Equilibrium and Le Châtelier

Introduction

The effect of temperature on the position of an equilibrium can easily be seen by observing the colour changes of the octahedral hexaaquacobalt(II) cation and the tetrahedral tetrachlorocobaltate(II) anion as the sample is moved from a low temperature to a high temperature.

What you will need

Chemicals

cobalt(II) chloride
industrial methylated spirits (IMS, clear)
distilled water
hydrochloric acid (concentrated)

Equipment

balance
spatula
weighing boat
measuring cylinder, 100 cm^3
beaker, 250 cm^3
beaker of iced water, 100 cm^3
water bath at 50°C (or beaker of hot water and a thermometer)
measuring cylinder, 10 cm^3 or bulb pipette
test tube
hair dryer
polystyrene, small square with hole cut in it (diameter of the test tube)

Preparation of the solution

Prepare a solution of the cobalt salt in the large beaker by dissolving 2 g in 100 cm^3 of IMS and 20 cm^3 distilled water.

Place 20 cm^3 of the solution in the test tube.

Place this in the water bath and bring it up to the required temperature of 50°C.

Using the measuring cylinder or bulb pipette, carefully add 2 cm^3 of the concentrated hydrochloric acid to the solution. It will turn from pink to blue.

Allow the solution to cool to room temperature. It should turn mauve in colour.

The equilibrium equation can be expressed as follows:

$[Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6H_2O(l)$ ΔH +ve

Pink — Blue (see colours on Fig. 1)

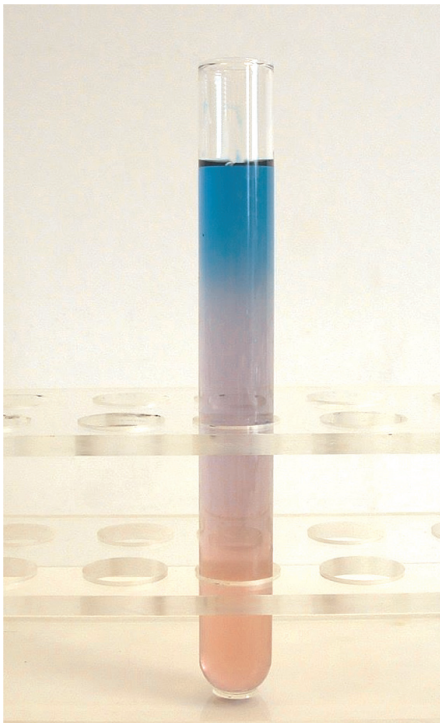

Figure 1 - Thermochromic gradation

The demonstration

Fill the test tube with the cooled solution.

Place the polystyrene collar about a third of the way down the test tube.

Place the test tube in the beaker of iced water to a depth of about a third its length.

At the same time use the hair dryer to heat the top third of the solution above the polystyrene (this to stop the middle third of the test tube heating up).

Observe the colour changes (Fig. 1)!

If desired, test tubes of the solution can be prepared for students to carry out the experiment for themselves.

If they are given the equilibrium equation and the colours of the ions in solution, their observations of the colours at low and higher temperatures can lead them to predict if the sign of ΔH for the forward or reverse reaction is positive or negative.

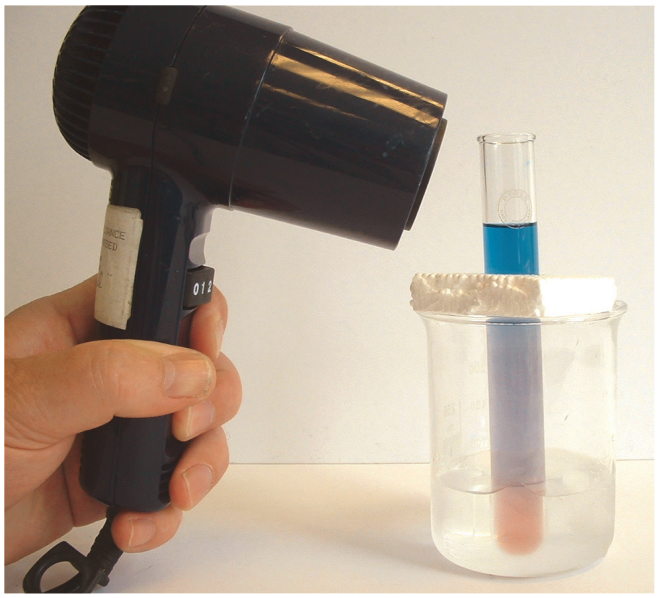

Figure 2 - Using hairdryer used to heat upper half of test tube

Chemical	Main Hazard	Control Measures
Cobalt(II) chloride	**Category 2 carcinogen** by inhalation. Sensitiser by skin contact.	Avoid raising dust. Wear eye protection and gloves to prepare solution from the powder.
Hydrochloric acid (concentrated)	Extremely irritant and corrosive vapour. Liquid and vapour causes severe burns to eyes, lungs and skin.	Wear nitrile gloves/gauntlets and eye protection. Fuming hydrochloric acid should only be handled in a fume cupboard.

Curricular references

Higher Chemistry, Unit 3, Chemical Reactions, (c) - the concept of dynamic equilibrium and shifting the equilibrium position.

Advanced Higher Chemistry, Unit 2: Principles of Chemical Reactions, (b) Chemical equilibrium.