

Ion Exchange in Industry and Medicine

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THE phenomenon of ion exchange¹ is usually defined as the exchange of ions that occur on contacting an ionic solid with an electrolyte solution. Although this phenomenon is generally considered as occurring solely in heterogeneous systems involving electrolyte solutions and ionic solids it can also take place at other interfaces. Ion exchange has been found to occur in such substances as silicates, phosphates, fluorides, humus, cellulose, wool, proteins, alumina, resins, lignin, living cells, glass and other inorganic precipitates.

The importance of ion exchange techniques in industry, agriculture and medicine has increased considerably since 1940 due to the availability of ion exchange agents. Ion exchange emerged as an industrial tool at the beginning of 20th century. The studies of Gans² on the use of natural and synthetic silicious exchangers for softening of water were the first major attempts to utilise ion exchange on an industrial basis. The use of ion exchange in industry was limited to water softening until 1935. In the same year Adams and Holmes³ discovered that certain synthetic resins were capable of exchanging ions quite readily. Their studies revealed that sulphonic, phenolic and amino type resins could be prepared which would enable one to exchange either anions or cations reversibly. The stability, high capacity and versatility of these ion exchange resins were immediately recognised by many academic and industrial chemists and a new era of ion exchange was inaugurated. Since 1942 many new uses have been found and proposed for these resins and many attempts have been made to improve and modify them. Recent synthetic studies have shown that these ion exchangers can be "tailor

made" to have physical properties and chemical characteristics for specific applications.

Ion exchange in the field of industry:

In the field of chemical technology, ion exchange principles⁴ can be used to achieve (1) removal of undesired ions (2) isolation of "desirable dissociating end products (3) catalysis of certain chemical reactions. The best example of "removal of undesired ions" is the manufacture of demineralised water for injectable purposes in pharmaceutical industry, purification of amino acids obtained during the hydrolysis of proteins^{5,6}, preparation of low calcium cow's milk, deacidification and demineralisation of fruit juice concentrates and wines etc. Ion exchangers are used with increasing frequency in the preparation of high grade biological products like enzymes, muscle extracts, hormones, plasma toxins, growth regulators^{7,8} etc. In the isolation of "desirable dissociating end products" the ion exchange technique is used to absorb the desired end product on a suitable exchanger and enrich it in the purified form, finally it is liberated from the exchanger and worked up. This technique is of special use in the isolation of small quantities of active ingredients from very dilute solutions and the merit lies in the fact that the active ingredients can be concentrated and isolated quickly without the costly process of extraction and evaporation etc. Thus the extraction of alkaloids from crude drug extracts, recovery of heavy metals from industrial waste^{7,8,9} etc. are but few examples of this category. In the field of antibiotics⁷, penicillin for instance, can be separated from raw culture filtrates and purified from impurities by adsorption on an ion

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exchange column. The impurities pass down and penicillin can be liberated as sodium or potassium salt from the exchanger. Streptomycin and other antibiotics are now being purified by ion exchange technique. The use of "ion exchange catalysers" for chemical reactions have been widely studied and many processes have been worked out on commercial scale. Thus esterification of organic acids, hydrolysis of proteins and many condensation reactions are of special interest. One unique merit of these exchanger catalysers is that they can be readily separated from the reaction product, because they are solids and the catalytically active ions are fixed on the resins. By their use, the interfering side reactions can be avoided and the purity and yield can be improved.

Ion exchange reactions have been a very useful tool in hands of analytical chemists¹⁰ also. For instance, in the quantitative inorganic analysis removal of interfering ions such as tartrates, oxalates, phosphates etc. can be achieved by ion exchangers. Similarly ion exchangers are employed to achieve separation of metal ions. Thus arsenic can be separated from a solution of arsenic, antimony and tin. Bismuth can be separated from a solution of bismuth, copper and lead. In quantitative analysis both cations and anions can be determined by ion exchange agents. Cations can be exchanged for hydrogen ions on cation exchanger in the *H*-form and the liberated acid is titrated with standard alkali and the equivalent quantity of original cation can be calculated. Ion exchangers come in for special use in the separation of rare earths which is very difficult otherwise, for example, recovery of magnesium from seawater and separation of zirconium from hafnium^{9,7,8}. The property of rare earths to form complexes with citric acid is used and these complexes show great differences in adsorbability by the exchangers. In exchangers have also found some applications in microanalysis. A good example is the

determination of calcium in human serum. The use of ion exchangers in the chemical study of plant constituents is also worth mentioning. Thus the qualitative estimation of cinchona alkaloids have been done with great ease by use of ion exchange technique. In the field of glycosides the use of ion exchangers is not much but their applications are soon developing. The utilisation of ion exchange agents in the analysis of chemotherapeutic drugs is worth referring. Local anaesthetics like procaine and amylocaine can be exchanged with Amberlite *IRA-400* and determined quantitatively. Similarly ephedrine, amphetamine and antihistamines like antazoline, promethazine and mepyramine are also assayed by use of these ion exchangers. Ion exchange chromatography has been used to a large extent in the separation and analysis of amino acids and nucleotides.

Ion exchange in the field of medicine :

The use of ion exchange in the field of medicine has produced sensational results. Ion exchange agents have been used to mitigate some of the common human diseases. Majority of human population to-day, suffers from gastrointestinal troubles such as diarrhea, dysentery, chronic ulcerative colitis and peptic ulcers etc. The human gastrointestinal tract is a seat of absorption of nutrients. Along with this some toxic principles of exogenous and endogenous origin are also absorbed. These toxic principles produce profound physiological alterations. And it is the summation of many such deleterious agents that constitutes the pathological straw breaking the back of physiological normality¹¹. Therefore, the general principle underlying the ion exchange and adsorption therapy is that of differential or selective adsorption. The exchangers used must remove the toxic substances from the seat of their absorption while permitting the normal absorption of nutrients. This point was emphasized by the work of Melnick

*et al.*¹² (1945) in which they demonstrated that fullers earth but not kaolin markedly reduced the availability of thiamine. Studies with sodium and aluminium silicate Martin and Wilkinson¹³ (1936) and with ion exchange resins Martin and Wilkinson (1946)¹³ have demonstrated that feeding of diet containing 5% of these materials does not interfere with normal nutrition. The most frequently used adsorption and exchanger agents are kaolin aluminium hydroxide, charcoal, magnesium trisilicate, sodium aluminium silicate, bentonite sulphonic cation exchange resins, carboxylic cation exchange resins, polyamine anion exchange resins etc. Some of these are broad spectrum agents removing toxins of bacterial origin also. Anion exchange materials are found to be very effective in removing from the gut, toxic products like histamine skatole, and indole etc.

The use of combination of cation and anion exchange agent in the control of diarrhea is worth noting. In 1950, Joslin of Batlimore reported the study of combination of exchangers and adsorbent agent in the management of diarrhea in pediatric practice. A composition of 10% of poly amine exchange resin, 10% of sodium aluminium silicate and 1.25% magnesium silicate was used. The dose was one tablespoonful thrice daily; no other medicine was used; diarrhea was controlled within 24 to 48 hours.

Ion exchange materials have been used to stop the nausea and vomiting of pregnancy (Fitzpatric *et al.*¹⁴ 1950). It was observed that histamine and similar agents induce vomiting when applied directly to the vomiting centre (Best and Taylor 1943) Histamine was observed to be an important etiological factor in nausea and vomiting of pregnancy (Hofbauer¹⁵ 1926)¹¹ Kapeller-Adler and Adler¹⁶ Histamine like substances produced by the bacterial action in the gut were found to cause this distressing clinical syndrome. The use of multi-

phasic intestinal exchange and adsorbent agents gave good results in nausea and vomiting of pregnancy.

In summing up it is worth while to emphasize that an ideal intestinal adsorbent and exchanger should possess the following qualifications:

- (1) Maximum capacity for removal of toxic principles such as tyramine, histamine putrescine, cadavarine etc.
- (2) Maximum capacity for removal of toxic bacterial metabolic products like indole, skatole, etc.
- (3) Maximum capacity for removal of irritant chemicals.
- (4) Absence of any tendency to remove essential food factors such as vitamins and amino acids etc.
- (5) Non toxicity generally, through total insolubility.
- (6) Patient acceptability.

Ion exchange and adsorption materials will no doubt play a major role in the ultimate resolution of this intriguing human problems in the years to come.

References

1. Kirk and Othmer, *Encyclopedia of Chemical Technology*, vol. 8. The Interscience Encyclopedia Inc., New York.
2. Gans, R. *Jahrb, Preuss, Geol. Landesanstalt*, 26, 179 (1905).
3. Adams, B. A. and Holmes, E. L., *J. Soc., Chem. Ind.*, 1935, 54, 1-6T.
4. H. R. Nanji, *Indian J. Pharm.*, 1956, 18, 284.
5. Kunin, R., Meyers, R. J., *Ion Exchange Resins*, Willey, N. Y. 1950.
6. Kunin, R., Meyers, R. J., *Discussions. Faraday Soc.*, 1949, No. 7, 114.
7. Kunin, R., Winter, J. C., *Colloid Symposium Army Chemical Centre*, June, 1947.
8. Nachod, F. C., *Ion Exchange*, Academic Press, N. Y., 1949.

9. Kraus, K. A. and Moore, G. E., J. Am. Chem. Soc., 1949, 71, 3263.
 10. H. R. Nanji, Indian J. Pharm., 1956, 18, 332.
 11. Gustav, J. Martin, Ion Exchange and Adsorption Agents in Medicine, 1954. Little, Brown and Co., Boston, Toronto.
 12. Melnick, D., M. Hoehburg, and B. L. Oser, J. Nutrition, 1945, 30, 233.
 13. Martin, G. J. and Wilkinson, Gastroenterology, 6, 315, 1946.
 14. Fitzpatrick, V. de P., R. E. Hunter, C. E. Brambel, Am. J. Dig. dis., 1951, 18, 340.
 15. Hofbaur, J., Am. J. Obst. Gynæcs, 1926, 12, 159.
 16. Kapeller-Adler, R. and E. Adler, J. Obst. Gynæcs. Brit. Emp., 1943, 50, 117.
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