CHEMICAL EQUILIBRIUM

Aim

Study of the shift in equilibrium in the reaction between $[Co(H_2O)_6]^{2+}$ and Cl^- ions, by changing the concentration of any one of these ions.

Theory

In the reaction between $[Co(H_2O)_6]^{2+}$ and Cl^- ions, the following displacement reaction takes place.

$$\underset{\text{Pink}}{[Co(H_2O)_6]^{2+}} + 4Cl^- \rightleftharpoons \underset{\text{Blue}}{[CoCl_4]^{2-}} + 6H_2O$$

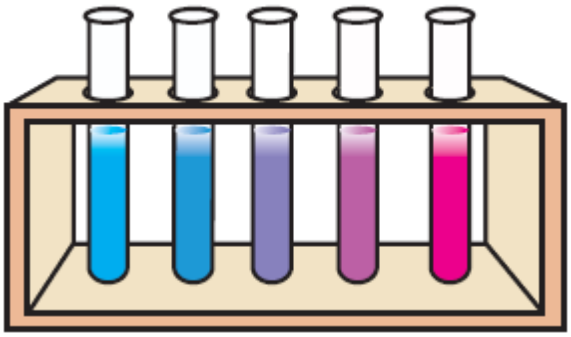
This reaction is known as ligand displacement reaction and the equilibrium constant, *K*, for this is written as follows:

$$K = \frac{[[CoCl_4]^{2-}]}{[[Co(H_2O)_6]^{2+}][Cl^-]^4}$$

Since the reaction occurs in the aqueous medium, it is believed that concentration of H_2O is almost constant and is included in the value of *K* itself and is not shown separately in the expression for equilibrium constant.Now if at equilibrium the concentration of either $[Co(H_2O)_6]^{2+}$ ion or Cl^- ions is increased, then this would result in an increase in $[CoCl_4]^{2-}$ ion concentration thus, maintaining the value of *K* as constant. In other words we can say that equilibrium will shift in the forward direction and will result in a corresponding change in colour.

Chemicals and Material Required

- Conical flask (100 mL) : One
- Beakers (100 mL) : Three
- Burettes : Three
- Test tubes : Six
- Test tube stand : One
- Glass rod : One
- Acetone/alcohol : 60 mL
- Concentrated hydrochloric acid : 30 mL
- Cobalt chloride : 0.6000 g



Procedure

(i) Take 60 mL of acetone in a 100 mL conical flask and dissolve 0.6000 g $CoCl_2$ in it to get a blue solution.

(ii) Take 5 test tubes of same size and mark them as A, B, C, D and E. Add 3.0 mL of cobalt chloride solution in each of the test tubes from 'A' to 'E' respectively. Now add 1.0 mL, 0.8 mL, 0.6 mL, 0.4 mL and 0.2 mL of acetone respectively in these test tubes. Add 0.2 mL, 0.4 mL, 0.6 mL and 0.8 mL of water to test tubes B, C, D and E respectively, so that the total

volume of solution in each of the test tubes is 4.0 mL.
(iii) Note the gradual change in colour of the mixture from blue to pink with an increase in the amount of water. Record your observations in tabular form (Tables 4.3).
(iv) Take 10 mL cobalt chloride solution in acetone prepared above and add 5 mL distilled water to it. A solution of pink colour will be obtained.
(v) Take 1.5 mL of pink solution from step (iv) in five different test tubes labeled as A2 B2, C2, D2 and E2. Add 2.0 mL,1.5 mL, 1.0 mL and 0.5 mL of water to the test tubes labeled from A2 to D2 and 0.5 mL, 1.0 mL, 1.5 mL, 2.0 mL and 2.5 mL concentrated HCl respectively in the test tubes A2 to E2 so that total volume of solution in the test tubes is 4 mL.
(vi) Note the gradual change in colour of pink solution to light blue with increasing amounts of hydrochloric acid. Record your observations in tabular form (Tables 4.4).

Table 4.3 : Shift in equilibrium on adding water

Sl. No.	Test tube	Volume of acetone added in mL	Volume of $CoCl_2$ solution added in mL	Volume of water added in mL	Colour of mixture
1.	A	1.0	3.0	0.0	
2.	B	0.8	3.0	0.2	
3.	C	0.6	3.0	0.4	
4.	D	0.4	3.0	0.6	
5.	E	0.2	3.0	0.8	

Table 4.4 : Shift in equilibrium on adding Cl^- ions

Sl. No.	Test tube	Volume of conc. HCl added in mL	Volume of aquo complex solution added in mL	Volume of water added in mL	Colour of mixture
1.	A′	0.5	1.5	2.0	
2.	B′	1.0	1.5	1.5	
3.	C′	1.5	1.5	1.0	
4.	D′	2.0	1.5	0.5	
5.	E′	2.5	1.5	0.0	

Note : *• In the first set of experiments concentration of chloro complex is constant and concentration of water is changing.*
• In the second set concentration of aqua complex is constant and concentration of chloride ions is increasing.

Result:- At equilibrium when the concentration of Cl^- ions is increased, then this results in an increase in $[CoCl_4]^{2-}$ ion concentration thus, maintaining the value of *K* as constant and equilibrium shifts in the forward direction and results in a change in colour from pink to blue. Similarly when the concentration of H_2O is increased, then this results in an increase in $[Co(H_2O)_6]^{2+}$ ion concentration thus, maintaining the value of *K* as constant and equilibrium shifts in the backward direction and results in a change in colour from blue to pink.

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