Equilibrium continued

Introduction

In *SSERC Bulletin 219* [1] we gave details of a simple demonstration showing the effect of temperature change on the position of an equilibrium. Using the solution of cobalt chloride and additional chloride ions the colour change between blue and pink takes place over a particular, smallish temperature range with an intermediate colour of mauve.

When the solution is blue the predominant species is the tetrachlorocobaltate anion with very little hexa-aquocation present. When it is pink the latter cation is the most populous species. The mauve solution contains both of the coloured ions in approximately equimolar proportions. An easy way of convincing pupils of this is for them to hold a *blue* test-tube across a *pink* and see the mauve colour in the area of overlap (Figure 4).

By altering the proportions of cobalt salt and extra chloride added, the solution can be tuned to change colour at different temperatures. A set of tubes so tuned can function as a crude thermometer.

What you will need

Chemicals

cobalt(II) chloride
industrial methylated spirits (IMS, clear)
distilled or de-ionised water
hydrochloric acid (concentrated)
sodium chloride

Equipment

balance
spatula
weighing boat
test tubes, 5 off
pipette, 5 cm^3 or small measuring cylinder
measuring cylinder, 100 cm^3
burette + stand
beakers, 250 cm^3, 6 off
supply of hot water (also iced water optional)
thermometer, 0-100°C

Preparation of solutions

Dissolve 2 g of cobalt chloride in 100 cm^3 of IMS and 16 cm^3 of distilled water.

Tuning each tubeful - Dispense three aliquots of 5 cm^3 of the cobalt solution into 3 test tubes labelled *A*, *B* and *C*. Place one tube in a water bath (250 cm^3 beaker three quarters filled with water at 20°C). Run in concentrated hydrochloric acid from the burette, dropwise with shaking or stirring and allowing time for temperature equalisation, until the colour **just** turns blue. That tubeful is now *tuned* to change colour slightly below 20°C. Repeat with tubes *B* and *C* in the beaker waterbaths at other temperatures, say 30°C and 40°C.

The equilibrium equation can be expressed as follows:

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

Pink — Blue (see colours below)

Now place the three tuned tubes in turn in 5 beaker waterbaths and see if the colour change is remembered. Alternatively place them together in the same waterbath, raise the temperature slowly and observe the colour in the tubes turn blue in succession at their tuned temperature. Could this be the next executive desk toy?

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.

Figure 1 - *A* is tuned to change colour at slightly below 20°C

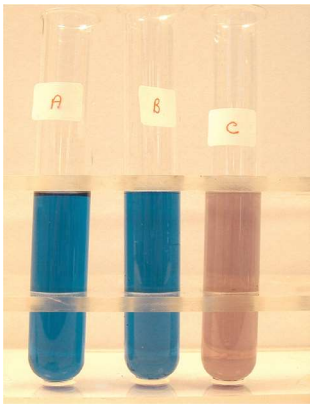

Figure 2 - *B* is tuned to change colour at 30°C

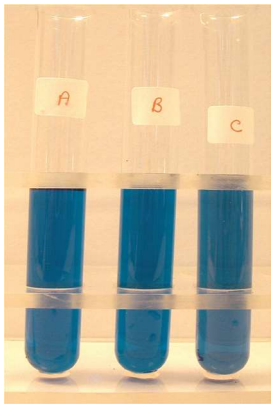

Figure 3 - *C* is tuned to change colour at 40°C

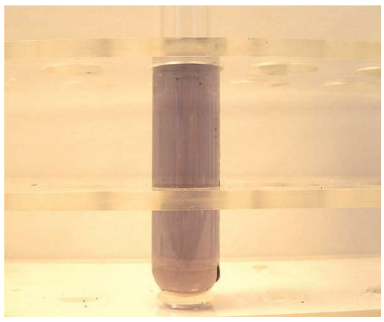

Figure 4 - mauve colour

Reference

1. *SSERC Bulletin No. 219*, Autumn 2006, p6

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. The solution poses negligible risk.
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.

Variations

1. The chloride could be supplied by using saturated sodium chloride solution instead of the acid. This avoids the corrosiveness of the acid. However, owing to the limited solubility of the salt, a larger volume of up to 10 cm^3 is needed to supply a sufficiently high concentration of chloride ions.

2. Using a small scale as described above gives the advantage of a more rapid temperature equilibration. A teacher demonstration might need a larger scale.

3. Ideas for a further extension would be to use it as the basis of an investigation on a more quantitative basis. Using a colorimeter, the concentration of each species could be measured and thus the constancy of the equilibrium constant at a given temperature. If the equilibrium constant were measured at a few temperatures the enthalpy of the reaction could be calculated.