Problem 12-02 Membrane equilibria

The vessel is divided in two compartment of the same volume. The barrier is a membrane non-permeable for high molecular ions. One compartment (A) is filled with 0.01 molar CsCl solution, the other (B) contains the same volume of 0.01 molar CsCl solution in which some amount of high molecular chloride RCl is dissolved. Determine the concentration of RCl, needed to expel 75 % of CsCl from the compartment B to A. Both electrolytes are completely dissociated.

[c_{RCl} = 0.012 mol dm^{-3}]

Solution:

c(CsCl) = 0.01 mol dm^{-3} CsCl = $Cs^+ + Cl^-$

c(RCl) = 0.01 mol dm^{-3} RCl = $R^+ + Cl^-$

$c_{R+} = c$(RCl)

Balance:	at the beginning		in equilibrium	
	A	B	A	B
R^+	0	c_{R+}	0	c_{R+}
Cs^+	0.001	0.001	0.001 + x	0.001 – x
Cl^-	0.001	0.001 + c_{R+}	0.001 + x	0.001 + c_{R+} – x

Donnan equilibrium condition for CsCl:

$$(c_{Cs^+})_A \cdot (c_{Cl^-})_A = (c_{Cs^+})_B \cdot (c_{Cl^-})_B$$

$$(0.001+x)\cdot(0.001+x) = (0.001-x)\cdot(0.001+c_{R^+}-x)$$

$$(0.001+c_{R^+}-x) = \frac{(0.001+x)^2}{(0.001-x)}$$

75 % of CsCl has to go from B to A:

$$x = 0.75\cdot 0.001 = 0.00075 \text{ mol dm}^{-3}$$

$$0.001+c_{R^+}-0.00075 = \frac{(0.001+0.00075)^2}{(0.001-0.00075)} = 0.01225$$

$$c_{R^+} = c_{R^+Cl^-} = 0.01225+0.00075-0.001 = 0.012 \text{ mol dm}^{-3}$$