1 Reaction Under Study

The reaction under study is the equilibrium reaction between two complex ions of cobalt, being $CO(H_2O)_6$ and $COCl_4$. The Cobalt ion with water appears to be a pink colour whereas the cobalt ion containing chlorine will be a blue solution. This investigation aims to explore the effect of stress on the equilibrium value.

$$[CO(H_2O)_6]^{2+}\,(aq) + 4\,Cl^-\,(aq) \rightleftharpoons [COCl_4]^{2-}\,(aq) + 6\,H_2O\,(l) \tag{1}$$

2 Experimental Procedure

For each of the experimental procedures below, record the observation after each step of the process has been completed. The experiment is split into two separate parts, the first part being conducted in dropper bottles and the second part of the experiment being conducted in sealed vials.

2.1 Dropper Bottle Experiments

2.1.1 Water (H_2O) + Hydrochloric Acid (HCl)

1. Place 2-3 drops of $CoCl_2\,(aq)$ in a well plate.
2. Add 3-5 drops of $H_2O\,(l)$.
3. Add 5-10 drops of concentrated $HCl\,(aq)$ in the fume hood.

2.1.2 Hydrochloric Acid (HCl) + Water (H_2O) + Lead (II) Nitrate ($Pb(NO_3)_2$)

1. Place 2-3 drops of $CoCl_2\,(aq)$ in a well plate.
2. Add 5-10 drops of concentrated $HCl\,(aq)$ in the fume hood.
3. Add 3-5 drops of $H_2O\,(l)$.
4. Add 3-5 drops of $Pb(NO_3)_2\,(aq)$ solution.

2.1.3 Hydrochloric Acid (HCl) + Lead (II) Nitrate ($Pb(NO_3)_2$)

1. Place 2-3 drops of $CoCl_2\,(aq)$ in a well plate.
2. Add 5-10 drops of concentrated $HCl\,(aq)$ in the fume hood.
3. Add 3-5 drops of $Pb(NO_3)_2\,(aq)$ solution.

2.2 Sealed Vial Experiments

2.2.1 Cobalt Chloride ($CoCl_2\,(aq)$) + Ice-Water Mixture ($H_2O\,(l) + H_2O\,(s)$)

1. Placed the sealed Cobalt Chloride ($CoCl_2\,(aq)$) solution in a 250 mL beaker.
2. The beaker should contain approximately 100 mL of ice-water mixture ($H_2O\,(l) + H_2O\,(s)$).
3. Record observations after 5 minutes.

2.2.2 Cobalt Chloride ($CoCl_2\,(aq)$) + Hot Water Bath ($H_2O\,(l)$)

1. Placed the sealed Cobalt Chloride ($CoCl_2\,(aq)$) solution in a hot water bath (do not let go of test tube in the water bath).
2. Record observations after 5 minutes.

3 Raw Data

3.1 Dropper Bottle Experiments

3.1.1 Water (H_2O) + Hydrochloric Acid (HCl)

The addition of H_2O (l) caused the $CoCl_2$ (aq) to turn more pink (diluted colour) and after adding HCl (aq), the solution turns blue and becomes green in colour over time.

3.1.2 Hydrochloric Acid (HCl) + Water (H_2O) + Lead (II) Nitrate ($Pb(NO_3)_2$)

The addition of HCl (aq) caused the $CoCl_2$ (aq) to turn blue and the further addition of H_2O (l) turns the solution back to pink. When the $Pb(NO_3)_2$ (aq) solution was added, white precipitate was formed and the solution became pink in colour.

3.1.3 Hydrochloric Acid (HCl) + Lead (II) Nitrate ($Pb(NO_3)_2$)

The addition of HCl (aq) to a blue colour and the $Pb(NO_3)_2$ forms white precipitate and reverts the solution back to a pink colour.

3.2 Sealed Vial Experiments

3.2.1 Cobalt Chloride ($CoCl_2$ (aq)) + Ice-Water Mixture (H_2O (l) + H_2O (s))

The $CoCl_2$ (aq) solution was placed in a 52.9 ^{o}C hot water bath and the solution turned to a blue colour.

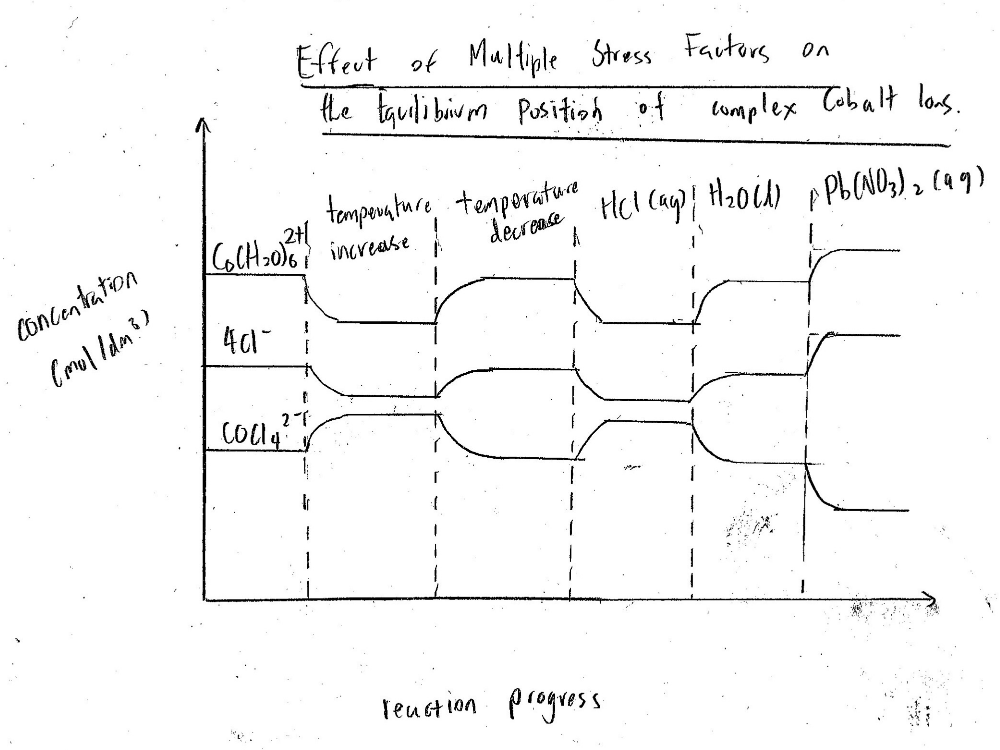
3.2.2 Cobalt Chloride ($CoCl_2$ (aq)) + Hot Water Bath (H_2O (l))

The $CoCl_2$ (aq) was placed in a 4.8 ^{o}C ice water bath and the solution turned to a pink colour.

4 Data Processing

4.1 Equilibrium Graph

The effect of each stress on the position of equilibrium as can be seen in the graph below. The detailed explanation of each stress will be explained in the section **4.2**.



4.2 Explanation of Stresses

The equilibrium constant of the reaction above is given as follows:

$$K_c = \frac{[COCl_4{}^{2-}]}{[Co(H_2O)_6{}^{2+}][Cl^-]^4} \tag{2}$$

Therefore, as the concentration of chlorine ions is decreased, the overall K_c value will increase, which will shift the equilibrium towards the products. The reverse is true, where if the concentration of chlorine ions is increased, the K_c value will decrease and shift the equilibrium towards the reactants.

Furthermore, as the stresses are added over time instead of instantaneous, the graph should not experience as spike, but rather a gradual change over time.

4.2.1 H_2O (l)

The addition of H_2O (l) as a stress caused the equilibrium to shift towards the reactants (became more pink) as it diluted the concentration of chlorine ions. The decrease in reactant causes the equilibrium to shift leftwards.

4.2.2 HCl (aq)

The addition of HCl (aq) as a stress caused the equilibrium to shift towards the products (became more blue) as it increased the concentration of chlorine ions. The increase in reactant causes the equilibrium to shift rightwards.

4.2.3 $Pb(NO_3)_2$ (aq)

The addition of $Pb(NO_3)_2$ (aq) as a stress caused the equilibrium to shift towards the reactants (became more pink) as it reacted with the complex chlorine ion to form Lead (II) Chlorine ($PbCl_2$ (s)) which was observed to be the white precipitate. This decreases the concentration of chlorine ions. The decrease in reactant causes the equilibrium to shift leftwards.

4.2.4 Temperature Increase

The increase in temperature of the solution as a stress caused the equilibrium to shift towards the products (became more blue). Due to the overall endothermic nature of the reaction, an increase in temperature will cause the equilibrium to shift rightwards.

4.2.5 Temperature Decrease

The decrease in temperature of the solution as a stress caused the equilibrium to shift towards the reactants (became more pink). Due to the overall endothermic nature of the reaction, a decrease in temperature will cause the equilibrium to shift leftwards.

5 Conclusion

The purpose of this investigation was to determine the effect of various stresses on the equilibrium position of the complex ions of cobalt. The stresses that caused an increase in the concentration of chloride ions caused the reaction to shift towards the products and the decrease of chloride ions caused the reaction to shift leftwards to the reactants. Furthermore, the increase in temperature shifted the equilibrium towards the products and the decrease in temperature shifted the equilibrium towards the reactants due to the overall endothermic nature of the reaction.