1. Equilibrium in a Saturated Solution

You will investigate the equilibrium in saturated sodium chloride solution:

$$NaCl(s) \rightleftarrows Na^+(aq) + Cl^-(aq)$$

Pour some solid NaCl into a 13- × 100-mm test tube and fill the tube 3/4 full of distilled water. Cork and shake to form a saturated solution. If all the NaCl dissolves, pour some additional NaCl in the tube and shake until a saturated solution with some excess solid is obtained.

Filter the solution into a second test tube. To this saturated solution of NaCl, add some Cl^- ions in the form of concentrated HCl. Record and explain the results.

2. An Acid–Base Indicator Equilibrium

Acid–base indicators are large organic molecules that can gain and lose hydrogen ions to form substances that have different colors. The reaction of the indicator bromthymol blue can be illustrated as follows:

$$HIn(aq) \rightleftarrows H^+(aq) + In^-(aq)$$

yellow blue

In this reaction HIn is the neutral indicator molecule, and In^- is the indicator ion after the molecule has lost a hydrogen ion. Equilibrium reactions can easily be forced to go in either direction. Reactions like this are said to be reversible.

Fill a small test tube about half-full of distilled water. Add several drops of bromthymol blue indicator solution. Add 5 drops of 0.1 M HCl and stir. This will increase the amount of H^+ in solution. Note the color of the indicator.

Next add 0.1 M NaOH drop by drop with stirring until no further color change occurs. Adding OH^- ions causes the H^+ ion concentration to decrease as the ions combine to form water molecules. Again, note the color. See if you can add the right amount of acid to this test tube to cause the solution to be green in color after it is stirred (half of the indicator is blue and half is yellow).

3. A Complex Ion Equilibrium

An equilibrium system can be formed in solution with the following ions:

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftarrows FeSCN^{2+}(aq)$$

colorless colorless red-brown

The iron ion (Fe^{3+}) and the thiocyanate ion (SCN^-) are both colorless; however, the ion that forms from their combination, the $FeSCN^{2+}$ ion, is colored a dark red-brown. It is the color of this ion that will indicate how the equilibrium system is being affected.

Pour about 25 mL of 0.0020 M KSCN solution (a source of SCN^- ion) into a beaker. Add 25 mL of distilled water and 5 drops of 0.20 M $Fe(NO_3)_3$ solution. Swirl the solution and note the following: the color of the KSCN solution, the color of the $Fe(NO_3)_3$ solution, and the color of the resulting complex ion.

You will stress the equilibrium system that has resulted in several ways. Pour equal amounts of the solution from the beaker into four test tubes. The solution in the first test tube will be the reference solution.

To the second test tube add 2–3 crystals of solid KSCN. Describe the results.

To the third test tube add 6 drops of $Fe(NO_3)_3$ solution. Stir and describe the results.

To the fourth test tube add small crystals of Na_2HPO_4, a few at a time. Stir and note the results. Phosphate ions, PO_4^{3-}, have the ability to form complex ions with Fe^{3+}, which has the same effect as removing Fe^{3+} from solution.

4. An Equilibrium with Cobalt Complex Ions

In this section we will investigate the equilibrium between two different complex ions of cobalt. The reaction is endothermic:

$$Co(H_2O)_6^{2+}(aq) + 4\ Cl^-(aq) \rightleftarrows CoCl_4^{2-}(aq) + 6\ H_2O(l) \quad \Delta H = +50\ kJ/mol$$

pink blue

Obtain a sealed Beral pipet containing some of the alcoholic cobalt chloride–water system. Note its color. Immerse the large end of the pipet in some hot water (about 60°C) and see if there is a color change.

Lastly, chill the Beral pipet in an ice bath to see if the color change in the previous step is reversible. Explain the effect of the temperature change on the equilibrium in terms of the fact that the value of ΔH for the reaction is +50 kJ/mol.