Assessing the feasibility study of highly efficient and selective co-sequestration process for cesium and strontium utilizing calix-crown and crown-ether based combined solvent systems

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Abstract

Efficient and selective extraction of ^{137}Cs and ^{90}Sr from high level liquid waste (HLLW) is of utmost importance in the back end nuclear fuel cycle to minimize long term radiological surveillance of HLLW due to the long half-life of ^{137}Cs ($t_{1/2} = 30$ years) and ^{90}Sr ($t_{1/2} = 29$ years). 1,3-di-octyloxycalix[4]arene-crown-6 (CC6) and dicyclohexano-18-crown-6 [DCH18CH] are suggested as potential candidates for individual extraction of ^{137}Cs and ^{90}Sr, respectively. An attempt was made for simultaneous separation of ^{137}Cs and ^{90}Sr with enhanced distribution ratio using combined solvent system having suitable combination of CC6 and DCH18CH in n-octanol from simulated HLLW. Using the combined solvent system in 100% n-octanol, ^{137}Cs and ^{90}Sr were found to have significantly high extraction efficiency ($D_{Cs} = 18.8$ and $D_{Sr} = 3.1$) with 5 min extraction time. No interference from mono and divalent cations (Na$^+$ and Mg^{2+}) was observed. The extraction processes were found to be spontaneous.

Keywords Crown ether · Co-extraction · Metal–ligand stoichiometry · Interference

Introduction

A considerable amount of the radioactivity in HLLW generated from spent nuclear fuel recycling comes from the fission products ^{137}Cs and ^{90}Sr [1]. Collectively, ^{137}Cs and ^{90}Sr account for over 99% of the relative radioactivity of dissolved nuclear fuel solutions; once the actinides have been separated. Removal of ^{137}Cs ($t_{1/2} = 30$ years) and ^{90}Sr ($t_{1/2} = 29$ years) would increase the safe handling of liquid waste and minimize the storage and disposal costs of these radioactive components [2–10]. Effective separation of ^{137}Cs and ^{90}Sr from spent nuclear fuel is also a vital issue

in nuclear industry due to short-term heat loading in a geological repository. ^{137}Cs has a potential to migrate in soil particles along with surface waters [11]. ^{137}Cs has imposed serious public-health related problem; due to transportability through the atmosphere and high solubility. ^{137}Cs has huge bioavailability, which is very similar to potassium (K$^+$) ions and ^{137}Cs easily assimilated through aquatic organisms and terrestrial [12]. Consequently, ^{137}Cs can simply enter into human body and stay there for long time, resulting to potential irradiation of human living tissue. Thus, effective removal of ^{137}Cs needs to be investigated with very urgency. ^{90}Sr is one of the most important anthropogenic radionuclides present in marine environment, mainly due to accidents and operation of nuclear facilities [13]. At the same time, ^{90}Sr is difficult to separate using conventional methods from the aqueous medium due to its lower chemical potential i.e. charge to size ratio [14].

It is important to find out a suitable system, having higher selectivity for targeted ions. Cs was selectively recognized by calix[4]arene crown-6 moeities [15–20], and Sr was effectively separated using supramolecular compounds, crown ether derivatives, like 4,4′(5′)-di-tert-butyldicyclohexano-18-crown 6 (DT) and DCH18C6 [21–25]. Several separation processes like cesium extraction (CSEX) [26],

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caustic-side solvent extraction process (CSSX) [27], and strontium extraction (SREX) [28] have been reported in literature for individual separation of Cs and Sr. In this regards, Rais et al. reported the effective separation of Cs and Sr using 25,27-bis(1-octyloxy)calix[4]arene-26,28-crown-6 and DCH18C6 ligands respectively [29]. Recently, different solvent extraction based method were studied to remove Sr [28, 30–32] and Cs [26, 33–39]. Though, majority of literature reported the separation of Sr and Cs individually; the separation processes for Cs and Sr can be made easier by combining both the extraction processes together. The first literature report on this approach was using polyethylene glycol and chlorinated cobalt dicarbollide in a phenyltrifluoromethyl sulfone diluent [40]. Cs and Sr were also reported to be separated simultaneously using calix[4]arenebis-(tert-octylbenzo-crown-6) (BOBCalixC6) and 4',4',(5')-di-(t-butyldicyclohexano)-18-crown-6 (DtBu18C6) mixed with a phase modifier, 1-(2,2,3,3-tetrafluoropropoxy)-3-(4-s-butylphenoxy)-2-propanol (Cs-7SB) [41]. DCH18C6 in n-octanol medium for separation of Sr and 25,27-bis(isopropoxy) calix[4]-26,28-crown-6 (iPr-C[4]C-6) in n-octanol medium for separation of Cs from HLLW were also reported [42, 43].

The aim of present study is to separate ^{137}Cs and ^{90}Sr simultaneously from HLLW. Based on earlier reports, DCH18C6 for ^{90}Sr [21–25] and CC6 for ^{137}Cs [15–20] in n-octanol medium were selected for the present investigation. A novel combined solvent system using a mixture of 1,3-dioctyloxycalix [4]arene-crown-6 (CC6) and dicyclohexano-18-crown 6 [DCH18CH] in n-octanol was successfully demonstrated for simultaneous extraction of ^{137}Cs and ^{90}Sr from simulated HLLW. The potential and feasibility of the solvent system were evaluated. The results clarified that, the simultaneous ^{137}Cs and ^{90}Sr removal process was rapid and reached saturation almost instantly. The effects of different promising diluents were examined on the extraction behavior of ^{137}Cs and ^{90}Sr. The effect of competitive ions, monovalent cation like sodium (Na$^+$) and di-valent cation magnesium (Mg^{2+}) were studied. This solvent system revealed to be promising for the simultaneous removal of ^{137}Cs and ^{90}Sr due to its fast kinetics, selectivity, considerable volume reduction capacity and cost benefit as both the radionuclide can be removed in a single step and represent an effective scheme to develop a systematic process flow sheet for removal of ^{137}Cs and ^{90}Sr from simulated HLLW solution.

Experimental

Materials: chemicals, isotopes and solutions

CC6 and DCH18CH (Fig. 1, 2) were purchased from S. D. Fine Company, India. The radiotracer, ^{137}Cs and $^{85/89}$Sr
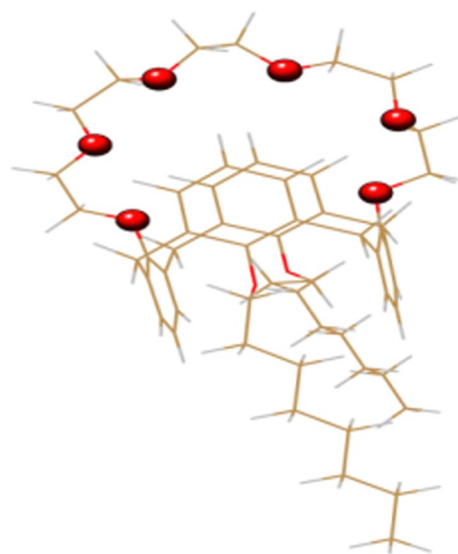

Fig. 1 1, 3-dioctyloxy calix[4]arene-crown-6 (CC6). (Color code: O = Red; H = Light grey C = Tan
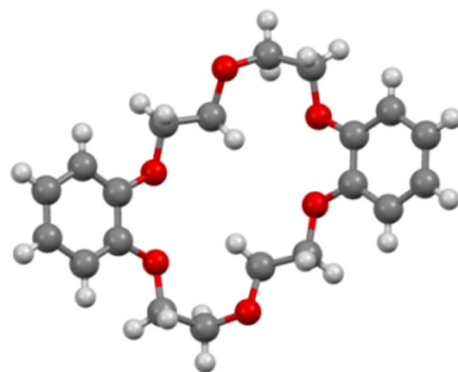

Fig. 2 Dicyclohexano-18-crown-6 (DCH18C6) In the structure, O = Red; C = Tan; H = Light grey)

used in the present study, were purchased from Board of Radiation and Isotope Technology (BRIT), India. The solvent 100% n-octanol was procured from S.D. Fine company, India. Double distilled water and Supra-pure HNO$_3$ were used throughout the investigation. The composition of simulated HLLW given in Table 1 represents the HLLW obtained from 3 years cooled Pressurized Heavy Water Reactor (PHWR) spent fuel reprocessing. All the experiments were conducted with an appropriate quantity of ^{137}Cs and $^{85/89}$Sr radiotracer spiked into HNO$_3$ medium. During the experiment, radiation monitoring instruments and proper personal protective equipment (PPE) were used.

Table 1 Composition of simulated HLLW

Sr. No	Property		Value	
1	Molarity		3–3.5 Acidic	
2	*Specific Activity*			
2.1	Gross α		17.05 Ci/lit	
2.2	Gross β		75.40 mCi/lit	
3	*Principal Isotopes Identified*			
3.1	Cs^{137}		7.082 Ci/lit	
3.2	Sr^{90}		4.587 Ci/lit	
3.3	Cs^{134}		56.00 mCi/lit	
3.4	Zr^{95}		27.60 mCi/lit	
3.5	Eu^{154}		17.89 mCi/lit	
3.6	Sb^{125}		16.70 mCi/lit	
3.7	Ru^{106}		9.00 mCi/lit	
3.8	Am^{241}		71.00 mCi/lit	
3.9	Pu^{239}		3.80 mCi/lit	
4.0	*Elemental Analysis (gm/litre)*			
	U	5.2	La	0.12
	Na	4.5	Ce	0.04
	Fe	1.65	Pr	0.06
	Cr	0.17	Nd	0.08
	Ni	0.20	Y	0.04
	Mn	0.48	Al	0.17
	K	0.20	Cs	0.244
	Sr	0.04	Sm	0.057
	Mo	0.13	Zr	0.004
	Ru	0.04	Se	0.051
	Pd	0.03	Te	0.024
	Ba	0.25		

Distribution ratio and radiometry

To determine the distribution ratio (D_M) of metal ions, 5 mL of organic phase constituting CC6 and DCH18CH in *n*-octanol and 5 mL of aqueous phase having ^{137}Cs and $^{85/89}$Sr radio tracer was equilibrated for 20 min. After equilibration the complete phase separation was achieved by centrifuging the above biphasic system for 5 min. For understanding the dependency of distribution ratio of cesium and strontium ion on varying solvent composition having different diluent polarity; the diluent compositions were varied with respect to relative composition of *n*-dodecane and *iso*-decyl alcohol, while other parameters were kept constant. D_M of the respective metal ions were determined in terms of the ratio of the analytical concentration of metal ions in organic phase to aqueous phase. All extraction experiments were conducted at 25 ± 1 °C in a thermostatic water bath procured from Lab India, Mumbai, India. ^{137}Cs (604.7 keV) and $^{85/89}$Sr (514 keV) activity were counted using gamma counting system having intrinsic HPGe detector associated with 4 K MCA.

Concentration of nitric acid in aqueous and organic phases were estimated by potentiometric titration (0.1 M NaOH), using a Metrohm 905 Titrando device. It was confirmed that, the mass balance has error with in ± 5% for all the techniques.

The dependency of distribution ratio of cesium and strontium ion on varying solvent composition as the diluents phase was carried out using the experimental parameters mentioned below. Organic phase: 0.03 M CC6 and 0.1 M DCH18C6 in variable solvent compositions; aqueous phase: spiked with ^{137}Cs and $^{85/89}$Sr radio tracer in 5 M HNO$_3$. 5 mL of organic and aqueous phase were taken for the experiment. Contact time: 30 min. Triplicate experiments were carried out and the error is within the limit of ± 5%. The temperature of the extraction was kept 30 °C.

Determination of D_{Cs} and D_{Sr} values as a function of contact time was performed using the experimental parameters as stated below. Organic Phase: 0.03 M CC6 and 0.1 M DCH18C6 in 100% *n*-octanol; aqueous phase: spiked with ^{137}Cs and $^{85/89}$Sr metal in 5 M HNO$_3$. Equal volume (5 mL) of organic phase and aqueous phase was taken for the study. The temperature of the experiment was kept 30 °C. Triplicate experiments were carried out and error is within the limit of ± 5%. Others parameters remained constants unless otherwise mentioned.

Determination of D_{Cs} values as a function of variable concentration of CC6 was carried out using the parameters mentioned herewith. Organic Phase: (0.003–0.03) M CC6 in *n*-octanol; aqueous phase: spiked with ^{137}Cs metal ions in 5 M HNO$_3$. Experiment was carried out at room temp. Triplicate experiments were carried out and error limit is within ± 5%.

Determination of D_{Sr} values as a function of varying concentration of DCH18C6 were done using the experimental parameters described below. Organic Phase (0.01–0.3) M DCH18C6 in *n*-octanol; aqueous phase: spiked with $^{85/89}$Sr metal ions in 5 M HNO$_3$. Extraction study was conducted at 25 ± 1 °C. Triplicate experiments were carried out and error limit is within ± 5%.

Extraction dependency of cesium and strontium on the varying acid concentration (HNO$_3$, HCl, HClO$_4$) were performed as follows: Organic phase: 0.015 M CC6 and and 0.1 M DCH18C6 in *n*-octanol; Aqueous phase: varying concentration of acid (HNO$_3$, HCl, HClO$_4$) spiked with ^{137}Cs and $^{85/89}$Sr metal ions. Experiment was carried out at 25 ± 1 °C. Triplicate experiments were carried out and the error limit is ± 5%.

Extraction dependency of D_{Cs} and D_{Sr} on the interfering metal (Na$^+$, Mg^{2+}) ion concentrations have been investigated using the following procedure. Organic phase: 0.015 M CC6 and 0.1 M DCH18C6 in 100% *n*-octanol; Aqueous phase: varying concentration (0.1–3.0) M of metal ions (Na$^+$ and Mg^{2+}) spiked with ^{137}Cs and $^{85/89}$Sr metal ions in 5 M HNO$_3$.

Experiment temp was kept at 25 ± 1 °C. Triplicate experiments were carried out and the error limit is $\pm 5\%$.

Results and discussion

Effect of diluents phase composition on D_{Cs} and D_{Sr}

Along with metal binding nature of the ligands/extractant, polarity of the solvent phase also has an important role in the distribution ratio of the radionuclides from an aqueous phase standpoint. In view of this, different solvent systems with varying polarity were studied to determine the polarity effect on extraction efficiency of D_{Cs} and D_{Sr}. Appropriate choice of solvent system was carried out for maximum extraction efficiency based on previous report [45]. D_{Cs} and D_{Sr} values were determined in 1:1 mixture of *iso*-decyl alcohol and *n*-dodecane with 0.03 M CC6 and 0.1 M DCH18C6, individually. The distribution value obtained for cesium (($D_{Cs} = 7.4$) was found to be similar compared to the results reported by Sharma et al. (2014) [46]. By increasing solvent polarity (i.e. increasing the concentration *iso*-decayl alcohol), extraction efficiency for Cs (D_{Cs}) and Sr (D_{Sr}) were found to increase (Fig. 3). This experimental result motivated us to employ highly polar *n*-octanol medium as the diluent in the present investigation. The choice of diluents can also be justified considering its environmental friendly nature. Very good D_{Cs} (~ 21.8) value along with moderate D_{Sr} (~ 2.8) (Fig. 3) values were achieved by using 0.03 M CC6 and 0.1 M DCH18C6 in 100% *n*-octanol. Hence, further extraction experiments were carried out using 100% *n*-octanol.

Effect of contact time on D_{Cs} and D_{Sr} extraction

Extraction kinetics is one of the most vital properties of the solvent systems for presenting an efficient metal ion extraction process. In majority cases, the evaluation of extraction rate is based on determining equilibrium time for the metal ions separation. However, several ligands (calix- crown/ crown-ether) showed their own equilibrium times; due to the different inherent physical and chemical characteristics, which consists of solvent polarity and binding nature based on the metal ligand complexation. Therefore, the optimum equilibration time required for the maximum extraction of Cs^+ and Sr^{2+} from the acidic aqueous phase with 0.03 M CC6 and 0.1 M DCH18C6 in *n*-octanol was studied, individually. The extraction profiles for Cs^+ and Sr^{2+} were established by varying equilibration time in the range of 2 to 30 min (Fig. 4). The extraction efficiency of Cs^+ and Sr^{2+} increased with equilibration time from 2 to 5 min. With further increase in equilibration time, there was no change in D_{Cs} and D_{Sr} values. Therefore, a contact time of 5 min was chosen for further extraction procedures.

Understanding the speciation and thermodynamics

To determine the optimum concentration of CC6 and DCH18C6 for maximum extraction of Cs and Sr;
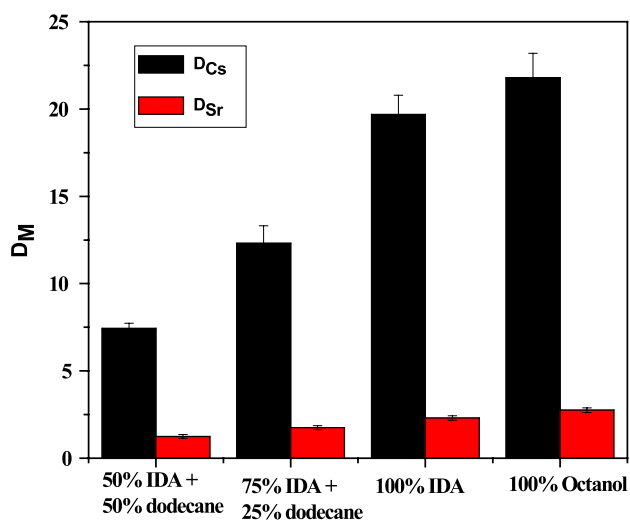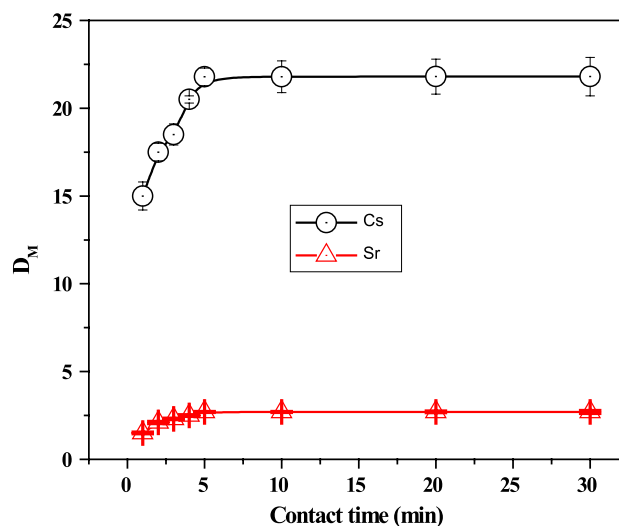

Fig. 3 Dependency of distribution ratio of cesium and strontium ion on varying solvent composition as the diluents phase. Organic phase: 0.03 M CC6 and 0.1 M DCH18C6 in variable solvent compositions; aqueous phase: spiked with ^{137}Cs and [85/89]Sr radio tracer in 5 M HNO$_3$. Contact time: 30 min. (Triplicate experiments were carried out and the error is within the limit of $\pm 5\%$)

Fig. 4 Determination of D_{Cs} and D_{Sr} values as a function of contact time, Organic Phase 0.03 M CC6 and 0.1 M DCH18C6 in 100% *n*-octanol; aqueous phase: spiked with ^{137}Cs and [85/89]Sr metal in 5 M HNO$_3$. (Triplicate experiments were carried out and error is within the limit of $\pm 5\%$)

experiments were carried out using CC6 and DCH18C6 in *n*-octanol.

The complexation between Cs^+ and CC6 can be expressed in presence of nitrate ions using the following equation as described below. To understand the nature of complexation; the metal–ligand stoichiometry was determined.

$$Cs_{aq}^+ + n\,CC6_{org} + NO_{3aq}^- = [CsNO_3.(CC6)_n]_{org} \qquad (1)$$
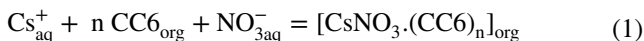
The equilibrium constants or the extraction constant of equation 0.1 can be expressed as

$$k_{ex} = \frac{[[CsNO_3.(CC6)_n]_{org}]}{[Cs_{aq}^+]}\frac{1}{[CC6_{org}]^n}\frac{1}{[NO_{3aq}^-]} \qquad (2)$$

At constant HNO_3 concentration and temperature, concentration of nitrate ion is constant in aqueous phase and the first term is nothing but the analytical concentration of Cs^+ ion in organic phase divided by that in aqueous phase, i.e. D_{Cs}. Then Eq. (2) can be simplified as

$$k'_{ex} = \frac{D_{Cs}}{[CC6_{org}]^n} \qquad (3)$$

where; k'_{ex} is known as conditional extraction constant. The 'n' is the number of ligand molecules attached to Cs^+ ion. Now applying logarithm on both sides of the equation,

$$\log D_{Cs} = \log k'_{ex} + n.\log[CC6_{org}] \qquad (4)$$

The change in Gibb's free energy due to the complexation and subsequent mass transfer can also be calculated from the equilibrium constant using the following equation

$$\Delta G = -2.303\,RT\log k'_{ex} \qquad (5)$$

A plot of $\log D_{Cs}$ versus $\log[CC6_{org}]$ (Fig. 5) was found to be a straight line having a slope of 0.998 ± 0.014 conforming the formation of 1:1 metal–ligand complex. The change in Gibb's free energy was calculated as -16.42 kJ/mole. Cs^+ ion was also reported to form 1:1 stoichiometric complex with similar type of ligands [11, 14]. The negative ΔG value for the extraction revealed that, the process is thermodynamically favourable i.e. spontaneous in nature. Similar attempt was also made to understand the mechanism of the complexation of Sr extraction using DCH18C6 in *n*-octanol medium. The equilibrium constants can be expressed as

$$Sr_{aq}^{2+} + nDCH18C6_{org} + 2NO_{3aq}^- = [Sr(NO_3)_2.(DCH18C6)_n]_{org} \qquad (6)$$
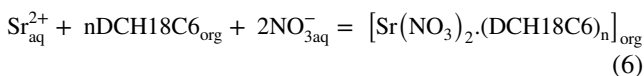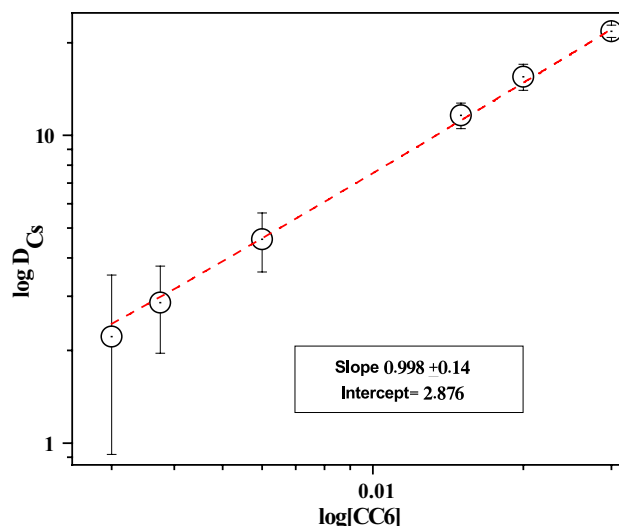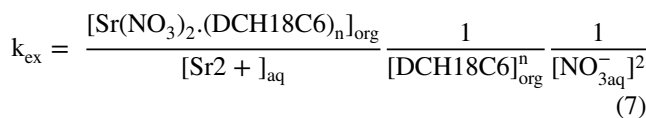
From Eq. 6 can be expressed as

Fig. 5 Determination of D_{Cs} values as a function of variable concentration of CC6, Organic Phase (0.003- 0.03) M CC6 in *n*-octanol; aqueous phase: spiked with ^{137}Cs metal ions in 5 M HNO_3. (Triplicate experiments were carried out and error limit is within $\pm 5\%$)

$$k_{ex} = \frac{[Sr(NO_3)_2.(DCH18C6)_n]_{org}}{[Sr2+]_{aq}}\frac{1}{[DCH18C6]_{org}^n}\frac{1}{[NO_{3aq}^-]^2} \qquad (7)$$

At a particular nitric acid concentration, aqueous phase nitrate ion concentration is constant and the above equation can be simplified as follows

$$k'_{ex} = \frac{D_{sr}}{[DCH18C6]_{org}^n} \qquad (8)$$

where, k'_{ex} is known as conditional extraction constant. Now using logarithm in both side of Eq. 8, we can be get the Eq. 9

$$\log D_{Sr} = \log k'_{ex} + n\log[DCH18C6]_{org} \qquad (9)$$

$$\Delta G = -2.303\,RT\log k'_{ex} \qquad (10)$$

A plot of $\log D_{Sr}$ versus $\log[DCH18C6]_{org}$ (Fig. 6) obtained a straight line having a slope of 0.99 ± 0.002, revealing the formation of 1:1 metal–ligand complex. Beyond a certain concentration of ligand, the distribution ratio became almost unchanged with increase in ligand concentration as shown in Fig. 6. The change in Gibb's free energy (ΔG) was evaluated as -7.70 kJ/mole. The negative ΔG value revealed the extraction process was spontaneous in nature.
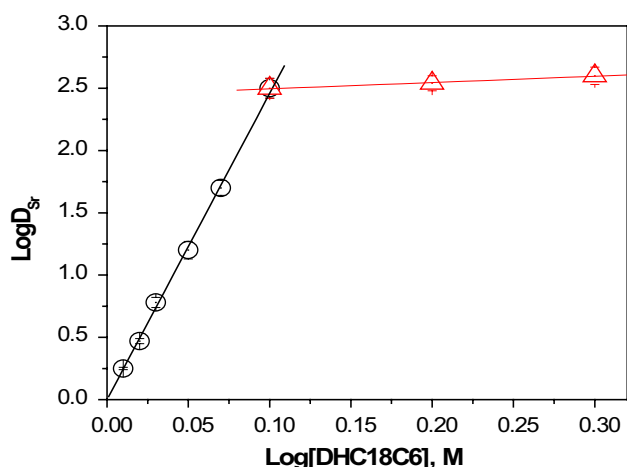
Fig. 6 Determination of D_{Sr} values as a function of varying concentration of DCH18C6, Organic Phase (0.01–0.3) M DCH18C6 in *n*-octanol; aqueous phase: spiked with [85/89]Sr metal ions in 5 M HNO$_3$. (Triplicate experiments were carried out and error limit is within ± 5%)

## Formulation of combined solvent system and simultaneously extraction of Cs$^+$ and Sr^{2+}

For simultaneous separation of Cs$^+$ and Sr^{2+} from simulated HLLW, mixed organic solvents (0.015 M CC6 + 0.1 M DCH18CH) were used in 5 M HNO$_3$ medium. For this purpose, simulated HLLW was prepared, where [85/89]Sr and ^{137}Cs radiotracers were spiked. Then mixed organic solvents i,e 0.015 M CC6 + 0.1 M DCH18C6 were prepared in 100% *n*-octanol medium. To achieve the maximum extraction efficiency, equivalent amount of organic phase (i.e. 0.015 M CC6 + 0.1 M DCH18C6 in 100% *n*-octanol) and aqueous phase (spiked with [85/89]Sr and ^{137}Cs radiotracers) were equilibrated. After separating the two phases by centrifuging the activity of Cs & Sr was analysed using gamma spectrometry and D$_M$ values for the metal ions were calculated. Significantly high D value of Cs$^+$ (D$_{Cs}$ = 18.8) and Sr^{2+} (D$_{Sr}$ = 3.1) were observed. Figure 7 represents the extraction of Cs$^+$ and Sr^{2+} using 0.015 M CC6 + 0.1 M DCH18C6 in *n*-octanol.

Extraction of D$_{Cs}$ and D$_{Sr}$ in different acids (HNO$_3$, HCl, HClO$_4$)

The extraction profiles for Cs$^+$ and Sr^{2+} were established as a function of different acid concentrations (HNO$_3$, HCl, HClO$_4$) using 0.015 M CC6 and 0.1 M DCH18C6 in *n*-octanol [Fig. 8]. The experimental results revealed that, the D$_{Cs}$ and D$_{Sr}$ followed the order HNO$_3$ > HClO$_4$ > HCl in the range of 1–6 M acidity, advocating the 'ion-pair' mechanism. In case of HCl, the extraction efficiency for Cs$^+$ and Sr^{2+} were observed to be lower value. This might be attributed to the lower proficiency of [Cs$^+$-Cl$^-$] and [Sr^{2+}-Cl$^-$] ion-pair formation. This can be explained in terms of comparatively higher hydration energy

Fig. 7 Representation of Cs$^+$ and Sr^{2+} complexation with combined ligand consisting of CC6 and DCH18C6 for selective extraction of Cs and Sr in the presence of high concentration of Na$^+$, Mg^{2+}, OH$^-$ and NO$_3^-$ ions
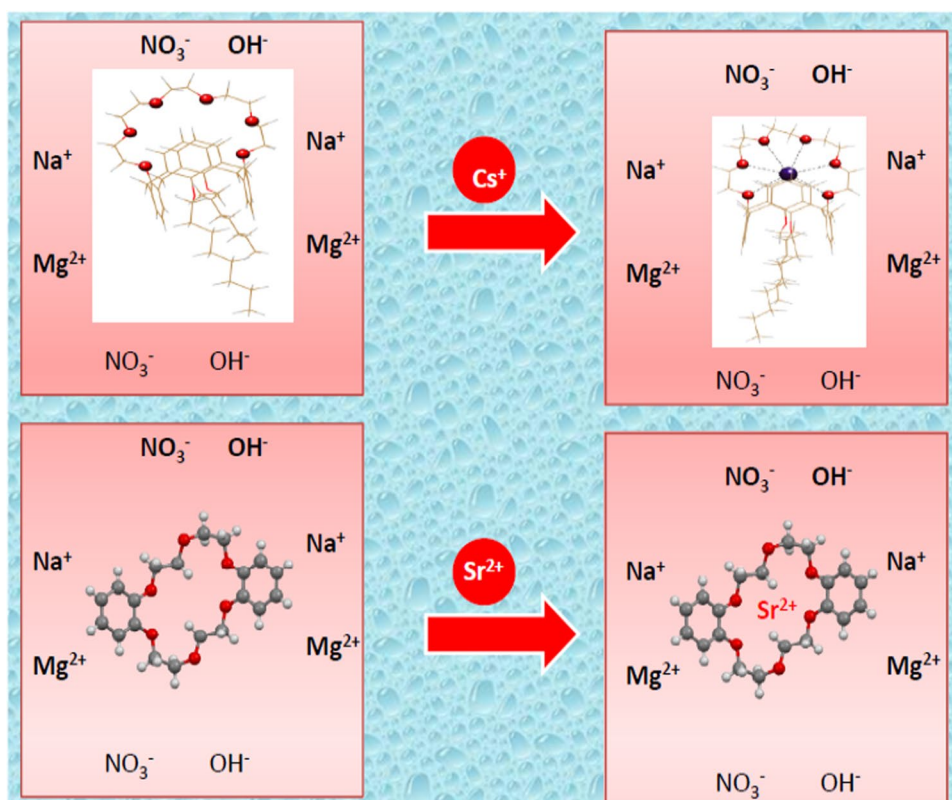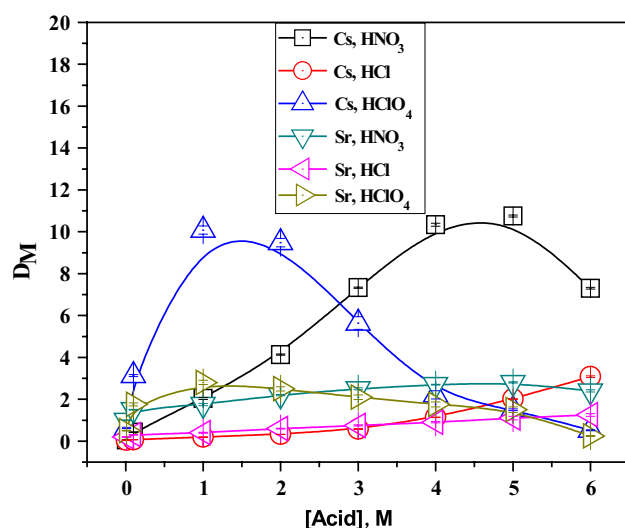
Fig. 8 Extraction dependency of cesium and strontium on the varying acid concentration (HNO_3, HCl, $HClO_4$). Organic phase: 0.015 M CC6 and and 0.1 M DCH18C6 in *n*-octanol; Aqueous phase: varying concentration of acid (HNO_3, HCl, $HClO_4$) spiked with ^{137}Cs and $^{85/89}Sr$ metal ions (Triplicate experiments were carried out and the error limit is $\pm 5\%$)

Fig. 9 Extraction dependency of D_{Cs} and D_{Sr} on the interfering metal (Na^+, Mg^{2+}) ion concentrations. Organic phase: 0.015 M CC6 and 0.1 M DCH18C6 in 100% *n*-octanol; Aqueous phase: varying concentration (0.1- 3.0) M of metal ions (Na^+ and Mg^{2+}) spiked with ^{137}Cs and $^{85/89}Sr$ metal ions in 5 M HNO_3. (Triplicate experiments were carried out and the error limit is $\pm 5\%$)

of Cl^- ion. For HNO_3, with an increase in acid concentration, the D_{Cs} and D_{Sr} values were found to increase gradually, reaching maximum at 5 M HNO_3 with a subsequent marginal reduction. The initial rise might be attributed to the requirement of NO_3^- ions in formation of Cs^+-NO_3^- / Sr^{2+}-NO_3^- ion-pairs. However, beyond 5 M HNO_3, the competition between Cs^+/Sr^{2+} and H^+ for ion-pair formation with NO_3^- ions played influential role in determining the trend in D values.

Interference study of Na^+ and Mg^{2+} on distribution ratio of metal ions Cs^+ and Sr^{2+}

Selectivity is a crucial parameter for extraction of particular metal ion as the distribution ratio can be influenced in presence of similar type of metal ions (like mono-valent Na^+ ions and di-valent Mg^{2+} ions). Thus, it is essential to understand the effect of these ions on the extraction property of Cs^+ and Sr^{2+}. Figure 9 clearly represented the interference of Na^+ and Mg^{2+} on the extraction of Cs^+ and Sr^{2+}. Experimental data showed that, there was no imperative effect of Na^+ and Mg^{2+} on the extraction behaviour of Cs^+ and Sr^{2+}. This can be attributed to the size selective complexation of these ligands with metal ions.

Conclusions

A novel combined solvent system comprising of CC6 (0.015 M) and DCH18C6 (0.1 M) dissolved in 100% *n*-octanol was successfully demonstrated as effective materials for efficient separation of Cs and Sr in a single
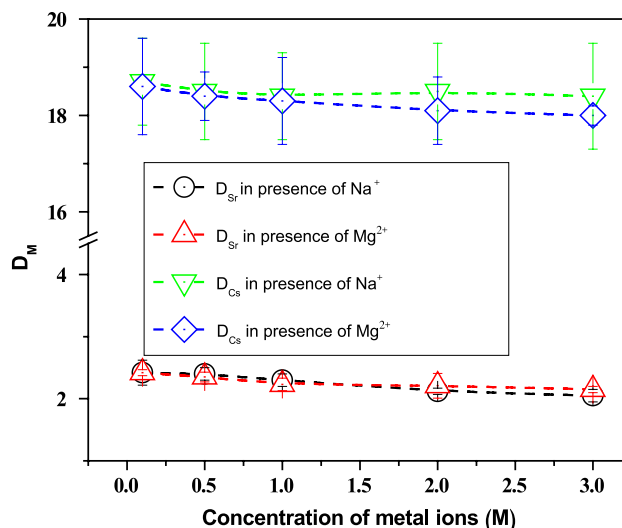
step from simulated HLLW with high selectivity and fast kinetics. The highly polar *n*-octanol can effectively be used to boost the distribution ratio of metal ions (D_{Cs} and D_{Sr}) significantly with respect to iso-decyl alcohol and *n*-dodecane. Highly polar *n*-octanol tends to satisfy easily the primary coordination sphere of metal ion (Cs^+ and Sr^{2+}) and thus enhancing efficient mass transfer from aqueous phase to the organic phase. Effect of interfering cations like Na^+ and Mg^{2+} were studied and no such effect on the extraction of Cs^+ and Sr^{2+} were observed. The formation of ion-pair complex involving nitrate as counter anion with 1:1 metal–ligand stoichimetry has been confirmed for both the metal ions. High distribution ratio were achieved for Cs and Sr ($D_{Cs} = 18.8$ and $D_{Sr} = 3.1$) by using the combined solvent system. This has a potential for Cs and Sr removal in a single step process from radioactive waste management facility. The extraction processes were found to be spontaneous in nature.

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