} \rightleftharpoons RI + I^{*}_{(aq)}$$

Concentration of iodide ion solution 0.010 M
Amount of labeled ion exchange resins 0.500 g

Temperature (°C)	27.0	32.0	38.0	43.0	48.0
Specific reaction rates (min^{-1})	0.092	0.111	0.122	0.132	0.144

TABLE-3
EFFECT OF AMOUNT OF ION EXCHANGE RESIN ON REACTION RATES OF FORWARD ION EXCHANGE REACTION

$$RI + I^{*}_{(aq)} \rightleftharpoons RI^{*} + I_{(aq)}$$

Concentration of labelled iodide ion solution 0.005 M at 27°C

Amount of ion exchange resin (g)	1	2	3	4	5
Specific reaction rates (min^{-1})	0.121	0.138	0.230	0.276	0.368

TABLE-4
EFFECT OF AMOUNT OF ION EXCHANGE RESINS ON REACTION RATES OF REVERSE ION EXCHANGE REACTION

$$RI^{*} + I_{(aq)} \rightleftharpoons RI + I^{*}_{(aq)}$$

Concentration of iodide ion solution 0.010 M at 27°C

Amount of labeled ion exchange resin (g)	0.250	0.500	0.750	1.00	1.250	2.00
Specific reaction rate (min^{-1})	0.080	0.092	0.115	0.122	0.150	0.173

TABLE-5
VARIATION OF AMOUNT OF IODIDE ION EXCHANGED WITH CONCENTRATION OF POTASSIUM IODIDE SOLUTION IN FORWARD ION EXCHANGE REACTION

$$RI + I^{*}_{(aq)} \rightleftharpoons RI^{*} + I_{(aq)}$$

Amount of ion exchange resin 1.0 g at 27°C

Concentration of ion labeled iodide ion solution (M)	Specific reaction rates (min^{-1})	Millimoles of iodide ions in 200 cm^3 of solution	Amount of iodide exchanged (millimoles)
0.005	0.121	1.00	0.680
0.010	0.123	2.00	1.164
0.020	0.129	4.00	1.650
0.040	0.127	8.00	2.693
0.100	0.126	20.00	5.537

TABLE-6
VARIATION OF AMOUNT OF IODIDE ION EXCHANGED WITH CONCENTRATION OF POTASSIUM IODIDE SOLUTION IN REVERSE ION EXCHANGE REACTION

$$RI^{*} + I_{(aq)} \rightleftharpoons RI + I^{*}_{(aq)}$$

Amount of labeled ion exchange resin 0.500 g at 27°C

Concentration of ions iodide ion solution (M)	Specific reaction rate (min^{-1})	Millimoles of iodide ions in 200 cm^3 solution	Amount of iodide exchanged (mllimoles)
0.0025	0.098	0.500	0.185
0.0050	0.099	1.000	0.712
0.0100	0.092	2.000	1.144
0.0200	0.100	4.000	3.288

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