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γ-Radiation Effects on the Nuclear Grade Ion Exchanger Resin—Indion -223

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A gel type polystyrene sulphonic acid resin Indion-223 of nuclear grade was irradiated up to dose 12MGy in Li^+, Cr^{3+} and Fe^{3+} cationic forms using ^{60}Co source and the chemical yields as the result of radiolytic degradation are calculated. The capacity of the resin decreases due to irradiation pH values and hence the H_2son yield as milliequivalent and concentration of cations increases as the γ-dose.

INTRODUCTION

Ion exchange is an integral part of nuclear power plants and nuclear industry. This is because selected few ion exchangers are found to be stable towards high intensity radiation. In general[1], the anion exchangers are more susceptible to radiation damage than the cation exchangers and the H^+ or OH^- forms are less stable than the salt forms. Present work on radiation stability focuses attention on changes in the exchange capacity, pH values, H_2son yield and concentration of cation. Radioactive charged species transfer energy to an ion exchanger making the system more susceptible to rapid deterioration. It results in loss of exchangable sites and decrosslinking of resin matrix. Hence quantitative knowledge of degraded product in ion exchange system is of prime importance. However only limited data appear to be available in this regard.

EXPERIMENTAL

0.5 g gel type sulphonic acid resin of nuclear grade of trade name Indion-223 in Li^+, Cr^{3+} and Fe^{3+} cationic forms was irradiated under aqueous condition upto dose of 12 MGy using ^{60}Co source after conditioning and converting the resin in required cationic form. The exchange capacity of the resin was determined by eluting with 4% Na_2SO_4 after washing with double distilled water. All washings and effluents were collected carefully and concentrations of cations were determined as ppm. H_2SO_n yield was calculated from pH value of effluent.[2–4]

RESULTS AND DISCUSSION

The most important physico-chemical property of an ion exchanger from the point of its applications is the exchange capacity. In order to see the radiation effect the capacity of the resin in different ionic forms was determined in the virgin state. The capacity values for the nuclear grade resin under the air-dry condition are for Li^+, Cr^{3+} and Fe^{3+} are presented in Table-1 Our data indicates that the ion exchange capacity depends on various factors, namely, valence state of cation, ratio of relative charge and size of ion, nature of hydration shell, ionic radius and length of metal oxygen bond. Similar observations were reported by others on resins[5, 6] with code name KU-2 and Dowex-50.

Our data shows that the capacity with respect to cations are in the order as $Fe^{3+} > Cr^{3+} > Li^{+}$ for the exchanger. From this trend it is revealed that the Fe^{3+} salt form of the resin is more stable than the Li^{+} form. Ionic radius and metal oxygen bonding values are also given in Table-1, for comparison with the exchange capacity values. It is seen that among the different forms of the resin the binding in the Fe^{3+} form is stronger. The above results can be explained on the basis of nature of hydration shell of the cation. The Li^{+} form is hydrated more indicating the hydration shell much larger[7] as compared with the other forms. The situation is reversed in the case of Fe^{3+} form of the resin. Lesser hydration shell will result in stronger contact pair formation between Fe^{3+} ion and the functional group.

TABLE-1

THE PROPERTIES OF NUCLEAR GRADE ION EXCHANCER

Property	Ionic form		
	Li^{+}	Cr^{3+}	Fe^{3+}
Exchange Capacity/Meg g^{-1}	4.00	6.20	6.80
Ionic radius/Å	0.60	0.64	1.70
M—O bond length/Å	1.00	2.35	2.78

Radiation effect on the exchange capacity of nuclear grade resin is shown in Fig. 1. Up to a dose of 12 MGy in the case of polystyrene nuclear grade resin,

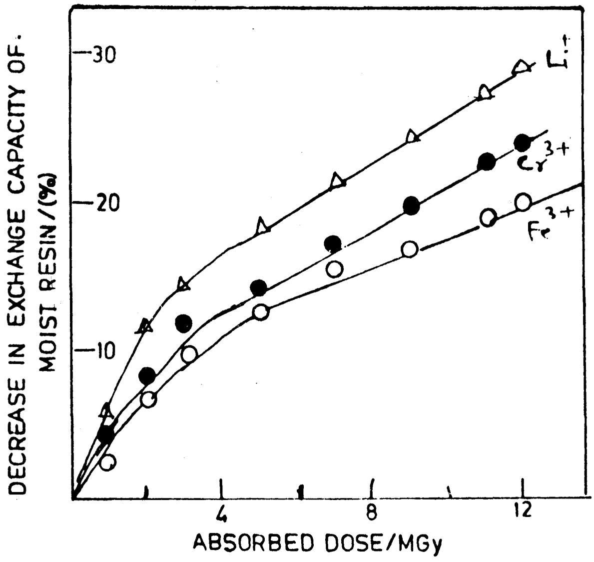

Fig. 1 Loss of exchange capacity of water suspended nuclear grade polysterene resin with radiation dose absorbed.

there is steady decrease in the exchange capacity with increasing γ dose followed by a limiting value with further increase of absorbed dose. The radiation effect is found minimum for Fe^{3+} form of resin while it is maximum for the Li^+ form. Decrease in capacity is always less for the air -dry sample than for the resin suspended under water (Table-2). Decrease in the case of water suspended resin is almost double as compared to that for the air-dry resin.

pH values and hence the H_2son yield as milliequivalents and concentration of cations increases as the γ-dose (Table-2). Here Fe^{3+} ionic form gives less chemical yields and the trend is $Li^+ > Cr^{3+} > Fe^{3+}$. This is because of compactness of metal ion to the exchangable site and large ionic radius of cation (Table-3). Here Li^+ form of resin is found less stable towards irradiations as compared to Cr^{3+} and Fe^{3+} cationic forms.

TABLE-2
EFFECT OF IRRADIATION OF THE EXCHANGE CAPACITY OF POLYSTYRENE NUCLEAR GRADE RESIN DURING AIR-DRY AND WATER-SUSPENDED CONDITIONS

Dose/MGy	Decrease in exchange capacity %			pH of aqueous effluent		
	Li^+	Cr^{3+}	Fe^{3+}	Li^+	Cr^{3+}	Fe^{3+}
0	0.0	0.0	0.0	6.54	6.70	6.80
1	2.2 (5.75)	1.6 (3.75)	1.5 (1.7)	3.60	3.80	3.90
2	5.5 (11.5)	2.3 (8.0)	2.0 (6.5)	3.10	3.55	3.67
3	7.5 (14.6)	3.2 (11.7)	3.0 (9.9)	2.70	3.10	3.15
5	13.5 (18.5)	5.0 (14.0)	4.0 (12.5)	2.46	2.70	2.81
7	15.3 (21.6)	6.5 (17.0)	6.0 (16.0)	2.38	2.65	2.69
9	18.0 (24.8)	7.8 (19.5)	7.8 (17.0)	2.31	2.50	2.58
11	18.0 (28.2)	8.8 (22.5)	8.0 (19.0)	—	—	—
12	19.0 (29.0)	9.9 (24.0)	8.0 (20.0)	2.28	2.46	2.55

(Values within parentheses are for the samples suspended under water during γ-irradiation)

TABLE-3
DOSE DEPENDENT CONCENTRATION OF CATIONS IN AQUEOUS EFFLUENT AS ppm

Dose /MGy	Concentration in ppm		
	Li^+	Cr^{3+}	Fe^{3+}
1	138	96	84
2	638	380	326
3	618	562	504
5	1026	666	634
7	1208	812	716
9	1388	934	872
11	1548	1072	980
12	1610	1124	1026

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