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Application of Tracer Isotope in Kinetic Study of First Order Ion Exchange Reaction

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Analysis of first order ion exchange reaction rates at different temperatures (27°–48°C) and particularly at low concentration of potassium iodide solution (electrolyte) ranging from 0.005 M to 0.040 M is carried out by application of radioactive tracer isotope ^{131}I. With increase in concentration of electrolyte, amount of iodide ion exchanged in millimoles increases. Specific reaction rates of ion exchange reaction are calculated for different temperatures and for different amount of ion exchange resins. It is observed that with increase in temperature, reaction rate increases but the increase is more pronounced for increase in amount of ion exchange resins. For 0.005 M solution of electrolyte, the reaction rate increases from 0.121 min^{-1} at 27°C to 178 min^{-1} at 48°C. For 0.005 M solution of electrolyte, the reaction rate increases from 0.121 min^{-1} at 27°C to 0.178 min^{-1} at 48°C. For 0.005 M solution of electrolyte at 27°C the reaction rate increases from 0.121 min^{-1} for 1.0 g of resin to 0.368 min^{-1} for 5.0 g of resin. From the reaction rates calculated at different temperatures, energy of activation in KJ/mole is calculated. It is observed that for 0.005 M solution of electrolyte, energy of activation is 4.62 kJ/mole which decreases to 2.87 kJ/mole for increase in concentration of electrolyte to 0.100 M.

INTRODUCTION

Radioactive tracers[1] have gradually become integrated into process analysis as a measuring tool for diagnosing industrial systems. As a result of development of methods for process analysis, the majority of radioactive tracer applications are now-a-days directed towards investigation of material transport in full-scale industrial process plants. Fission products[2,3] of long half life like Cs-137 and Sr-90 in multicurie quantities find a variety of applications in food irradiators and in systems for nuclear power. In study of numerous migration problems[4] other than self-diffusion, particularly when movements of very small amounts of materials are involved, radioactive tracer isotopes are widely used for analysis as a sensitive and relatively convenient analytical tool.

The present investigation is an important application of radioactive tracers for analysis of first order ion exchange reaction by using ^{131}I as a tracer isotope and Amberlite IRA-400 as an ion exchanger.

EXPERIMENTAL

Amberlite IRA-400 which is a strongly basic anion exchager in chloride form was converted into iodide form by using 10% potassium iodide solution, in a conditioning column. The conditioned resins were then air-dried and used for further study.

In the present investigation potassium iodide solutions of different concentrations from 0.0025 M to 0.100 M were prepared and by using diluted ^{131}I solution these solutions of different concentrations were labeled, such that 1.0 mL of this labeled solution will have known initial activity 15,000 to 16,000 counts per minute (c.p.m.) as measured on gamma ray spectrometer. To these solutions of different concentrations of known initial activity (c.p.m.), fixed amounts of ion exchange resin (1.0 g) in iodide form are added and under continuous stirring of solution the activity of 1.0 mL solution is measured at an interval of every minute. Due to rapid exchange of radioactive iodide ions in solution with iodide ion exchange resins, activity of 1.0 mL solution decreases rapidly for initial interval of time but after some time interval it decreases slowly. The decrease in activity (c.p.m.) of solution will correspond to the activity on the resin surface. When the graph of log activity against time is plotted a composite curve is obtained which includes activity exchanged due to rapid as well as slow process. The composite curve so obtained is then resolved for calculating specific reaction rates (min^{-1}) of rapid process. Similarly the experiment is repeated for different temperatures ranging from 27°–48°C. The temperature of solution is maintained accurately with deviation of ± 0.1°C by using insurf water bath with automatic on-off control system. Similar set of experiments is performed by varying amounts of ion exchange resin from 1.0 g to 5.0 g for fixed temperature of 27°C and for fixed concentration 0.005 M of iodide ion solution.

RESULTS AND DISCUSSION

Kinetic study carried in present investigation reveals many interesting observations. The reaction rates (min^{-1}) were observed to increase in temperature (Table-1) which is due to increase in number of effective collisions with rise in temperature, but increase is more sharp with increase in amount of ion exchange resin (Table-2). With increase in amount of ion exchange resin the number of exchangeable counter ions increases resulting in increase in specific reaction rates (Table-2). From the specific reaction rates calculated at different temperatures the graph of reaction rates (min^{-1}) against temperature is plotted which gives a straight line with negative slope. From this negative slope, energy of activation kJ/mole is calculated by the equation $E = \text{slope} \times -2.303R$ where R is a gas constant with value of 1.987 cals/mole. When the energy of activation (E) is calculated for different concentrations it is observed that energy of activation value decreases with increase in concentration of electrolyte (Table-3) which is due to increase in number of effective collisions with rise in temperature.

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

Concentration of labeled iodide ion solution		0.005 M			
Amount of ion exchange resin		1.0 g			
Temperature (°C)	27.0	32.0	38.0	43.0	48.0
Specific reaction rates (min^{-1})	0.121	0.138	0.158	0.167	0.178

TABLE-2
EFFECT OF AMOUNT OF ION EXCHANGE RESIN ON ION EXCHANGE REACTION RATES

Concentration of labeled iodide ion solution		0.005 M			
Temperature		27°C			
Amount of ion exchange resin (g)	1.0	2.0	3.0	4.0	5.0
Specific reaction rate (min^{-1})	0.121	0.138	0.230	0.276	0.368

TABLE-3
EFFECT OF CONCENTRATION OF IODIDE ION SOLUTION ON ENERGY OF ACTIVATION OF ION EXCHANGE REACTION

Amount of ion exchange resin	1 g				
Volume of labeled iodide ion solution	200 cc				
Concentration of labeled iodide ion solution (M)	0.005	0.010	0.020	0.040	0.100
Energy of activation kJ/moles	4.62	3.66	3.51	3.35	2.87

The amount of iodide ion exchanged in millimoles when calculated for different concentrations of iodide ion solution were observed to increase with increase in concentration of iodide ion solution (Table-4). Although this increase takes place for fixed temperature, fixed amount of ion exchange resin and for specific reaction rate which also remains constant.

TABLE-4
EFFECT OF CONCENTRATION OF IODIDE ION SOLUTION ON AMOUNT OF IODIDE ION EXCHANGED IN ION EXCHANGE REACTION

Amount of ion exchange resin		1.0 g			
Volume of labeled iodide ion solution		200 cc			
Temperature		27°C			
Concentration of labeled iodide ion solution (M)	0.005	0.010	0.020	0.040	0.100
Millimoles of iodide ion in 200 cm^3 of solution	1.00	2.000	4.000	8.000	20.000
Amount of iodide ion exchanged (millimoles)	0.680	1.164	1.650	2.693	5.537

The amount of iodide ion exchanged in millimoles increases efficiently with increase in amount of ion exchange resins (Table-5). For solution containing

1.0 millimoles of iodide ion, amount of iodide ion exchanged is 0.680 millimoles for 1.0 g of resin and is maximum of 0.931 millimoles for 5.0 g of resin at 27°C (Table-5).

TABLE-5
EFFECT OF AMOUNT OF ION EXCHANGE RESIN ON AMOUNT OF IODIDE ION EXCHANGED IN ION EXCHANGE REACTION

Concentration of labeled iodide ion solution	0.005 M				
Amount of iodide ion in 200 cm^3 of solution	1.0 millimoles				
Temperature	27°C				
Amount of ion exchange resin (g)	1.0	2.0	3.0	4.0	5.0
Amount of iodide ion exchanged (millimoles)	0.931	0.680	0.761	0.838	0.907

REFERENCES

1. K. Lundgren, XXIV International Congress of Pure and Applied Chemistry, Vol. 6 (1973).
2. *Isotopes and Radiation Technology*, **1**, 325 (1964).
3. Large scale production and application of radio isotopes, Proceedings of American Nuclear Society, National Topical Meeding, USA, DP-1066 (1960).
4. G. Friedlander, Nuclear and Radiochemistry, 2nd Edn., John Wiley and Sons, Inc. (1956).

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